ASSESSMENT OF COMBINED EFFECTS OF CHEMICAL TOXICITY OF POTABLE WATER IN BANGLADESH.

By

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DEDICATED TO MY PARENTS

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ABSTRACT

Nowadays, majority of the people of Bangladesh are completely depending on groundwater for household potable water use because surface water usage has previously led to some detrimental health effects causing diarrhea, cholera etc. But, recently this groundwater source has also become a dubious resource for the whole country as Arsenic and many other harmful metals were discovered in it from national surveys. As a result of drinking this water, people are severely suffering from skin and internal cancers as well as other non-cancer effects at many places throughout the whole country. But it is unclear whether these effects are due to any antagonistic or synergistic effect of toxic elements present in water. This study addresses mixtures of chemicals in drinking water and potential interactions that might affect the joint non-cancer toxicity (Cardiovascular, Neurological, Hematological and Renal effects) of chemicals present in potable drinking water in Bangladesh. Secondary data of Arsenic, Cadmium and Manganese were garnered from potable drinking water sources of Bangladesh to evaluate the individual as well as combined mixture toxicity of different chemicals. The present study has utilized empirical methods with environmental data to analyze the additive hazard index and interactive hazard index for illustrating different health effects. Results might help in scaling up risk assessment studies for complex mixtures of different types of chemicals throughout the entire country on a regional basis. The spatial variation of toxicity indices have also been presented using Arc-GIS with three hazard index scores (additive, synergistic, and antagonistic) for each mixture at upazila scale. Present analysis shows that, for cardiovascular, hematological and neurological health effects, the individual effects of binary and ternary mixture of chemicals are strongly interactive (synergistic or antagonistic) whereas for renal health effects binary mixtures are mostly additive. More specifically, for neurological effects in almost every upazilas of Bangladesh there is strong synergistic interaction of chemicals whereas for cardiovascular effects in few places especially the northeastern zone and Meghna delta's of Bangladesh, there is strong likelihood of potential toxicity.

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LIST of ABBREVIATIONS

Arc-GIS	Geographic Information System (GIS)
ATSDR	Agency for Toxic Substances and Disease Registry (ATSDR)
BBS	Bangladesh Bureau of statistics
BGS	Bangladesh Geological Survey
DPHE	Department of Public Health and Engineering
EPA	Environmental Protection Agency
HQ	Hazard Quotient
HI	Hazard Index
IRIS	Integrated Risk Information System
JMP	Joint Monitoring Program
MRL	Minimal Risk Level
MCL	Maximum Contaminant Level
MICS	Multiple Indicator Cluster Survey
NAMIC	National Arsenic Mitigation Information Centre
NDWQS	National Drinking Water Quality Survey
RfC	Reference Concentrations
RfD	Reference Doses
TTD	Target Organ Toxicity Dose
U.S.	United States
UNICEF	United Nations International Children’s Emergency Fund
WHO	World Health Organizations
WOE	Weight of Evidence

Chapter 1
INTRODUCTION

1.1 Background

Toxic heavy metals such as cadmium, chromium, lead, manganese and arsenic are among the major contaminants in food supplies (Mohamed and Ahmed, 2006). Their presence in the atmosphere, soil, water and in various agricultural products such as cereals, even in trace amounts, can cause serious health problems; especially cardiovascular, kidney, nervous as well as bone diseases and bioaccumulation of toxic heavy metals in the food chain can be highly dangerous to human health due to their persistent nature and potential toxicity (Das et al., 1997; Melamed et al., 2003). Thus information on the intake of toxic heavy metals through the food chain is important in assessing risk to human health. Heavy metals enter the human body through inhalation and ingestion, with ingestion being the main route (Tripathi et al., 1997). The People's Republic of Bangladesh is a developing country in South Asia and is overburdened with an enormous population, severe poverty, illiteracy and frequent natural disasters (Seth et al., 2002). It is an agriculture based country with the vast majority of its people involved in food production. Water is one of the most valuable natural resources on earth and contains mineral which are extremely important in human nutrition (Bulut et al., 2010). Groundwater is highly valued because of certain properties not possessed by surface water. The supply of safe potable water has a significant impact on the prevention of water-transmissible diseases (Lerda and Prosperi, 1996; Altin and Iscen, 2009). The abundance of organic compounds, toxic metals, radio-nuclides, nitrites and nitrates in potable water may cause adverse effects on human health (Ikem et al., 2002). Therefore, assessment of water quality is important for knowing its suitability for various purposes.

Traditionally, Bangladeshis have been drinking surface water from streams, rivers, and ponds. But starting in the 1970s, widespread bacterial contamination became a problem, and people were coming down with diarrhea and cholera. Since then around 10 million wells were drilled to tap into clean underground water resources for drinking. Eventually, over a generation, more than 95 percent of Bangladeshis became dependent on groundwater for household potable water use. When it was discovered that Arsenic was widespread in a large number of these tube-well (an incident termed as the largest mass poisoning of human history by WHO), it significantly limited the safe drinking water options in this country (Smith et al., 2000). It was discovered from national survey of arsenic-affected water that many of the wells also contain other harmful metals like manganese, cadmium etc. and they were making people sick (Khan et al., 1997).

As a result of drinking this water, people are severely suffering from skin and internal cancers as well as other non-cancer effects at many places throughout the whole country. But it is unclear whether these effects are due to any antagonistic or synergistic effect of toxic elements present in water. The aim of this project is to study mixtures of chemical in drinking water and to specifically address potential interactions that might affect the joint non-cancer toxicity (cardiovascular, neurological, hematological and renal effects) of chemicals present in potable drinking water in Bangladesh.

In recent years U.S. federal agencies have devoted increasing attention to health risks from exposure to multiple chemicals (Hertzberg et al., 2002). In 1996, the U.S. Congress directed the U.S. Environmental Protection Agency (EPA) to “develop new approaches to the study of complex mixtures, such as mixtures found in drinking water, especially to determine the prospects for synergistic or antagonistic interactions that may affect the shape of the dose-response relationship of the individual chemicals and microbes (Safe Drinking Water Act Amendments, 1996). A practical problem in such a task result from the size of the problem; the methodologies of characterizing all possible mixtures in drinking water are potentially overwhelming, and the task of assessing each mixture’s net toxicity is even more overwhelming. Given this challenge, researchers have called for the development of new approaches to mixture risk assessment, a new focus on real-world exposures, and more interdisciplinary collaboration in the study of mixture toxicity (Teuschler et al., 2002). In the toxicology and regulatory worlds, several incremental approaches have been proposed to estimate the toxicity of a mixture from existing information on the mixture’s chemical components (Teuschler et al., 2002; ATSDR 2004; Schreiber, 2000). One component of this research categorizes chemicals’ joint effects as additive (either dose or response-additive; this analysis focuses on dose additivity), synergistic (more-than-additive), or antagonistic(less-than-additive).

1.2 The Objectives of the project

- Study mixtures of chemical (arsenic, cadmium, and manganese) in drinking water and specifically address potential interactions that might affect joint toxicity of chemicals in potable drinking water in Bangladesh.
- Evaluation of effects of interactive and non-interacting health effects of chemicals as an additive function of the chemicals' doses.
- Geographical distribution of toxicity hazard index for the cardiovascular, neurological, renal and hematological effects of arsenic, cadmium, and manganese in Bangladesh.

This research makes use of existing data on three naturally occurring chemicals - arsenic, cadmium, and manganese in potable ground water from the entire country and assesses the risk of these chemicals' individual and joint non-cancer health effects. The results will demonstrate that environmental data may be used to better understand patterns in the additive effects of multiple chemicals to identify and prioritize those mixtures, environments, and health endpoints.

1.2 Structure of the Report

The research represents the total achievements carried out under the study. It is comprised of five chapters and a list of mentioned references in the report.

Chapter 1: Focuses on the background information of the study, its objectives and the structure of the study.

Chapter 2: Describes the literature review, definition of different terms, different health effects of arsenic, cadmium and manganese, presents the brief summary of the previous studies related to this study.

Chapter 3: Develops methodology, briefly describe secondary data sources, data characteristics and the geographic distribution of the concentration of Arsenic, Cadmium and Manganese in Bangladesh.

Chapter 4: Discusses about the base case scenarios, sensitivity of interaction model, compares the toxicity mixtures for different health effects, graphical distribution of additive and interaction model as per upazila wise.

Chapter 5: Presents the conclusion, limitations and recommendations that have been found during the study.

Chapter 2
LITERATURE REVIEW

Introduction:

The EPA and the ATSDR have developed well-established research programs on the health effects of chemical mixtures (Teuschler et al., 2001). Several US states have also taken steps toward regulating chemical mixtures in drinking water. However, most drinking water regulations are still developed for individual chemicals. The current body of toxicological literature indicates that, at low levels of exposure, chemicals’ joint action is fairly well approximated by dose additivity. However, the literature also includes a number of findings of synergistic and antagonistic health effects for specific mixtures and health endpoints.

2.1 The state of the art of mixture toxicology

During the last ten years, mixture toxicology has undergone a remarkable and productive development.

Published mixture studies were mainly conducted with one of the two following aims:

- To evaluate and quantify the overall toxicity of complex environmental samples (whole mixture approach), or
- To explain the joint action of selected pure compounds in terms of their individual effects (component based approach).

2.2 Prediction and assessment of mixture effects

One of the key aspirations of mixture toxicology has always been to anticipate quantitatively the effects of mixtures of chemicals from knowledge about the toxicity of its individual components. This can be achieved by making the assumption that several chemicals act in concert by exerting their effects without diminishing or enhancing each other’s toxicity, the so-called non-interaction or additivity assumption (La point and Waller, 2000).

One element of this research categorizes chemicals’ joint effects as additive (either dose- or response-additive; this analysis focuses on dose additivity), synergistic (more-than-additive), or antagonistic (less-than-additive) (Thorpe et al., 2006). Determinants of additive joint action of chemicals are fairly well established.

2.3 Definition of key terms

Mixture: A mixture is a combination of several chemicals with which organisms come into contact, either simultaneously, or sequentially. A binary mixture is a combination of two agents. The term “complex mixture” is used to denote a mixture of unknown composition, isolated from environmental media or other sources. “Complex mixture” is sometimes used to describe combinations composed of three or more chemicals, but for the purposes of this review, the term “multi-component mixture” is preferred.

Mixture effect, combination effect, joint effects: The response of a biological system to several chemicals, either after simultaneous or sequential exposure. The terms are used synonymously.

Additivity: In the context of mixture toxicology, additivity cannot be equated with “additivity” in the mathematical sense. It refers to a situation, termed “non-interaction”, where the toxicity of a mixture resembles the effects expected to occur when all mixture components act without diminishing or enhancing their effects. Additivity expectations for mixtures can be derived from the concepts of dose addition and independent action. In certain situations, valid expectations for additive combination effects can also be calculated by building the arithmetic sum of the individual effects of all mixture components (“effect summation”).

Antagonistic mixture: A combination of two or more chemicals with joint toxicological effects less than the individual component chemicals’ effects.

Synergistic mixture: A combination of two or more chemicals with joint toxicological effects greater than the individual component chemicals' effects.

Doses and concentrations: The dose of a compound or mixture is understood as the amount that is taken up by an organism (derived from the Greek word which means "that what is given"). Dosage is dose per unit body weight over a defined period of time. Certain dosages result in certain concentrations of substances at or near their target site, i.e. within the body of the exposed organism. The term "concentration" is understood in a more general way and can refer to the amount per unit volume of the test chemical(s) at the target site, the surrounding medium (water, air, soil) or the food that a test organism ingests.

2.4 Whole mixture approaches

In general, methods for mixture studies can be divided into 2 major classes, "whole mixture approaches" and "component based" approaches. Methods that use a whole mixture approach are based on the direct toxicological assessment of a given chemical mixture, such as a complex environmental sample, an engine exhaust or a human blood sample. They closely resemble the assessment of individual chemicals and do not require new, mixture-specific methodologies. Any synergistic or antagonistic interactions between the compounds are inherently captured in the observed responses of the exposed organisms. Hence, whole mixture approaches are often applied in situations where only a fragmented knowledge on the chemical composition is at hand (La point and Weller, 2000).Whole mixture approaches have found widespread application in the area of whole effluent testing (La point and Weller, 2000 ; Thorpe et al., 2006). Whole mixture approaches have several appealing characteristics, but also severe limitations. Obviously, the mixture itself has to be available for a direct experimentation, which makes this approach largely unsuitable for prospective approaches such as the setting of environmental quality standards.

2.5 Component based approaches

Many of the limitations of whole mixture approaches can be overcome by making inferences from the effects of the mixture components to their joint action. This can be done purely empirically, i.e. by testing all possible combinations of the components in a mixture (Kortenkamp et al, 2009). They are used in a purely empirical way. They allow the analysis of a broad range of mixture ratios and effect levels, but conclusions are restricted to a given set of components (Kortenkamp et al, 2009). This seriously hampers the applicability of such purely empirical approaches for environmental hazard and risk assessment with its multi-component mixtures of varying compositions.

2.6 Toxicity assessment

The exposure dose estimates are mapped against information about the toxicity of each chemical to be considered. Key to these toxicity assessments are so-called reference doses (RfD) or reference concentrations (RfC) for single chemicals that denote doses not associated with discernible risks (Kortenkamp et al, 2009). Quantitative data about those estimates are found in the IRIS data base (http://www.epa.gov/IRIS/). Together with exposure assessment data, these estimates from the input for risk characterization of mixtures.

2.6.1 Risk characterization for mixtures

The risk characterization for mixtures distinguishes carcinogens from non-carcinogens. A total cancer risk estimate is obtained by summing individual chemical risk estimates across pathways and routes. In dose ranges corresponding to low cancer probabilities, it is assumed that there is no dose threshold, and that the dose-response function is essentially linear (Kortenkamp et al, 2009).

For each non-carcinogenic chemical, each pathway, and each averaging period, a hazard quotient (HQ) is calculated as:

$$HQ = \frac{\text{Average dose rate}}{\text{RfD}} \text{ or } \frac{\text{Average concentration}}{\text{RfC}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2.1)}$$

Where, the summation is over all routes of exposure and time frames.

An overall summary hazard index (HI) is then calculated as the sum of *HQ*'s for each pathway and each chemical, so

$$HI = \sum HQ \ldots\ldots\ldots\ldots\ldots \quad (2.2)$$

The concept of HI is an application of dose addition. If the HI is less than or equal to unity, it is assumed that there is unlikely to be an appreciable risk of deleterious effects and the analysis is complete. If the summary of HI is larger than unity, further analysis may be performed with the aim of determining whether application of dose additivity to all the chemicals simultaneously is justifiable (ATSDR. 2004a).

2.6.2 The ATSDR mixtures guidance manual (ATSDR, 2004b)

ATSDR assesses whether adequate information on health effects is available for the priority hazardous substances. Where, such information is not available or under development, ATSDR initiates, in cooperation with the National Toxicology Program, a program of research to determine these health effects. The Act further directs that where feasible, ATSDR shall develop methods to determine the health effects of substances in combination with other substances with which they are commonly found.

ATSDR's Division of Toxicology has developed a chemical mixtures program. It includes a trend analysis to identify mixtures most often found in environmental media. As part of the mixtures program, ATSDR devised a guidance manual that outlines the latest methods for mixtures assessment (ATSDR, 2004b). In addition, a series of documents called interaction profiles are developed for certain priority mixtures that are of special concern to ATSDR. The purpose of the interaction profile is to evaluate data on the toxicology of the 'whole' priority mixture (if available) and on the joint toxic action of the chemicals in the mixture in order to recommend approaches for the exposure-based assessment of the potential hazard to public health.

ATSDR devised a mixtures guidance manual with the intention of assisting their Division of Toxicology in determining whether exposure to chemical mixtures at hazardous waste sites may impact public health. The manual is also intended to serve as a basis for the development of interaction profiles. The approaches developed in the mixtures guidance manual are consistent with US EPA guidance articulated since 1989. The preferred basis for assessments of the health risks stemming from mixtures at waste sites is information about the mixture of concern, both with respect to exposure, and to toxicological profile. For this purpose, whole mixture data are used, if they are available. Examples of such whole mixture assessments include coke oven emissions and a cocktail of groundwater contaminants. If data on a whole mixture are not available, recourse is made to a "similar" mixture. That is meant to be a combination of the same chemicals as in the mixture of concern, but at different mixture ratios. If analyses of "similar mixtures" are not possible, ATSDR adopts component-based approaches. Component-based mixture assessments make use of the hazard index and are fully compatible with US EPA approaches. There are two departures from the guidance articulated by US EPA: the target organ toxicity dose modification of the hazard index, and the weight-of-evidence approach to dealing with possible deviations from additivity.

2.6.2.1 Target organ toxicity dose (TTD)

In deriving hazard quotients, US EPA recommends the use of RfD also for effect that occur at higher doses, not only the critical effects. It is acknowledged that this may lead to overestimations of risks. To deal with this potential complication, TTDs were developed for chemicals that affect an endpoint at a dose higher than for the critical effect.

2.6.2.2 Weight of evidence (WOE) modification of hazard index

As discussed above, the hazard index concept assumes dose additivity and does not take account of the possibility of toxic interactions. The WOE modification to the hazard index is intended to fill this gap. It builds on a suggestion by the National Research Council of the US National Academies to use additional uncertainty factors to accommodate the possibility of deviations from expected additivity (NRC, 1989). It evaluates binary mixtures and introduces a classification that indicates the expected direction of interaction (synergistic or antagonistic) by using an alphanumerical scoring system. The scores are then combined with the hazard index.

2.7 Health effects of Arsenic

Chronic oral exposure to arsenic has resulted in serious damage to the vascular system in humans, including Blackfoot disease (a progressive loss of circulation in the fingers and toes that may lead to gangrene), Raynaud's disease, and cyanosis of fingers and toes (ATSDR, 2000a) . The intima of the blood vessels appeared to have thickened. Direct irritation of the gastrointestinal mucosa can occur. Arsenic has caused anemia in humans exposed by the oral route. Leukopenia has been reported in humans. Hepatic effects seen in humans were thought to be secondary to portal tract fibrosis and portal hypertension, which may have originated from damage to the blood vessels. Signs of renal damage generally are not seen or are mild in humans exposed to arsenic by the oral route. Characteristic dermal lesions caused by long-term oral exposure of humans to arsenic include hyperkeratinization (particularly on the palms and soles), formation of hyperkeratinized corns or warts, and hyperpigmentation of the skin with associated spots of hypopigmentation (ATSDR, 2000a). Signs of peripheral and/or central neuropathy are commonly seen in humans exposed to arsenic orally, with high-dose exposure producing central nervous system effects and low-dose exposure producing peripheral nervous system effects (ATSDR, 2000a). The potential for arsenic to cause subtle neurological effects, such as neurobehavioral effects in children, has not been fully investigated. Studies of associations between hair arsenic concentrations (a biomarker of exposure) and neurobehavioral effects in children have observed an inverse association between hair arsenic and reading and spelling performance (Moon et al., 1985).

2.7.1 Derivation of Target Organ Toxicity Dose (TTD) Values

TTDs for oral exposure to arsenic were derived for endpoints affected by arsenic and one or more of the other chemicals in the lead, arsenic, cadmium, and chromium mixture that is the subject of this Interaction Profile. The relevant endpoints for this mixture include neurological, renal, cardiovascular, hematological, and testicular effects. Chronic oral TTDs for these endpoints are derived by ATSDR (2000a).

2.7.2 Neurological Effects

A large number of epidemiology studies and case reports indicate that ingestion of arsenic can cause injury to the nervous system. A symmetrical peripheral neuropathy has been observed in individuals exposed to 0.004–0.5 mg As/kg/day for an intermediate or chronic duration (ATSDR, 2000a).The neuropathy is characterized by numbness in the hands and feet progressing to a painful pins and needles sensation. Additionally, a significant association between decreased reading and spelling performance and hair arsenic levels was found in a group of elementary school children (Moon et al., 1985), suggesting that arsenic may also cause neurobehavioral effects.

2.7.3 Renal Effects

Although there have been some reports of kidney injury in humans ingesting arsenic, most studies did not report clinical signs of significant renal injury (ATSDR, 2000a).When renal effects were observed they were often secondary to fluid imbalances or vascular injury. Several animal studies have reported renal effects following intermediate- or chronic-duration oral exposure. The effects include increased kidney weight, swollen mitochondria and increased numbers of dense autophagic lysosome-like bodies in the proximal tubules, increased pigmentation in the proximal tubules, and cysts (ATSDR, 2000a).

2.7.4 Cardiovascular Effects

The cardiovascular system is a very sensitive target of arsenic toxicity. A number of effects have been observed including heart damage (myocardial depolarization, hypertrophy of the ventricular wall, cardiac arrhythmias), vascular damage (Raynaud’s disease, Blackfoot disease, arterial thickening), and hypertension (ATSDR, 2000a). The series of studies by Tseng and associates (Tseng, 1977) provide suggestive evidence that Blackfoot disease and dermal hyperkeratosis and hyperpigmentation would occur at similar dose levels.

2.8 Health effects of Cadmium

Cadmium is considered a cumulative toxicant. The human exposure scenarios of greatest concern are long-term oral exposures. Cadmium accumulates in the kidney over a period of approximately 50 years; renal damage appears to be a consequence of this accumulation. Renal effects have been seen in humans and animals by both inhalation and oral exposure. Effects of cadmium other than renal damage are not considered by ATSDR (1999) to be sensitive effects. Nevertheless, some effects that are seen at moderately low levels of oral exposure are cardiovascular, hematological, neurological and testicular effects. Details regarding the mechanism of cadmium renal toxicity are uncertain; renal damage is hypothesized to occur when an excessive concentration of free cadmium occurs intra-cellularly in the kidney ATSDR (1999).

2.8.1 Derivation of Target Organ Toxicity Dose (TTD) Values

TTDs for oral exposure to cadmium were derived for endpoints affected by cadmium and one or more of the other chemicals in lead, arsenic, cadmium, and chromium mixture that is the subject of this Interaction Profile. The relevant endpoints for this mixture include neurological, renal, cardiovascular, hematological, and testicular effects. Chronic oral TTDs for these endpoints are derived, using the methods described by ATSDR 2000a.

2.8.2 Neurological Effects

Neurological effects consisting of decreased motor activity, weakness and muscle atrophy, aggressive behavior, increased passive avoidance, and alterations in brain dopamine, 5-hydroxytryptamine, succinic dehydrogenase, and monoamine oxidise levels have been observed in rats exposed to 3.1–24 mg Cd/kg/day for an intermediate duration (ATSDR, 1999).

2.8.3 Renal Effects

Numerous human and animal studies indicate that the kidney is the main target of cadmium toxicity (ATSDR, 1999). The kidney damage is characterized as decreased re-absorption of filtered low molecular weight proteins and mild tubular lesions progressing to necrosis.

2.8.4 Cardiovascular Effects

A number of human and animal studies have found a relationship between ingestion of cadmium and increased blood pressure, but other studies have not found any significant association (ATSDR, 1999). ATSDR (1999) concluded that the evidence for cardiovascular toxicity resulting from oral exposure to cadmium is suggestive of a slight effect and that the magnitude of any effect of cadmium on blood pressure is small compared with other determinants of hypertension.

2.9 Health effects of Manganese

Manganese is an element that exists naturally in the environment primarily as salts or oxides. Inorganic manganese in the (II), (III), and (IV) oxidation states are the forms most often encountered in the environment and in the workplace. The available information is insufficient to characterize any differences in toxicity for different manganese oxidation states, and they may be inter-convertible in the body (ATSDR, 2000).

2.9.1 Derivation of Target-Organ Toxicity Dose (TTD) Values

A TTD for chronic oral exposure to manganese was derived for the endpoint affected by manganese and one or more of the other chemicals in the lead, manganese, zinc, and copper mixture that is the subject of this Interaction Profile, using the methods described in ATSDR (2001). The relevant endpoints for this mixture include neurological and hematological. Manganese is neuro-toxic, but the available data for oral exposure were considered inadequate for MRL derivation by ATSDR (2000b) because no clear threshold level for neurological effects could be determined from the acute and intermediate-duration data, and because no firm conclusions were considered possible regarding a critical effect level of chronic intake versus essential dietary levels of chronic intake of manganese. Therefore, ATSDR (2000b) recommended a provisional guidance value for total dietary intake of 0.07 mg Mn/kg/day, based on the upper end of the ESADDI range (5 mg/day, divided by 70 kg, the weight of an average adult), to be used in ATSDR human health assessments. This value is suitable as a TTD for neurological effects.

2.9.2 Neurological effects

The evidence for neurological effects in humans from oral exposure is more limited, but collectively, the studies suggest an association between ingestion of water and/or food containing increased levels of manganese and adverse neurological effects (ATSDR, 2000b). Some of the studies reported symptoms and signs similar to those associated with inhalation exposure. Two of the studies focused on children, and associated increased oral intakes of manganese and increased hair manganese with poorer performance in school and on neurobehavioral exams. Other studies have reported higher manganese concentrations in the hair of learning disabled children than in normal children (ATSDR, 2001).

Table 1.1 Target-Organ Toxicity Doses (ATSDR, 2004a) for Arsenic, Cadmium and Manganese in Drinking Water

Chemical	MCL (mg/L)	Organ or System affected	Target Organ Toxicity Dose (mg/l)
Arsenic	0.01	Cardiovascular Hematological Neurological Renal	0.0105 0.021 0.0105 3.15
Cadmium	0.005	Cardiovascular Hematological Neurological Renal	0.175 0.028 0.007 0.007
Manganese	-c	Neurological	2.45

[a] Converted from mg/kg/day, assuming a 70 kg adult consuming 2 L water per day.

[b]The U.S. EPA has not established a target-organ toxicity dose (TTD) for the renal toxicity of cadmium. However, the ATSDR has developed an equivalent risk measure, a chronic oral minimal risk level (MRL) based on the renal toxicity of cadmium (ATSDR. 2004)

[c]The U.S. EPA has not established an MCL for manganese. The lifetime health advisory for manganese is 0.3 mg/L, and the secondary MCL is 0.05 mg/L.

(Abbreviations: mg/L = milligrams per liter; MCL = U.S. EPA maximum contaminant level; MRL = minimal risk level; TTD = target organ toxicity dose.)

2.10 Previous studies

The available toxicological studies have typically focused on different endpoints and mechanisms of action, with little replication or confirmation; and while a number of studies have produced qualitative classifications of potential interactions among components, few studies have quantified those interactions (Chang, 1996). Calabrese (1991) summarizes common statistical and graphical methods for evaluating experimental data for deviation from additivity (Calabrese, 1991). Working with these available toxicological studies, the ATSDR (2004) has examined the literature on the mixture toxicity of 25 inorganic chemicals that co-occur frequently in ground water. Among these, the ATSDR's weight-of-evidence analysis tentatively classified the binary mixture of arsenic and cadmium as non-interactive for renal effects; antagonistic (protective) for hematological effects; and unknown for cardiovascular and neurological effects (ATSDR, 2004b). The ATSDR's analysis was unable to classify the interaction potential of either arsenic or cadmium mixed with manganese, for any endpoint (ATSDR, 2004a). Whole-mixture models are not yet available for most mixtures found in drinking water. Mathematical components-based approaches are frequently used where whole-mixture dose-response data are not available (Ryker and small, 2008). The most commonly used components-based methods represent the effects of a non-interactive mixture as some additive function of the component chemicals, and the effects of an interactive mixture as a deviation from additivity (Kodell and Pounds, 1991; Cassee et al., 1999). This default assumption of additivity is supported by several laboratory studies (U.S. EPA, 1990) and literature reviews, including a 1990 U.S. EPA review of literature on 1465 chemical pairs, which found evidence of additivity for half of the pairs studied (EPA, 1990). The U.S. EPA (2000) and the ATSDR (2004a) have proposed mixture risk models based on dose addition.

Effects of cadmium other than 142 renal damages are not considered by ATSDR (1999) to be sensitive effects. Nevertheless, some effects that are seen at moderately low levels of oral exposure are cardiovascular, hematological, neurological, and testicular effects. Cardiovascular effects (hypertension) have been reported in humans and animals in some studies and not in others. ATSDR (1999) has concluded that the magnitude of any effect of cadmium on blood pressure is small compared with other determinants of hypertension, and that cardiovascular effects are not a sensitive endpoint for cadmium. Oral exposure to cadmium can cause anemia in humans and animals, but is not considered by ATSDR (1999) to be likely to result from low level exposure. Hepatic effects occur with higher oral doses of cadmium, usually for acute or intermediate durations. A few studies have reported associations between environmental cadmium exposure (using hair cadmium as a biomarker) and neuro behavior effects including verbal IQ in children and disruptive behavior in young adults. Neurological effects have been seen in animals exposed to cadmium orally, and include changes in behavior, including a decrease in motor activity, alterations in neurotransmitter levels, histopathological changes in the brain, and peripheral neuropathy. These effects occurred in animals at doses as low as 1.4 mg/kg/day. Testicular effects have been seen from oral dose ranges of 5–14 mg/kg/day in animal studies. Although inhalation exposure is the greatest concern, exposes from the lower doses of cadmium over a long period of time. The lower and long-term exposure to cadmium through air or through diet can cause kidney damage. Although the damage is not life-threatening, it can lead to the formation of kidney stones and affect the skeleton, which can be painful and debilitating. Lung damage has also been observed. (ATSDR, 2004)

Several studies have been carried out in Bangladesh representing the different concentration present in ground water and their health effects. The study in Shibganj area of Chapai Nawabganj, Rajshahi showed that, the presence of toxic metals Cd, and Mn content in ground water is in excess of the recommended limit prescribed by the WHO, Bangladesh and U.S. EPA standards and can cause synergistic health problems, especially cardiovascular, kidney, nervous as well as bone diseases to humans (Saha and Zaman, 2011). A recent survey showed that arsenic-related diseases resulted in 9,136 deaths per year and 174,174 disability adjusted life years (DALYs) among people who were exposed to arsenic concentrations of above 50 μg/L, and this constituted about 0.3% of the total burden of disease in Bangladesh (Khan et al., 1997). The clinical data from Bangladeshi arsenic-affected patients reported that the most common clinical manifestations are melanosis (87.4%), keratosis (67.7%), leukomelanosis (35.5%) and hyperkeratosis (38.7%). Other findings are conjunctivitis (6.3%), bronchitis (10.5%) and hepatomegaly (2.2%) (Khan et al., 1997).

A number of new studies of cadmium exposure and health impact in human populations have been carried out and reviewed by Jarup et al. (1998). These include studies of kidney dysfunction and osteoporosis. Cadmium affects the resorption function of the proximal tubules, the first symptom being an increase in the urinary excretion of low-molecular-weight proteins, known as tubular proteinuria (Krajnc EI et al., 1987). Contamination of drinking-water may occur as a result of the presence of cadmium as an impurity in the zinc of galvanized pipes or cadmium-containing solders in fittings, water heaters, water coolers and taps.

Chapter 3

DATA COLLECTION AND METHODOLOGY

3.1 Data Source

This research makes use of existing data on three naturally occurring chemicals - arsenic, cadmium, and manganese. These chemicals are selected based on the availability of both environmental and toxicological data. Arsenic, cadmium, and manganese are ubiquitous in ground water and have been measured in many settings across Bangladesh.

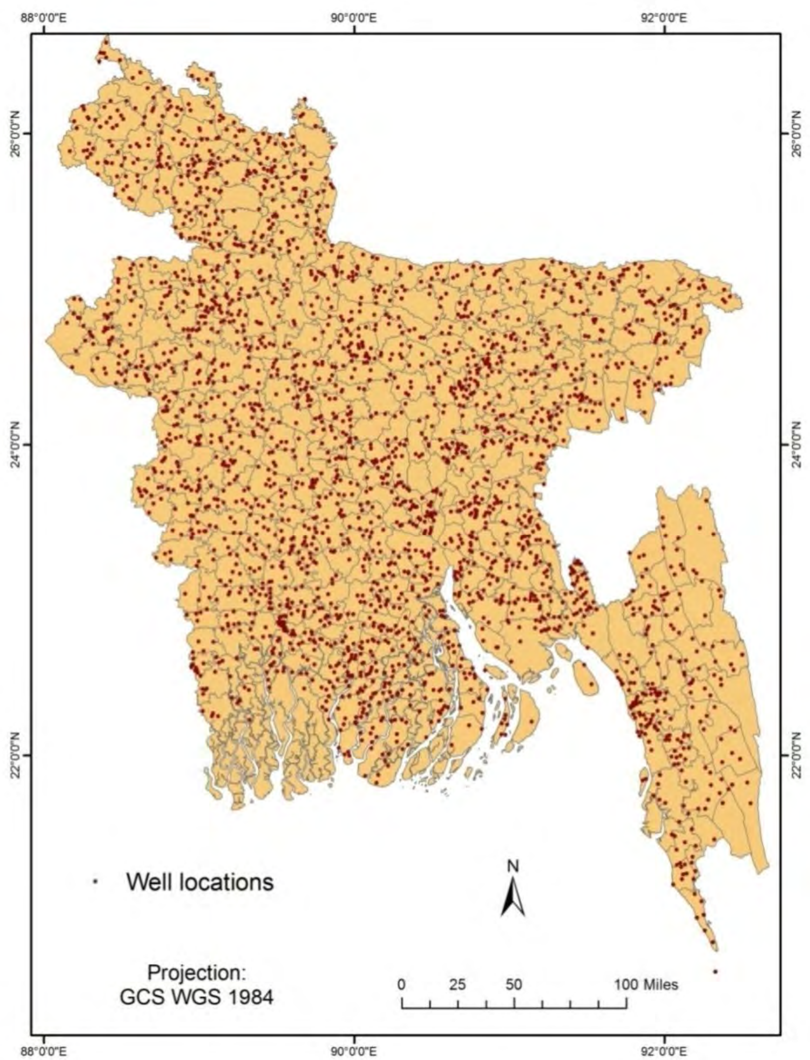


Figure 3.1: Geographic distribution of sample collection points in Bangladesh as per Upazila wise. These samples were analyzed for As, Cd, Mn which constitutes the secondary data source for current study. [UNICEF 2009]

The analysis presented here uses a dataset of approximately 2896 potable water sources in Bangladesh that have been sampled for arsenic, cadmium, and manganese by the UNICEF 2009. The data set includes 2060 samples were collected from shallow tube-wells, 536 samples from deep tube-wells and the remaining samples from other sources such as dug well, surface water, piped, spring etc. The UNICEF 2009 was conducted as part of the Multiple Indicator Cluster Survey (MICS) by the Bangladesh Bureau of statistics (BBS), with participation from the Department of Public Health and Engineering (DPHE). Since the mid 1990s, UNICEF has supported governments around the world in collecting and analyzing data in order to fill gaps for monitoring the situation of children and women, through Multiple Indicator Cluster Surveys (MICS). MICS findings are used in monitoring progress towards Millennium Development Goals, and have been used extensively as a basis for policy decisions and programme interventions (UNICEF 2009). In Bangladesh, MICS is implemented by the Bangladesh Bureau of Statistics (BBS) every year between 1995 and 2000, and since 2000 every three years. Field work of the MICS was completed by the BBS by the middle of 2009 and the final report was published in June 2010 (UNICEF 2009).

Compared to previous studies, UNICEF 2009 increased the sample size to 300,000 households in 15,000 randomly selected clusters around the country to allow disaggregated data analysis for 23 indicators at some district level. UNICEF 2009 shows that similar to UNICEF 2006, 97.8 percent of the population used an improved drinking water source as defined by the WHO/UNICEF joint monitoring Program (JMP).

3.2 OTHER WATER QUALITY SURVEYS

An overview of previous water quality surveys at national scale is provided below. Results of the UNICEF 2009, when applicable, are compared with data from earlier surveys in this report.

3.2.1 DPHE/BGS data

The most comprehensive water quality dataset for Bangladesh groundwater is the national survey conducted by the Bangladesh Department of Public Health and Engineering (DPHE) and the British Geological Survey (BGS) in 1994. It surveyed 3,207 shallow and 327 deep tubewells throughout the country (except for the Chittagong Hill Tracts, which are mostly free of arsenic), and tested groundwater samples in a British laboratory for 20 inorganic parameters (UNICEF 2009). The DPHE/BGS report found that 25% of all wells tested and 27% of shallow wells, exceeded the 50 μg/L standard for arsenic; 42% of all wells tested, and 46% of shallow wells exceeded the WHO provisional guideline value of 10 μg/L (Figure 3.2) . Where possible, data from the UNICEF 2009 are compared to the DPHE/BGS data; for chemicals which were not tested in the larger DPHE/BGS survey the smaller BWDB data set is used. It is important to note that the DPHE/BGS and BWDB surveys collected samples directly from tube wells, while the UNICEF 2009 collected samples of household drinking water. This results in differences in several water quality parameters.

3.2.2 NAMIC data

After the DPHE/BGS survey, it was clear that arsenic posed a national problem. It was also evident that arsenic levels were highly variable at the local level: a highly contaminated well might be located just meters away from a safe well. For this reason, it was decided to launch a massive blanket screening campaign, to test and mark every tube well in arsenic-prone areas. This screening was largely conducted from 2000 through 2003, though some testing continued until 2006. The resulting dataset consists of nearly 5 million field test kit results, and was maintained by the National Arsenic Mitigation Information Centre (NAMIC). The NAMIC dataset indicates that only about 20% of shallow tube wells exceed the 50 μg/L standard. The accuracy of this estimate is limited due to the lack of quality assurance measures (e.g. cross-checking subsets of results in laboratories) in the screening. The field kits used at the time could not reliably detect arsenic to 10 μg/L so no information can be gained regarding the number of wells exceeding the WHO guideline value. The NAMIC dataset serves as the basis for the correction factor currently applied by the JMP (UNICEF 2009).

3.2.3 BDHS 2004

The 2004 Bangladesh Demographic and Health Survey (BDHS) used field testing kits to measure arsenic levels in 10,465 respondent households. Unlike the DPHE/BGS and NAMIC surveys, BDHS measured water quality in the household, not at the tube well. The survey showed that 7.9% of household water samples exceeded the 50 μg/L limit, while 2.7% and 1.1% exceeded 100 and 250 μg/L, respectively. These data may be subject to negative bias, since the Hach kit used is known to underestimate arsenic in the 10-100 μg/L range, and no results were cross-checked in laboratories. Unfortunately the arsenic testing module was not retained in the 2007 BDHS (UNICEF 2009).

3.3 SAMPLING FOR METALS AND METALLOIDS ANALYSES

A household water quality testing component was included in the UNICEF 2009 Bangladesh for the first time. The sampling plan called for collection of one household drinking water sample from 15,000 clusters randomly selected from all geographic areas of Bangladesh. UNICEF field workers visited 15,000 clusters and conducted interviews in 20 households per cluster, for a total sample size of 300,000. The respondents answered questionnaires on the source of their drinking water. Tubewells reportedly deeper than 150 m were classified as 'deep tubewells', though no verification of the depth was made. Sample bottles, pre-acidified (To a 125-ml sample bottle, 1.5 ml of 1:1 diluted concentrated nitric acid of analytical grade, Merck, was added), were provided to field workers to collect a sample from the first household visited in each cluster. Survey respondents were asked to provide 'a glass of drinking water which you would give your child to drink', which was then poured into the bottle. A total of 17,205 sample bottles were filled, labeled and transported to Dhaka for analysis; 15,950 of these (93%), including 1,508 quality control samples, were adequately labeled and coded to be useful for geographical analysis. A total of 14,442 distinct household samples were analyzed for arsenic using Digital Arsenators (Wagtech, model WE-10500) in Dhaka. Approximately 20% of samples from each district were sent to a reference laboratory (Maxxam Analytics, Canada) for analysis of arsenic and a suite of metals and metalloids by inductively coupled plasma-mass spectrometry. The laboratory reported results from 2,896 distinct households. In addition, 375 quality control samples were analyzed, including 34 field replicates and 182 field blanks. Agreement was reasonable between field replicates. For 1,925 samples, arsenic measurements from both laboratory and Arsenator data were available, agreement between these two independent datasets was good.

3.4 Prevalence of existing As, Mn, Cd in Ground water in Bangladesh

UNICEF 2009 data provides a comprehensive distribution of potable water quality with respect to As, Mn, Cd in Bangladesh. Figure 3.1 shows the location of potable drinking water sources collected for each upazila.

Table 3.1: Concentration distribution of As, Cd and Mn in Bangladesh as per UNICEF 2009

Analyte	**25th %ile**	**Median**	**75th %ile**	**90th %ile**	**Maximum**	**Average**	**Bangledesh Standard (maximum)**
As	0.0009	0.0026	0.0147	0.041	0.495	0.0186	0.05
Cd	0.008	0.0139	0.03	0.0672	0.295	0.0272	0.005
Mn	0.121	0.324	0.719	1.168	4.1	0.479	0.1

The Bangladesh standard for arsenic in drinking water is 0.05 mg/l. From the current analysis, it shows that, approximately 90% of wells maintaining the Bangladesh standard (nearly 0.041) with an average values of 0.0186 for each upazila (Table 3.1). The WHO provisional guideline value is 0.01 mg/l. According to the data analysis, 8% of samples exceeded the Bangladesh standard, while 30% exceeded the WHO provisional guideline value [Figure 3.3(a)].

According to UNICEF 2009, 14,442 samples were analyzed using digital Arsenator Instruments in Bangladesh from which 1,935 (13.5%) were found to contain more than 0.05 milligrams per litre of arsenic considering the Bangladesh drinking water standard. Taking arsenic contamination into account, the proportion of the population using an improved drinking water source is 85.5 percent (93.3 percent in urban and 83.8 percent in rural areas) following the Bangladesh national standard for arsenic. Of these, 5.6 million are exposed to > 0.2 milligrams per litre and we are extreme health danger (UNICEF 2009).

The proportion of samples exceeding the permissible limits for arsenic is lower in the current survey than the previous national surveys (UNICEF 2009). The DPHE/BGS survey found 25% of samples to exceed 0.05 mg/l, while the NAMIC database shows an overall contamination rate of approximately 20%. According to UNICEF 2009, eighteen of the 64 districts are found to have more than 20% of the drinking water samples tested to contain more than 0.05 milligrams per litre of arsenic [Figure 3.3 (a)]. Nine of them, Comilla (49%), Gopalgonj (48%), Sunamgonj (48%), Chandpur (44%), Noakhali (40%), Faridpur (36%), Madaripur (32%), Netrakona (32%), Brahmanbaria (30%) are especially in a hazardous situation because of higher percentage in arsenic occurrence. Furthermore, in seven of these districts [Chandpur (27%), Comilla (25%), Brahmanbaria (17%), Gopalgonj (15%), Noakhali (13%), Madaripur (13%),Faridpur (11%)] more than 10% of drinking water samples contain very high level of arsenic (more than 0.2 milligrams per litre).

The standard drinking water limit for Manganese in Bangladesh is restricted to 0.1 miligrams per litre, where only 22% of the samples were found to maintain this standard. The average concentration of Mn observed for each upozila is 0.479 (Table 3.1), which is almost five times higher than its standard limit. Mn concentration also exceeded the WHO guideline values at many upozilas of Bangladesh, approximately 60% of the samples meeting the WHO guideline value of 0.4 milligrams per litre [Table 3.1 and Figure 3.3 (b)].

Cadmium (Cd) is used in metal plating, plastics, pigments and bateries. The WHO guideline value of 0.003 mg/L is set to protect against kidney damage. The analysis shows that, tube wells of different upazila’s contain very high level of cadmium, approximately 85% the samples exceeding the Bangladesh standard of 0.005 [Table 3.1 and Figure 3.3(c)].

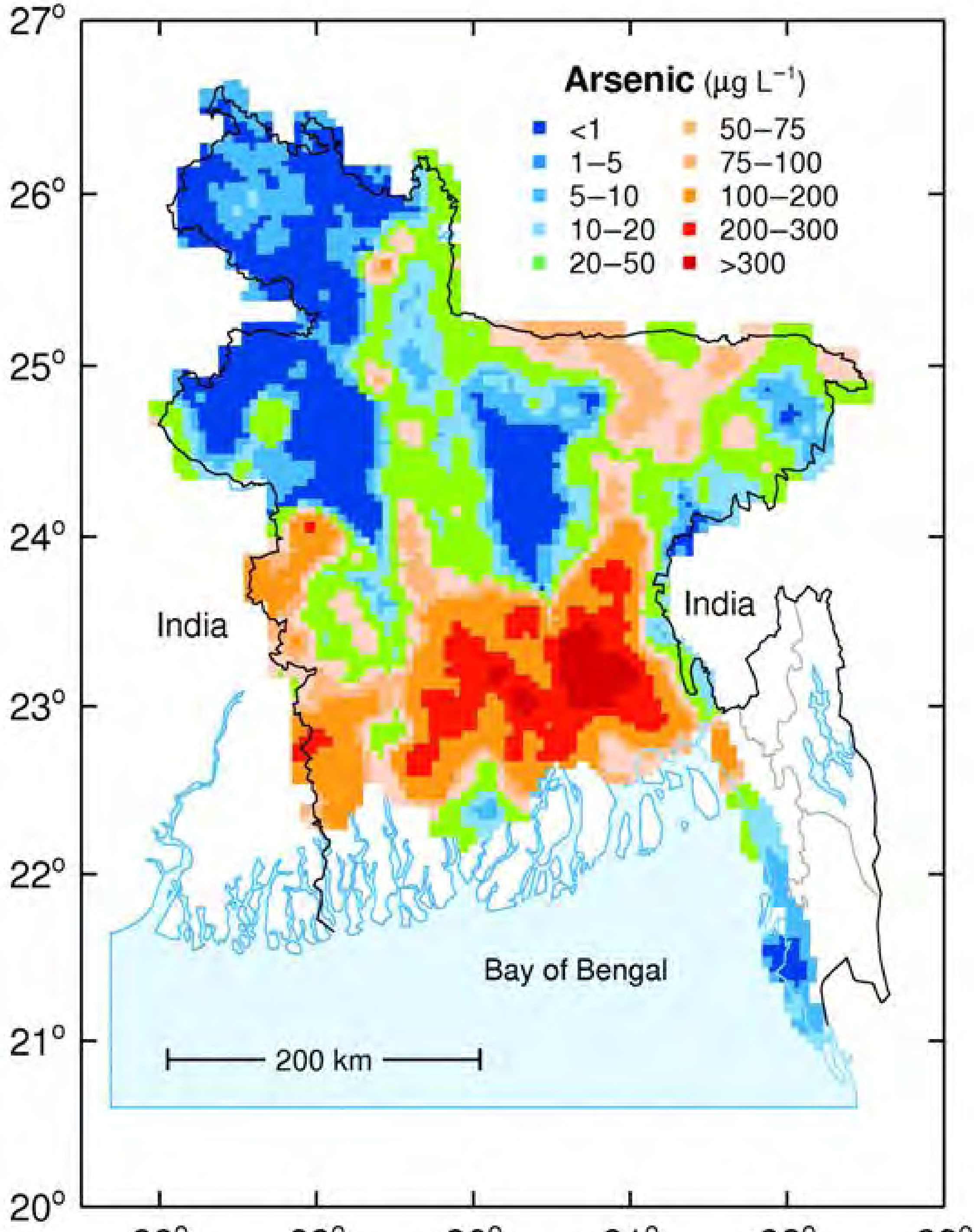


Figure 3.2: Geographic Distribution of Arsenic concentration in Bangladesh carried out by BGS and DPHE over the period 1998 to 2001. [BGS 2001]

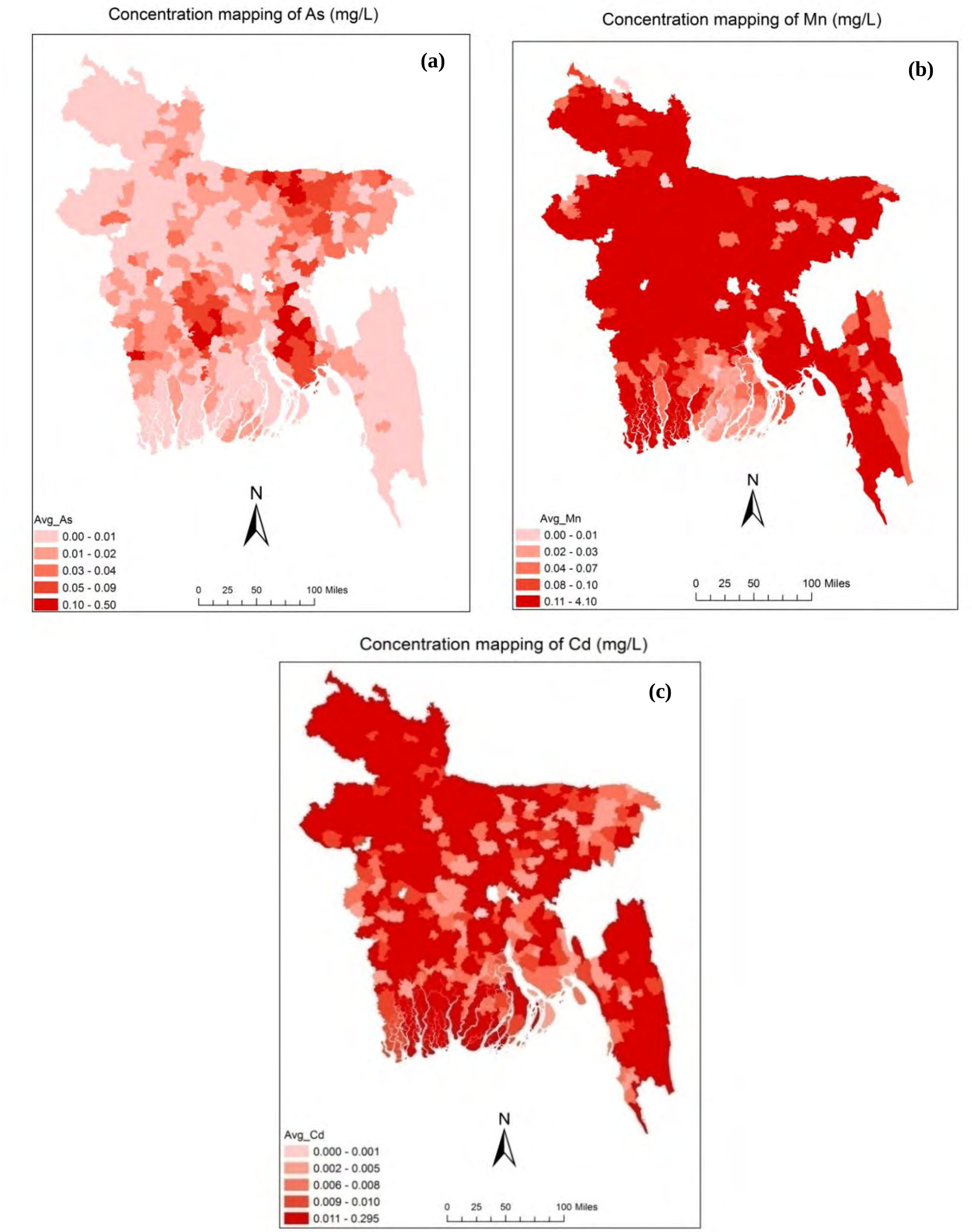


Figure 3.3: Geographic distribution of the concentrations (mg/L) of (a) As, (b) Mn and (c) Cd in Bangladesh as per Upazila wise. [UNICEF 2009]

3.5 Methodology for Risk Assessment

Arsenic, cadmium, and manganese has reasonably well-studied health effects. The U.S. EPA has recognized individual maximum contaminant limits (MCL) for arsenic and cadmium in drinking water, and a non-enforceable secondary MCL for manganese (ATSDR, 2004a) in Table 1.1. The three chemicals' joint effects are the matter of interest now. Arsenic and cadmium are remarkably well studied; the ATSDR has conducted a literature review characterizing potential non-cancer interactions between arsenic and cadmium for several health end points. However, such characterizations are not available for most mixtures. For example, adequate information was not available for the ATSDR to categorize the joint action of arsenic or cadmium with manganese [ATSDR (2004a)]. Manganese is thus of interest for its lack of mixture information. The models used are an initial additive model previously described by the U.S. EPA (1986, 1990) and the ATSDR (2004a) ; Mumtaz and Durkin, 1992 ; Mumtaz et al., 1997 and a more developed form of the model incorporating chemical interactions, proposed by the U.S. EPA (2000) and Hertzberg and Mac Donell, 2002.

This research represents the first application of these models to environmental data in Bangladesh. Classifications of mixture toxicology are typically qualitative, for example, 'interacting' (synergistic or antagonistic) or 'non-interacting' (additive) (Feron et al., 1998). Equation 3.1 represents an additive model previously described by the EPA (1986, 1990) and ATSDR (2004a), based on Mumtaz and Durkin 1992 ; Mumtaz et al., 1997, whereas Equation 3.2 represents EPA's form of the model incorporating chemical interactions (EPA 2002 ; Hertzberg and Mac Donell, 2002). The Additive and Interactive Hazard Index has been briefly discussed in the following sections.

3.5.1 The Additive Hazard Index

For component chemicals that do not interact, the EPA and ATSDR approaches make use of a simplified form of dose – response prediction. The resultant ratio is denoted the hazard quotient (*HQ*) (Equation 2.1), and the sum of all component chemicals' *HQ*'s constitutes the hazard index (HI) for the whole mixture's effect on the target organ (Equation 2.2)[ATSDR. 2004a ; Hertzberg and Mac Donell, 2002].

$$HI_{add,P} = \sum_{j=1}^{n} HQ_{pj} = \sum_{j=1}^{n} \frac{Dose_j}{TTD_{pj}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots[3.1]$$

Where, HI_P = multi-chemical index of concern for adverse effects to target organ P. HQ_{Pj} = ratio of exposure (concentration) to 'safe' level (Target organ toxicity dose, TTD) for the

jth chemical targeting dose response data.

A HQ above 1.0 indicates increased likelihood of a physiological response to an individual component chemical; and HI score above 1.0 indicates increased likelihood of a physiological response to the mixture (Hertzberg and Mac Donell, 2002).

3.5.2 The Interactive Hazard Index

The interactive hazard index for a mixture of n chemicals targeting organ P is given by:

$$HI_{int,P} = \sum_{j=1}^{n} \left(HQ_{pj} \cdot \sum_{j=1}^{n} f_{jk} \cdot M_{jk}^{B_{jk} \cdot g_{jk}} \right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots[3.2]$$

Where,

$$f_{jk} = \frac{HQ_K}{HI_{add} - HQ_J}$$

and

$$g_{jk} = \frac{\sqrt{HQ_j \cdot HQ_k}}{(HQ_j + HQ_k)/2}$$

Here, HQ_{Pj}= ratio of exposure (concentration) to TTD for the j^{th} chemical targeting organ P

M_{jk} = interaction magnitude, the influence of chemical j on the toxicity of chemical Target organ P.

B_{jk} = score for the strength of evidence that chemical j will influence the toxicity of chemical k.

The above Equation represents the interactive health effects incorporating chemical interactions.

The parameters (*f*, *g*) derive from the relative concentrations and toxicities of the component chemicals.

Ryker and Small (2009) has published some illustrative sensitivity analysis on the relationships between *f*, *g*, *B*, and *M*. The parameters (*f*, *g*) derive from the relative concentrations and toxicities of the component chemicals. The parameter scales each component chemical's contribution to the inter-action by its importance relative to all interacting chemicals. The exponent indicates whether one component chemical dominates the chemical pair's toxicity; when $HQ_j = HQ_k$ (when mixture toxicity for binary chemical is equal, termed as equitoxicity), $g = 1$. However, given this importance on equitoxicity as a factor of toxicological interaction, the model may understate interactions for mixtures in which one component chemical is nontoxic but promotes the toxic action of another chemical.

The exponent *B*, as used here is derived from the ATSDR's weight-of-evidence analysis, which classifies mixtures as additive, synergistic, or antagonistic and describes the uncertainty associated with this classification (ATSDR, 2004a; Mumtaz et al., 1997). If the ATSDR considers interaction unlikely, then $B = 0$ and $HI_{int} = HI_{add}$. For a binary mixture of the chemicals j and k, the magnitude of interaction (*M*) represents the degree to which one chemical alters the toxicity of the other, that is the maximum possible influence of chemical j on TTD_k. For a non-interactive mixture, $M = 1$ and $HI_{int} = HI_{add}$. In the available literature, *M* is not generally enumerated; only qualitative classifications of interaction (e.g., 'synergism') are available for most mixtures. It is expected that $1 \leq M_{jk} \leq 10$ for the low-dose mixtures typical of drinking water (ATSDR 2004).The EPA (2000) has suggested a default of $M = 5$. For demonstration resolutions, this study considers states in which *M* may be as high as 10.

To examine the potential for synergism and antagonisms, this analysis uses national arsenic, cadmium, and manganese data to parameterize binary and ternary models of the effects of non-interactive chemical mixtures for each water sample in the dataset. The collected data also used to parameterize models for mixtures whose component chemicals interact to increase or decrease each other's toxicity.

3.6 Hazard Index Mapping

Geographically disaggregated analysis can illustrate the three hazard index scores (additive, synergistic, antagonistic) for each mixture for the entire country. Hazard quotients will be determined based on arsenic, cadmium and manganese separately and additive hazard index scores for the mixture of arsenic + cadmium + manganese. Hazard index maps will be displayed in Upazila scale. The present analysis will use national ground water quality data to parameterize equation (3.1) and (3.2) for the individual and combined effects of binary and ternary mixtures of arsenic, cadmium, and manganese. The hazard index map will represent several types of relative health effects of mixture toxicology like, cardiovascular, neurological, hematological and renal effects by using drinking water data. This hazard index mapping would help us to observe different types of scenarios and surely it will support to enhance the decision making process and other policies related to it. Arc-GIS 10.2 will be used extensively for the entire spatial joining of the attributes and mapping processes. Moreover, maps will represent the index scores of separate Upazila's in Bangladesh very elaborately including hazard ranges associated with it for different health effects and chemical combinations.

Chapter 4

RESULTS

4.1. General

This chapter presents the individual as well as combined toxicity assessment for mixtures of arsenic, cadmium and manganese. This analysis makes use of the interactive HI model with drinking water data to determine how much potential for interaction is associated with each mixture and target organ. Initially based on the existing environmental data the distribution of HI values for each health effects will be determined assuming the chemical mixtures are additive. Then, sensitivity analysis of the interactive HI to the potential magnitude of interaction will be performed with different confidence levels. Finally, the geographic distribution of hazard index scores will illustrate the complete scenario of additive and mixture toxicology from interactions between different chemicals in Bangladesh.

4.2. Base Case Scenario for health effects of Mixtures

In order to assess base case scenario, the mixture toxicity of As, Mn and Cd has been assumed to be additive. For component chemicals that do not interact, doses are compared to TTD (target organ toxicity dose), a predetermined safe level for a given adverse effect to a target organ or system. The values of TTD for Arsenic, Cadmium, and Manganese for different health effects have been provided in Table 1.1 by ATSDR (2004). The resultant ratio is denoted as *HQ* (Equation 2.1) and the summation of all component chemicals constitute the additive HI scores are provided in Figure 4.1(Equation 2.2).

Figure 4.1 shows national distributions of dose-additive HI computed for the cardiovascular, renal, hematological and neurological effects of arsenic, cadmium, and manganese found in potable ground water in Bangladesh calculated at upazila wise. HI scores above 1.0 indicate a potential effect on the target organ (Ryker and Smell, 2008). In general, the HI scores are higher (though sometimes very slightly so) for binary mixtures than for single chemicals. Where there is a large difference between the potencies or the exposure concentrations of the component chemicals, the HI may be dominated by a subset of components.

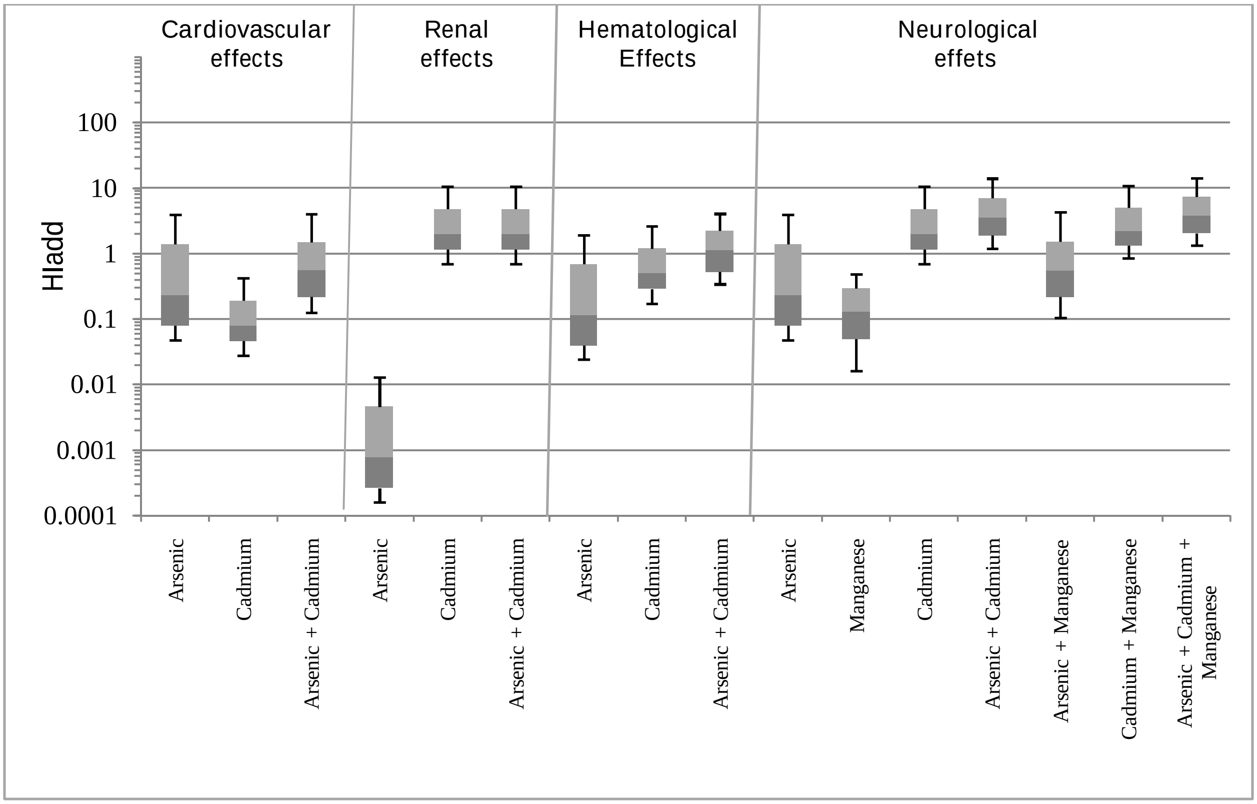


Figure 4.1: Percentile boxplots of national distributions of HI_{add} scores. Boxes extend from 25^{th} to the 75^{th} percentile and the line in the middle represent 50^{th} percentile of HI_{add} scores. Black whiskers extend from the box to the 10^{th} and 90^{th} percentiles.

For example, in the binary mixtures in Figure 4.1, mixture of arsenic dominates the cardiovascular HI. Because from the calculation of HI it can be seen that, 90% of As has additivity index of almost 3.86 whereas for Cadmium its additivity is too low, only 0.41. But surprisingly this phenomena illustrates a totally inverse relation in renal effects for As and Cd as Cd became the dominant factor here. Large difference exists between the percentile HI of Arsenic and Cadmium which were found to be 0.013 and 10.43 respectively for 90% of HI. Both arsenic and cadmium individually dominates the hematological HI.

In case of neurological effects, the assessment of HI shows different result with varied health effects. Cadmium is the dominating chemical for neurological effects, hazard index of which has been 0.68 and 10.43 (for 10^{th} percentile and 90^{th} percentile values respectively) whereas for Mn and As, it is almost 0.016 to 0.48 and 0.05 to 3.86 respectively (Table 4.1). Cd is the largest contributor in neurological HI, consequently the mixture of arsenic and cadmium represents the highest contributor of hazard among all the other binary mixtures. Again for ternary mixtures, 90% HI_{add} reached a maximum value of 13.94 which is only slightly greater than HI_{add}, contributed by the binary mixtures of arsenic and cadmium (which is 13.88 for the same percentile).

Table 4.1: Percentile values of Additive Hazard Index for different combination of As, Cd and Mn

Health effects	Chemicals and chemical composition	10th %ile	25th %ile	Median	75th %ile	90th %ile
Cardiovascular	As	0.05	0.08	0.23	1.37	3.86
	Cd	0.03	0.05	0.08	0.19	0.41
	As + Cd	0.13	0.22	0.56	1.48	4.00
Renal	As	0.0002	0.0002	0.0007	0.0045	0.013
	Cd	0.68	1.15	1.99	4.77	10.43
	As + Cd	0.69	1.15	1.99	4.77	10.43
Hematological	As	0.02	0.04	0.12	0.69	1.90
	Cd	0.17	0.29	0.49	1.19	2.60
	As + Cd	0.34	0.53	1.13	2.19	4.02
Neurological	As	0.05	0.08	0.23	1.37	3.86
	Mn	0.016	0.05	0.13	0.29	0.48
	Cd	0.68	1.15	1.99	4.77	10.43
	As + Cd	1.19	1.88	3.57	7.02	13.88
	As + Mn	0.10	0.22	0.54	1.51	4.29
	Cd + Mn	0.84	1.32	2.20	5.02	10.69
	As + Cd + Mn	1.32	2.05	3.77	7.25	13.94

4.3 Health effects considering mixture interaction

In order to assess HI_{int}, the sensitivity of interaction parameter M and B needs to be assessed. Section 4.3.1 describes the methodology to determine sensitivity of HI_{int} : HI_{add} with respect to parameters M and B. Using the most probable range of interaction, the interactive hazard index using Bangladesh dataset has been assessed in the subsets.

4.3.1 Sensitivity of HI_{int} to interaction parameters

In this section, the assessment of parameters *M* and *B* using Equation (3.2), which was discussed earlier can be expanded and rewritten to arrive at a relationship between *M, B* and HI_{int}.

According to Equation (3.2):

$$HI_{int,P} = \sum_{j=1}^{n}\left(HQ_{pj} \cdot \sum_{j=1}^{n} f_{jk} \cdot M_{jk}^{B_{jk} \cdot g_{jk}} \right)$$

$$= HQ_j \cdot \sum_{j=1}^{n} f_{jk} \cdot M_{jk}^{B_{jk} \cdot g_{jk}} + HQ_k \sum_{j=1}^{n} f_{jk} \cdot M_{jk}^{B_{jk} \cdot g_{jk}}$$

$$= \left(HQ_j + HQ_k\right) \cdot \sum_{j=1}^{n} f_{jk} \cdot M_{jk}^{B_{jk} . g_{jk}} \qquad \text{..........................}(4.1)$$

The parameters *(f, g*) can be derived from the relative concentrations and toxicities of the component chemicals.

$$f_{jk} = \frac{HQ_K}{HI_{add} - HQ_J}$$

$$= \frac{HQ_k}{\left(HQ_j + HQ_k\right) - HQ_j} = 1 = f_{kj}$$

The parameters *f* scales each component chemical's contribution to the interaction by its importance relative to all interacting chemicals. The exponent *g* indicates whether one component chemical dominates the chemical pair's toxicity; when $HQ_j = HQ_k$ (equitoxicity), $g = 1$.

Again,

$$g_{jk} = \frac{\sqrt{HQ_j \cdot HQ_k}}{\frac{1}{2}\left(HQ_j + HQ_k\right)} = g_{kj}$$

$$= \frac{\frac{\sqrt{HQ_j}}{\sqrt{HQ_k}}}{\frac{1}{2}\left(\frac{HQ_j}{HQ_k}+1\right)} \qquad Let, \frac{HQ_j}{HQ_k} = x$$

Again the additive HI from equation (2.1) for a pair of chemicals *j* and *k*,

$$HI_{add} = (HQ_j + HQ_k)$$

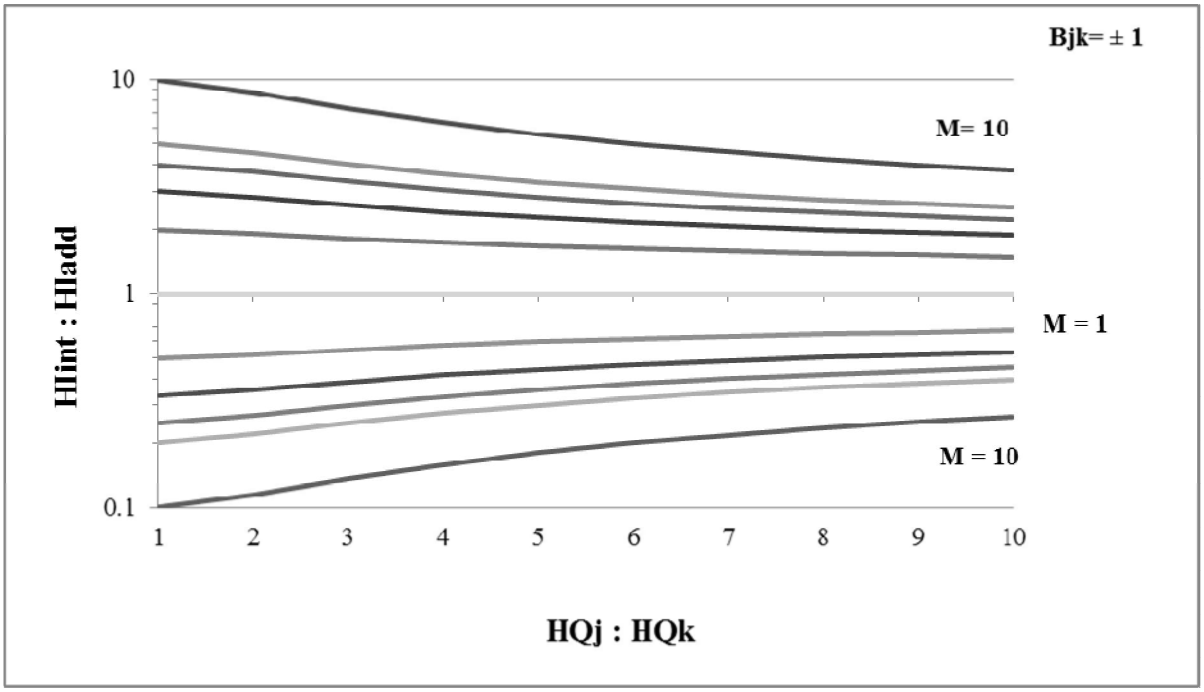
Dividing equation (4.1) by (2.1)

$$\frac{HI_{\text{int}}}{HI_{add}} = \sum_{j=1}^{n} M_{jk}^{B_{jk} \cdot g_{jk}}$$

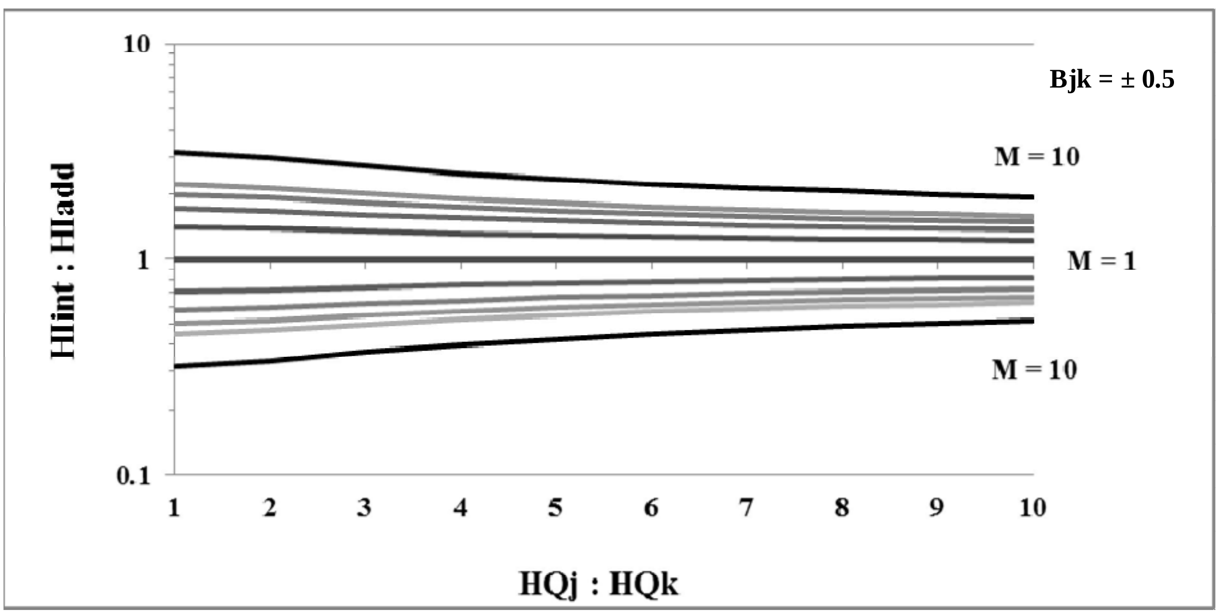
$$= \sum_{j=1}^{n} M_{jk}^{B_{jk} \cdot \frac{\sqrt{x}}{\frac{1}{2}(x+1)}} \quad \text{.......... ....(4.2)}$$

The assessment of HI interactive using Equation (4.2) shows that, the interaction range of HI is strongly dependent on the ratio of mixture toxicity ($HQ_j : HQ_k$) with the bounded range of B ($-1 \leq B \leq +1$) and M (1 to 10). The concentration of chemicals in drinking water also controls the HI_{int} range on the mixtures. For each water sample in the data set this equation can be used to qualitatively classify the direction of a mixture's interaction as additive (M = 1 and B = 0), synergistic (1≤ M ≤ 10 and 0 ≤ B ≤ 1), or Antagonistic (1≤ M ≤10 and -1 ≤ B ≤0). Using this bounded range of M and B, it is possible to compute a narrow range of possible HI_{int} scores for binary and ternary mixtures of arsenic, cadmium and manganese. Figure 4.2 illustrates the different conditions of *M* and *B* with varied ratios of mixture toxicity to calculate the possible range of HI_{int} to HI_{add}.

There is no toxicological interaction among mixtures when the value of *B* and *M* is low (*B* = 0 and *M* = 1) and mixture toxicity ratio is maximum. Consequently, it indicates that, the mixture toxicity is maintaining strictly additive effects. Decreasing the ratios of toxicity components (HQ_j:HQ_k) on the mixture increases the possibility of interaction. So, the interaction of HI will be maximum for strongly synergistic when the value of *B* and *M* is high (*B* = 1 and *M* = 10) and for strongly antagonistic interaction the value of B is lowest but M is high (B = -1, M = 10). To get maximum interaction of HI for both synergistic and antagonistic interaction, toxicity component ratios is closest to equitoxicity ($HQ_j : HQ_k$ near 1). For example, when $HQ_j : HQ_k = 1$ and $|B| = 1$, the maximum range of the HI_{int} is from approximately 10% to 1000% of the HI_{add}, more specifically the antagonistic HI_{int} is between 10% to 100% of the HI_{add} and Synergistic HI_{int} is between 100% to 1000% of the HI_{add} [Figure 4.2 (a)]. Again the lower values of *B* ($B = \pm 0.5$) with different conditions of M and mixture toxicity ratio, further constrains the interaction range of HI on the mixtures. For example when $HQ_j : HQ_k = 10$ and $|B| = 0.5$, the maximum range of the HI_{int} is from approximately 52% to 194% of the HI_{add} in Figure 4.2 (b).



(a)



(b)

Figure 4.2: The relationship between HI_{int} to the relative toxicities of component chemicals with different values of *M (M* = 1,2,3,4,5, 10) indicate (a) higher values of *B* increases the possibility of interaction on the mixture again (b) lower values of *B* constraints the possibility of interaction on the mixture.

4.3.2 Determination of interactive HI based on Bangladesh Dataset

To parameterize the terms *M* and *B* in computing the interactive HI using Equation (3.2), additional toxicological information is required. The term x in Equation (4.2), makes it possible to assess a range of possible interactive HI scores for binary and ternary mixtures of arsenic, cadmium, and manganese, based on the actual co-occurrence forms of the three chemicals. Based on Equation (3.2) and Figure 4.2 it is established that, the greatest possibility for component chemical interactions is for those mixtures that happens contiguous to equitoxicity in drinking water (when $HQ_j : HQ_k$ near 1). For this study the 10th percentile of $HQ_j : HQ_k$ has been taken, as a lower bound demonstrating the proximity to equitoxicity of each mixture normally occurring in the drinking-water data (assuming strong interaction, M = 10). In Figure 4.3, the lower and upper whisker represents the 10th percentile and 90% percentile of $HQ_j : HQ_k$ respectively. In Table 4.2 for cardiovascular effects it can be seen that, 10% of wells has mixture toxicity ratios ($HQ_j : HQ_k$) for arsenic and cadmium less than or equal to 1.4. Again, for 50% and 90% of wells, this relative toxicity of the component value has increased, showing $HQ_j : HQ_k \leq 4.4$ and $HQ_j : HQ_k \leq 94.65$ respectively. This verifies that, 10% of wells has arsenic and cadmium close to cardiovascular equitoxicity ($HQ_j : HQ_k \leq 1.4$) and therefore possess much greater potential for interaction as the range of HI_{int} varies from 10% to 970% of the HI_{add}. On the other hand, as the component toxicity is observed to maintain an increasing trend with increase of percentile value, therefore interactive HI will stretch closer to HI_{add}.

Table 4.2: Ratio of misture toxicity values ($HQ_j : HQ_k$) for different combination of binary mixtures using the Bangladesh dataset.

Health effects	Mixtures	10^{th} %ile	25^{th} %ile	Median	75^{th} %ile	90^{th} %ile
Cardiovascular	As + Cd	1.40	1.97	4.4	16.79	94.65
Renal	As + Cd	80.0	469	2575	9495	28904
Hematological	As + Cd	1.50	3.09	7.24	19.75	49.50
Neurological	As + Cd	1.40	2.21	4.35	11.84	56.51
	As + Mn	3.00	7.90	18.90	56.68	177.06
	Cd + Mn	1.80	3.48	10.42	31.99	96.34

A complete summery of numerous mixtures' likely range of HI_{int} : HI_{add} has been calculated using Equation (4.2). Tables 4.3 and 4.4 illustrates, the possible range of interactive HI for 90% of drinking-water wells, where the maximum magnitude of interaction (M = 10) and the maximum certainty of interaction (B = ±1) on the mixture. Without any previous toxicological investigation, the national drinking water data shows that arsenic and cadmium are nearly close to equitoxicity and highly interactive for Hematological effects ($HQ_j : HQ_k \leq 1.5$ in Table 4.3). Thus, for 90% of the drinking-water data set the Hematological HI_{int} should be within 10% to 960% of the HI_{add} (close to a factor 10 from additivity). Consequently for both cardiovascular and hematological effects, additional toxicological information will be required to assess the potential interaction between arsenic and cadmium.

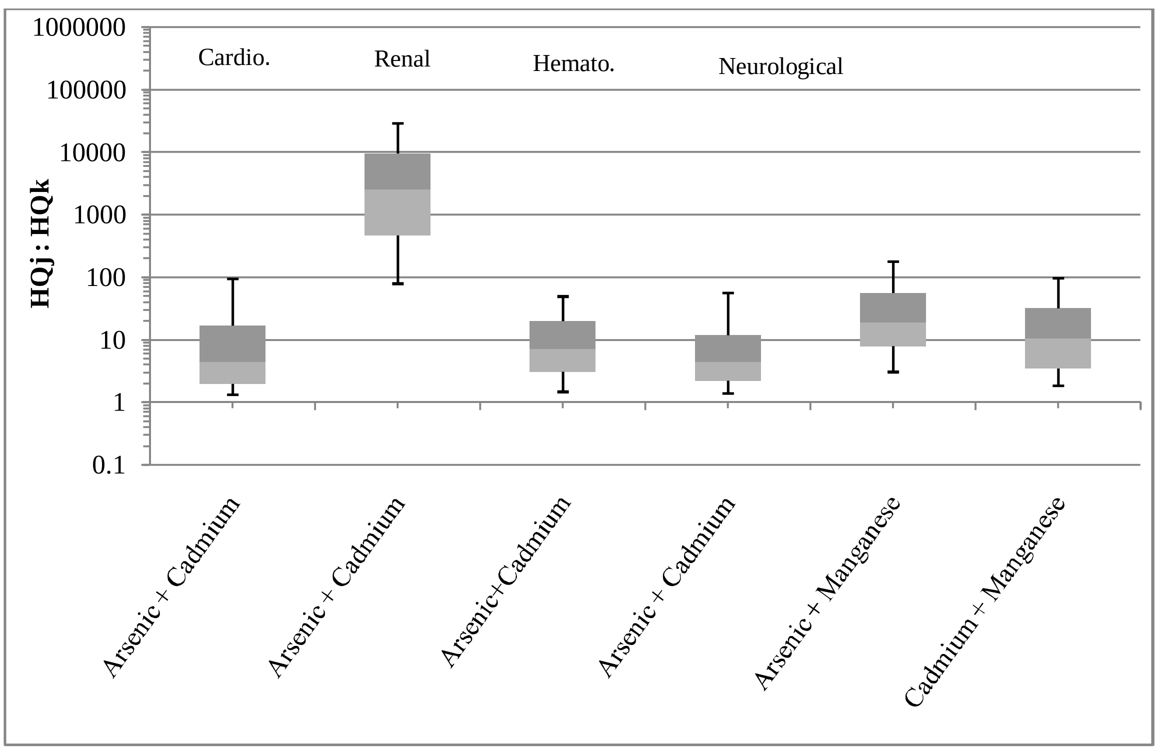


Figure 4.3: Percentile boxplot of the ratios of mixture toxicity (HQ_j:HQ_k) for selected binary mixtures with several health effects (i,g; cardiovascular, renal hematological or neurological). HQ_j is always the higher of the two chemicals' hazard quotients. Boxes extend from the 25^{th} to the 75^{th} percentile and the line in the middle represent 50^{th} percentile of ratios of mixture toxicity (HQ_j:HQ_k). Black whiskers extend from the box to the 10^{th} and 90^{th} percentiles.

For Renal effects, in contrast, environmental data indicate that arsenic and cadmium are far from equitoxicity with relative frequency of $HQ_j : HQ_k \geq 80$ for 90% of drinking-water wells (table4.3). Thus, for 90% of the renal HI_{int} should be within 60% to 170% of the HI_{add}, even if arsenic and cadmium were to interact to the maximum degree possible (M = 10). In other words, based on the environmental data and Equation (2.2) but no additional toxicological information, the renal effects of Arsenic and cadmium are likely to be approximately additive (or within a factor of 1.7 of additivity) in 90% of potable ground water samples. Based on the evaluation of environmental data it is clear that, as there is no interaction among chemicals, further investigation for renal health effects is not necessary.

For Neurological effects, the binary mixtures of Arsenic + Cadmium and Cadmium + Manganese occur closest to equitoxicity than mixture of Arsenic + Manganese. For 90% of wells, the mixture toxicity rario ($HQ_j : HQ_k$) of both Arsenic + Cadmium and Cadmium + Manganese is 1.40 and 1.80 respectively (Table 4.2 and Figure 4.3). So for both mixtures the maximum range of HI_{int} is from approximately 10% to 970% and 10% to 990% respectively. But for the same percentile, mixture toxicity ratio ($HQ_j : HQ_k \leq 3$) of Arsenic + Manganese narrows the *HI* interaction range from 10% to 740% of the HI_{add} (Table 4.2).

Table 4.3 depicts three different scenarios of mixture toxicity ratio ($HQ_j : HQ_k$) for Arsenic and Cadmium by estimating several mixture's likely range of $HI_{int} : HI_{add}$ for 90% of drinking water wells affecting four physiological systems. The first scenario shows the least information provided for 10^{th} percentile values of $HQ_j : HQ_k$ with maximum certainty of interaction ($B \pm 1$) and maximum magnitude of interaction (M = 10). The second scenario assume that for hematological effects, if the interaction is antagonistic then the interaction ranges various from 10% to 100%. In addition for renal effects, the mixture toxicity ratio ($HQ_j : HQ_k \leq 80$) is maximum so there is no interaction (additive) in the mixture. Similarly in the third scenario, only the certainty of interaction (B = - 0.23) has been changed, which resulted interaction ranges from 60% to 100%. These three scenarios are based on the qualitative information and uncertainty assessments for different health condition without confidence.

The first row of Table 4.3 shows the least information scenarios for 10^{th} percentile values to estimate mixture toxicity ratios for Arsenic and Cadmium. For cardiovascular, Hematological and Neurological health effects, the interaction range remains almost close to 10% to 970% indicating strong interaction as the relative toxicity ratio of component chemicals are close to equitoxicity ($HQ_j : HQ_k \leq 1.5$). For 90% of potable ground water samples, mixture toxicity ratio of Arsenic and Cadmium are likely to be approximately additive ($HQ_j : HQ_k \leq 80$) for renal effects. So, the interaction of HI bounded between 60% and 170% of the HI_{add}.

In the middle rows of Table 4.3, available toxicological information is incorporated to further limit the likely range of $HI_{int} : HI_{add}$. For renal effects, the ATSDR has conducted a literature review and classified Arsenic and Cadmium as additive (no interaction; $HI_{int} : HI_{add}$). For Hematological effects, The ATSDR has tentatively classified Arsenic and cadmium as antagonistic; this qualitative classification restricts *B* to values between -1 to 0, which in turn narrows the possible range of hematological HI_{int} from 10% to 100% of HI_{add}.

In the bottom rows of Table 4.3, incorporating a weight-of-evidence assessment of certainty (*B* = - 0.23) further narrows the HI_{int} to a multiplicative factor of 0.60 to 1.0; thus for 90% of the drinking water data set the hematological H_{int} is within 40% of HI_{add}. Combining all available information, the ranges of $HI_{int} : HI_{add}$ in the bottom rows of Table 4.3 generally support the hypothesis that, at concentration found in Bangladesh drinking water, the hematological, cardiovascular, renal effects of arsenic and cadmium are close to additive. However, this analysis provides no evidence as to whether the binary mixtures of neurological effects conform to additivity.

Table 4.3: Use of Empirical $HQ_j : HQ_k$ with Environmental Data and Weight-of-Evidence Classification, Where Available to Estimate $HI_{int} : HI_{add}$ for 90% of the potable drinking Water (ASTDR. 2004), and Where Arsenic and Cadmium Co-Occur; Values Are Rounded.[a]

	Potential Effects of Arsenic + Cadmium			
	Cardiovascular	Hematological	Renal	Neurological
Least information scenario (Bounds on HIint estimated from drinking – water data alone)				
10^{th} percentile of $HQ_j : HQ_k$ in water	1.4	1.5	80	1.4
Maximum range of $HI_{int} : HI_{add}$ ($-1 \leq B \leq +1$; M = 10)	0.1-9.7	0.1-9.6	0.6-1.7	0.1-9.7
Qualitative information scenario (Hint estimated from drinking – water data and qualitative interaction classification)				
Qualitative interaction classification (sign of B)	Unknown	Antagonistic	No Interaction (Additive)	Unknown
Range of $HI_{int} : HI_{add}$ qualitative Classification (B bounded; M = 10)	0.1-9.7	0.1-1.0	1.0	0.1-9.7
Qualitative information and uncertainty assessment scenario (Hint estimated from drinking – water data and qualitative interaction classification a confidence (B) for the classification)				
Confidence in current classification (value of B),	Unknown	- 0.23	Unknown	Unknown
Range of $HI_{int} : HI_{add}$ using B (B fixed ; M = 10)	0.1-9.7	0.6-1.0	1.0	0.1-9.7

[a]For pairs of chemicals, the ranges of $HI_{int} : HI_{add}$ are designed to be symmetric, that is, the HI_{int} ranges from K-fold less to K-fold greater than the HI_{add}. However, in this table the ranges of $HI_{int} : HI_{add}$ are rounded to one decimal place.

For Table 4.4, represents a similar bonding analysis on the possible magnitude of neurological interaction for binary and ternary combination of arsenic, cadmium, and manganese. These three elements have individual neurological effects but the ATSDR (2004b) found insufficient evidence to classify the neurological interaction potential of any of these mixtures. The upper rows of Table 4.4 provides bounds on each binary mixture's potential for interaction, based on concentrations found in 90% of the drinking –water data (10^{th} percentile values of in $HQ_j : HQ_k$ in Figure 4.3). Based on the environmental data, the binary mixture of Arsenic and Cadmium could deviate from additivity by upto nine fold ($0.1 \leq HI_{int} : HI_{add} \leq 9.7$) whereas for the same criteria, the ternary mixture also deviate from additivity to nine fold. (the HI_{int} may range from 10% to 990%). In addition, all three chemical pairs more or less frequently occur close to neurological equitoxicity (Figure 4.3 and Table 4.4) which was discussed earlier.

In the second rows of Table 4.4, assuming qualitative classification in the mixture of Arsenic and Cadmium as additive so the interaction changes upto 100%. Again as there is not sufficient information available for *B* and *M*, therefore the other mixture remains unchanged. So environmental data alone cannot decisively classify the binary mixtures potential for interaction.

Table 4.4: Use of Empirical $HQ_j : HQ_k$ to Estimate $HI_{int} : HI_{add}$ for potential Neurological Effects, for Concentration of Arsenic, Cadmium, and Manganese Found in Potable drinking Water[a]

Potential Neurological Effects				
	Arsenic + Cadmium	Arsenic + Manganese	Cadmium + Manganese	Arsenic + Cadmium + Manganese
Least information scenario (Bounds on HIint estimated from drinking – water data alone)				
10^{th} percentile of $HQ_j : HQ_k$ in water	1.4	3.0	1.80	
Maximum range of $HI_{int} : HI_{add}$ ($-1 \leq B \leq +1$; M = 10)	0.1-9.7	0.1-7.4	0.1-9.1	0.1-9.9
Qualitative information scenario (Hint estimated from drinking – water data and qualitative interaction classification) No qualitative interaction classification is available. The following scenarios are intended to demonstrate possible outcomes of additional toxicological research. Qualitative classification of Arsenic + Cadmium as additive would be reduce the range of $HI_{int} : HI_{add}$ to :				
Maximum range of $HI_{int} : HI_{add}$ ($-1 \leq B \leq +1$; M = 10)	1.0	0.1-7.4	0.1-9.1	0.1-9.9
Qualitative classification of all pairs as antagonistic would reduce the the range of $HI_{int} : HI_{add}$ to : Range of $HI_{int} : HI_{add}$ using qualitative classification :				
Maximum range of $HI_{int} : HI_{add}$ ($-1 \leq B \leq 0$; M = 10)	0.1-1.0	0.1-1.0	0.1-1.0	0.1-1.0
Qualitative classification of all pairs as synergistic would reduce the the range of $HI_{int} : HI_{add}$ to:				
Range of $HI_{int} : HI_{add}$ using qualitative classification : ($0 \leq B \leq +1$; M = 10)	1.0-9.7	1.0-7.4	1.0-9.1	1.0-9.9

The lower rows of Table 4.4 show how this range of HI_{int} could be narrowed by literature reviews or additional laboratory investigations that qualitatively classify each mixture as synergistic or antagonistic.

4.4 Geographic Distributions of additive Model Results

Figure 4.4 demonstrates the relatively simple layout of hazard index scores for the neurological effects of a potable water mixture. The Figure 4.4(a), 4.4(b) and 4.4(c) are showing individual hazard quotients for the neurological effects of arsenic, cadmium and manganese for different upazilas of Bangladesh and Figure 4.4(d) is showing the additive hazard index score for the ternary mixture. On each map, results are shown only for upazilas of Bangladesh. For a ternary mixture, the additive hazard index is properly instinctive; one can generate ideas about the hazard index map from the three hazards quotient maps.

Mixture of Arsenic + Cadmium + Manganese calculated using Equation 4.1 shows a hazardous condition for neurological effects in the entire country, where HI_{add} is greater than 5.0 at most of the places [Figure 4.4 (d)]. But it has been evaluated that, cadmium was solely responsible for neurological effects at half of the areas of the entire country as the hazard quotient value is greater than 5.0 at many Upazilas [Figure 4.4 (b)]. Secondly, Arsenic enhances the additivity of the mixture with its high hazard quotient value (> 5.0) at Northeastern side and Meghna delta region of Bangladesh [Figure 4.4 (a)]. Manganese was found to have no impact in the mixture for neurological effects. Individual hazard quotient for manganese varies from 0.05 to 0.5 as showed in Figure 4.4-(c).

Figure 4.5, 4.6 and 4.7 shows the distribution of individual and additive hazard index scores for cardiovascular, renal and hematological effects of Arsenic and Cadmium. In these analysis of health risks, there is no exposure to manganese as the target organ toxicity dose (TTD) for these health effects is not available which was discussed earlier. In Figure 4.5 (a)**,** the analysis of individual hazard quotient shows that arsenic has high toxicity values ($HQ \geq 5.0$) at many Upazilas of Bangladesh for cardiovascular health effects whereas for cadmium there is hardly any Upazila which exceeds *HQ* of 5.0 [Figure 4.5 (b)]. So this analysis provides clear evidence for Figure 4.5 (c) that, arsenic mostly dominates the cardiovascular HI additivity. This phenomena is totally inverse in Figure 4.6 for renal additivity of Bangladesh as Arsenic was found to have no impact in the mixture for renal effects [Figure 4.6 (c)]. Individual hazard quotient for arsenic varies from 0.01 to 0.10**,** whereas for cadmium, the hazard quotient values are greater than 5.0 at many Upazilas [Figure 4.6 (b)]. Consequently cadmium dominates the additivity for renal effects.

In Figure 4.7 (a) for hematological effects, the hazard quotient values of Arsenic for most of the places is very low ($HQ \leq 0.50$). Only a few places (Northeastern side and Meghna deltas) of Bangladesh has high HQ values [$HQ \geq 5.00$; Figure 4.7(b)] found from the analysis. Cadmium has high toxicity values comparing to arsenic as almost 80% of upazilas has Hazard quotient values of 2.0 ($HQ \leq 2.00$). So cadmium is responsible for dominating hematological additivity in Bangladesh.

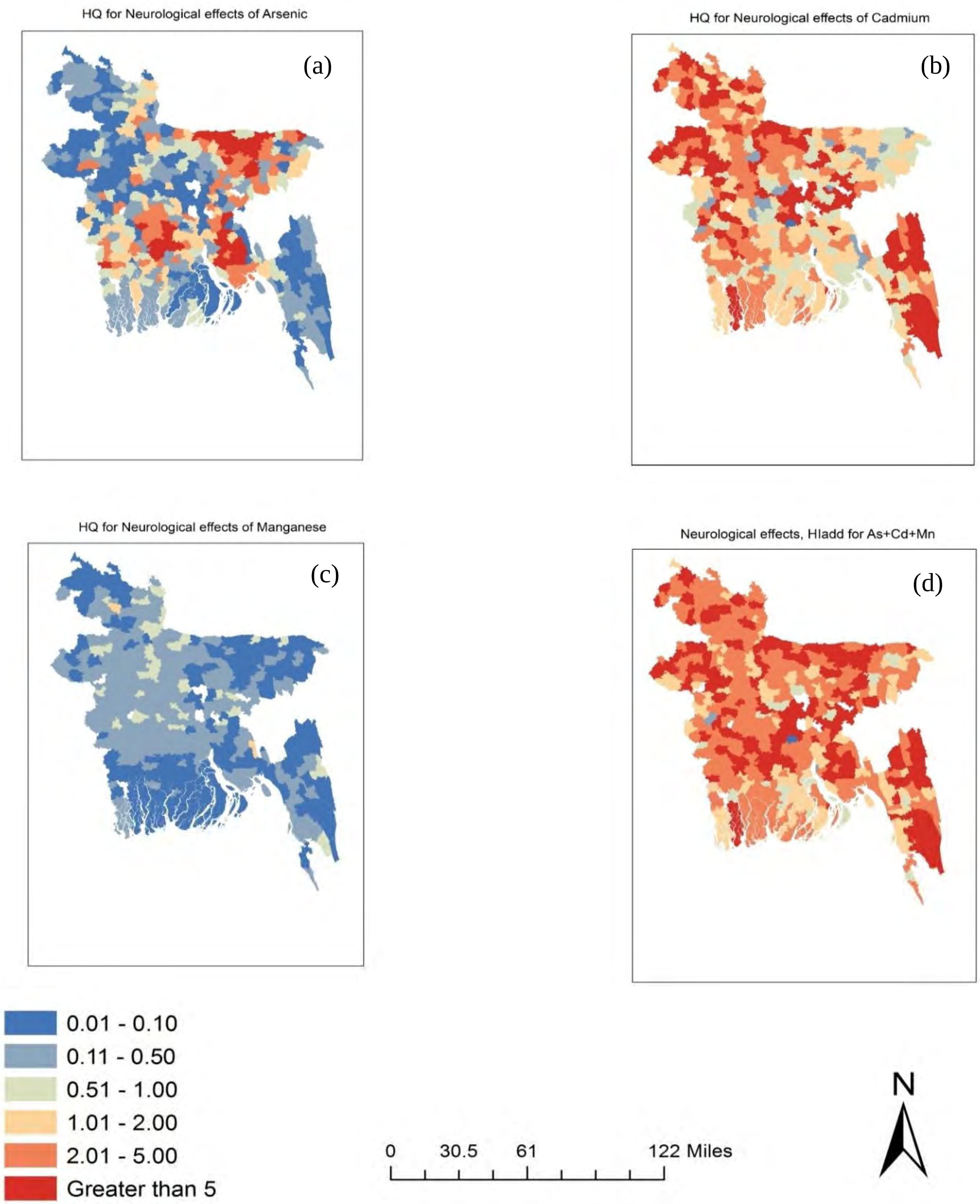


Figure 4.4: Estimates of drinking water-related risk of neurological effects. The map at (a) represents *HQ* scores based on Arsenic alone, (b) represents *HQ* scores based on Cadmium alone, (c) represents *HQ* scores based on Manganese alone, and (d) represents additive hazard index scores for the mixture of Arsenic + Cadmium + Manganese. On each map, results are shown only for Upazilas of Bangladesh.

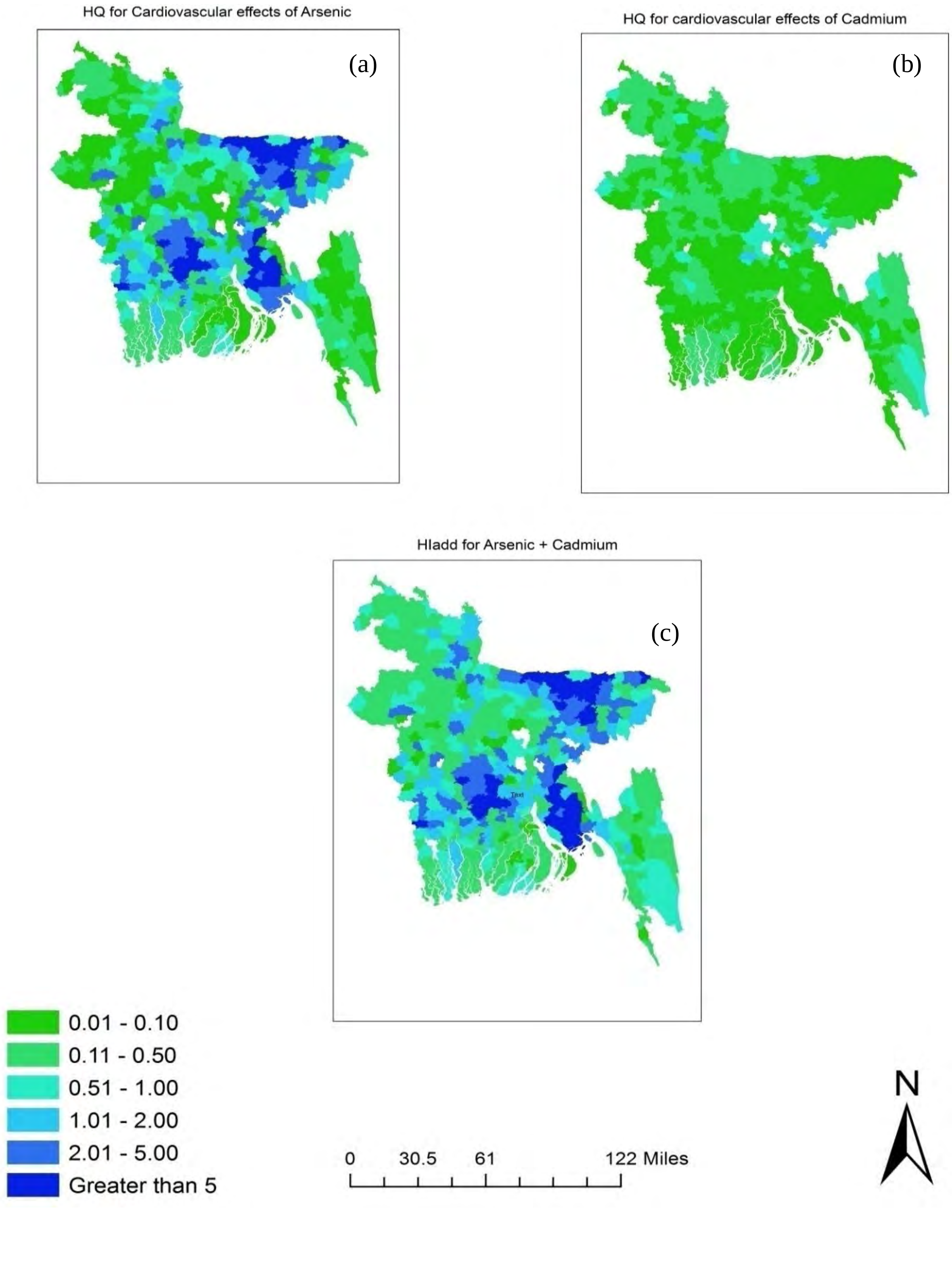


Figure 4.5: Estimates of drinking water-related risk of cardiovascular effects. The map at (a) represents *HQ* scores based on Arsenic alone, (b) represents *HQ* scores based on Cadmium alone and (c) represents additive hazard index scores for the mixture of Arsenic + Cadmium. On each map, results are shown only for Upazilas of Bangladesh.

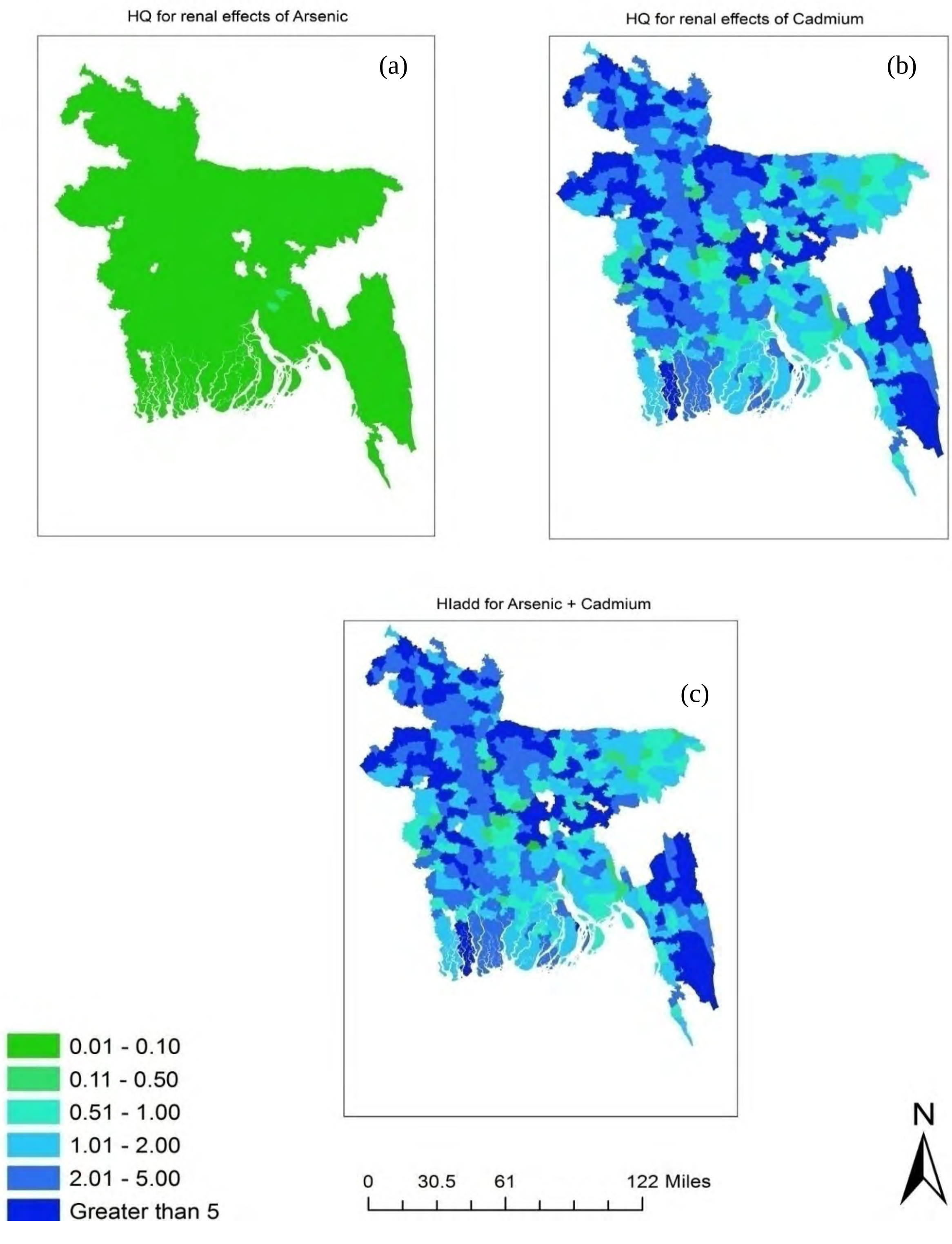


Figure 4.6: Estimates of drinking water-related risk of renal effects. The map at (a) represents *HQ* scores based on Arsenic alone, (b) represents *HQ* scores based on Cadmium alone and (c) represents additive hazard index scores for the mixture of Arsenic + Cadmium. On each map, results are shown only for Upazilas of Bangladesh.

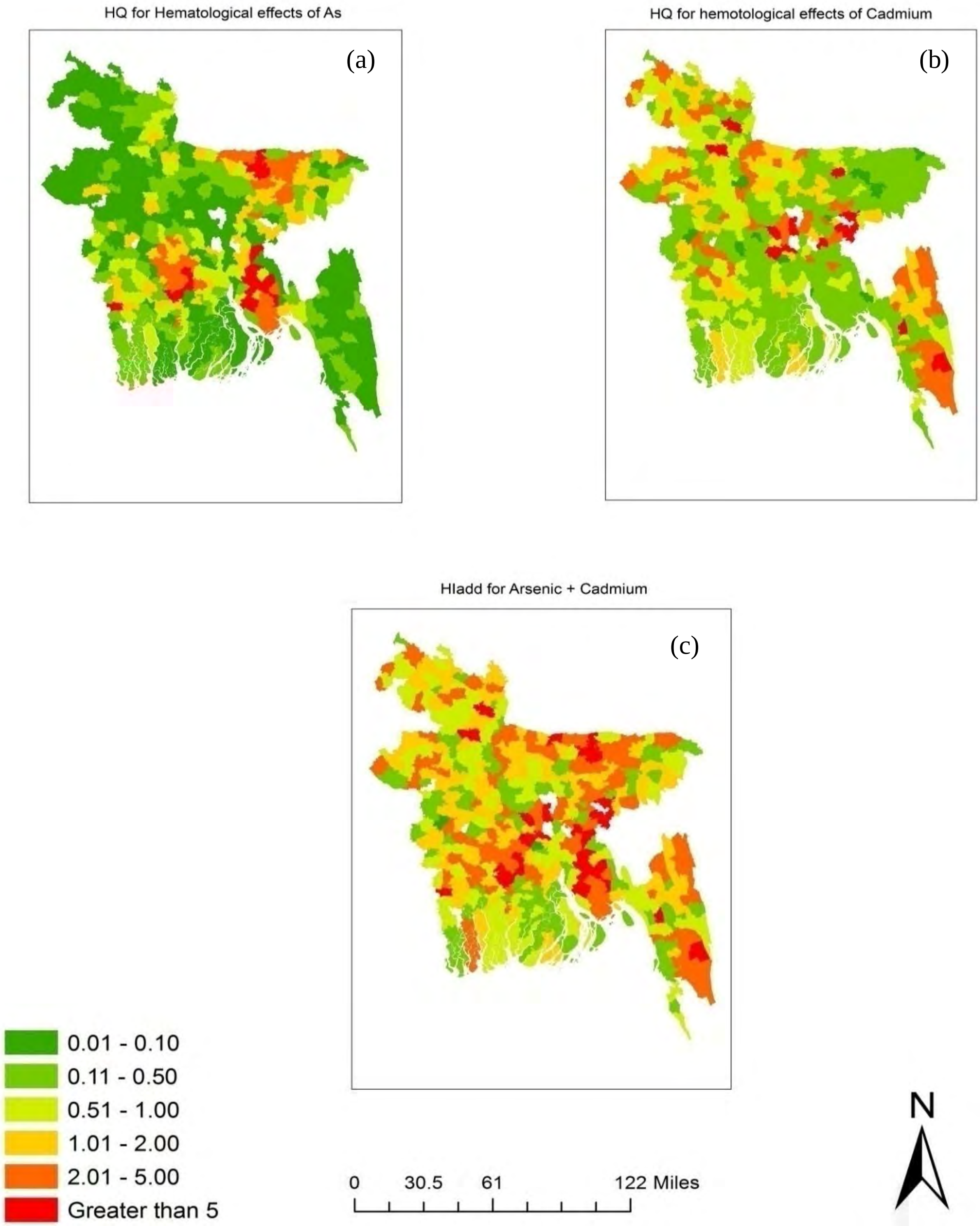


Figure 4.7: Estimates of drinking water-related risk of hematological effects. The map (a) represents *HQ* scores based on Arsenic alone, (b) represents *HQ* scores based on Cadmium alone and (c) represents additive hazard index scores for the mixture of Arsenic + Cadmium. On each map, results are shown only for Upazilas of Bangladesh.

4.5 Geographic Distributions of interactive Model Results

Figure 4.8 to 4.11 shows a geographically disaggregated analysis presenting three interactive hazard index scores (additive, synergistic, and antagonistic) for each mixture present in drinking water wells, mapped at upazila scale. These assessments will not provide complete risk assessments for the joint effects of arsenic, cadmium, and manganese; their resolution is to demonstrate the use of available drinking water data to examine proposed risk models in future rulemaking.

Figure 4.9, Figure 4.10 and Figure 4.11 shows the results of estimating binary hazard index scores for cardiovascular, renal and hematological effects of arsenic and cadmium (assuming no exposure to manganese). The national maps show hazard index model results for scenarios in which arsenic and cadmium are:

- Strongly synergistic [Figure 4.8(a), 4.9(a), 4.10(a), and 4.11(a), M = 10, B = +1 in equation 4.2 for each health effect.
- Additive [Figure 4.8(b), 4.9(b), 4.10(b), and 4.11(b), M = 1, B = 0, in equation 4.2 for each health effect.
- Strongly antagonistic [Figure 4.8(c), 4-9(c), 4-10(c) and 4-11(c), M = 10, B= -1 in equation 4.2 for each health effect.

In each map, upazilas sampled for both arsenic and cadmium are shaded according to the distribution of hazard index scores for local water sources. In Figure 4.8(c), 4.9(c), 4.10(c), and 4.11(c), map shows results of modeling a base-case scenario, assuming that the effects of arsenic and cadmium are additive and single-chemical dose–response information is adequate for cardiovascular, neurological, renal and hematological effects. The maximum hazard index was showed in Figure 4.8(a) and 4.8(b) estimates for each physiological endpoint, assuming strong synergistic and antagonistic relationship between arsenic and cadmium for cardiovascular health effects. To calculate interactive hazard index for renal health effects, again two different types of scenarios were taken into account, assuming strong synergy and strong antagonism between arsenic and cadmium as illustrated in Figure 4.9(a) and 4.9(b). In each cases arsenic and cadmium were only taken into consideration because target organ toxicity dose for manganese is not available currently. But for neurological health effects, relationships assuming strong synergy and antagonism have been established with the available target organ toxicity doses of arsenic, cadmium and manganese as demonstrated in Figure 4.10(a) and 4.10(b). From toxicological literatures it has been observed that arsenic, cadmium and manganese individually might affect the neurological system, but it is unclear whether exposure to a mixture of arsenic, cadmium and manganese would result in more-than or less-than additive neurological effects. Strong synergistic and antagonistic relationship between arsenic and cadmium for hematological effects has been illustrated in Figure 4.11(a) and 4.11(b) with the toxicity doses of arsenic and manganese.

Figure 4.8(a) demonstrates that according to the hazard index model, if arsenic and cadmium do interact with strong synergism, there is potential toxicity ($HI_{int} > 2.0$) for cardiovascular effects from the water samples in nearly every upazila sample and strong likelihood ($HI_{int} > 5.0$, dark red) in almost one third of the country. Figure 4.8(b) indicates that if arsenic and cadmium interact antagonistically, according to the hazard index model there is little likelihood of cardiovascular effects for most regions of the Bangladesh ($HI_{int} < 1.0$ in almost all Upazilas sampled). Moreover, there are few places especially in the northeastern zone of Bangladesh which are having strong likelihood ($HI_{int} > 5.0$) of potential toxicity for cardiovascular effects considering there is high interaction between Arsenic and Cadmium [Figure 4.8(c)].

Figure 4.9(a), 4.9(b), 4.9(c) shows that the choice of chemical-interaction scenario (synergism, antagonism or additivity) of Arsenic and Cadmium does not greatly vary the hazard index scores modeled for renal effects in Bangladesh. These two chemicals are found to have significant toxicity ranges for renal effects throughout the entire country with or without the potential interaction. Moreover, there remain a handful of upazilas in which water sources are modeled to have $HI_{int} > 5.0$, indicating the possibility of highly localized renal effects.

If arsenic, cadmium and manganese interact with strong synergism, there is significant potential toxicity (HI_{int} > 5.0) for neurological effects in almost every Upazilas of Bangladesh [(Figure 4.10 (a)]. This potential interaction hazard index has been calculated using Equation 2.2. Result shows strong synergism among these three chemicals can be very vulnerable for population of the entire country causing different types of neurological effects. Moreover, it was found from the analysis that, there is also potential toxicity for neurological effects without any interaction between arsenic, cadmium and manganese [Figure 10.(c)]. There is a handful number of upazilas in Bangladesh having hazard index HI_{int} > 5.0, when there is no interaction among those chemicals at all. This finding results from one chemical dominating the mixture. Antagonistic interaction between arsenic, cadmium and manganese was observed to have not so much of importance for neurological health effects in Bangladesh as mostly the hazard index value lies below 2.0. At few locations, like lower hilly areas of the country, antagonistic mixture generated potential hazard index value HI_{int} > 5.0 [Figure 4.10(b)].

The assumption of strong synergistic relationship between arsenic and cadmium in Bangladesh for hematological health effects was observed to have minor significance as are there few upazilas in Bangladesh having hazard index HI_{int} > 5.0 [Figure 4.11(a)]. There is substantial possibility of potential toxicity for hematological effects when Arsenic and Cadmium are related antagonistically or there is no interaction between them**.** At two-third of the country, the interactive HI was found range between 1.0- 5.0 with both the scenarios for hematological effects [Figure 4.11(b) and 4.11(c)].

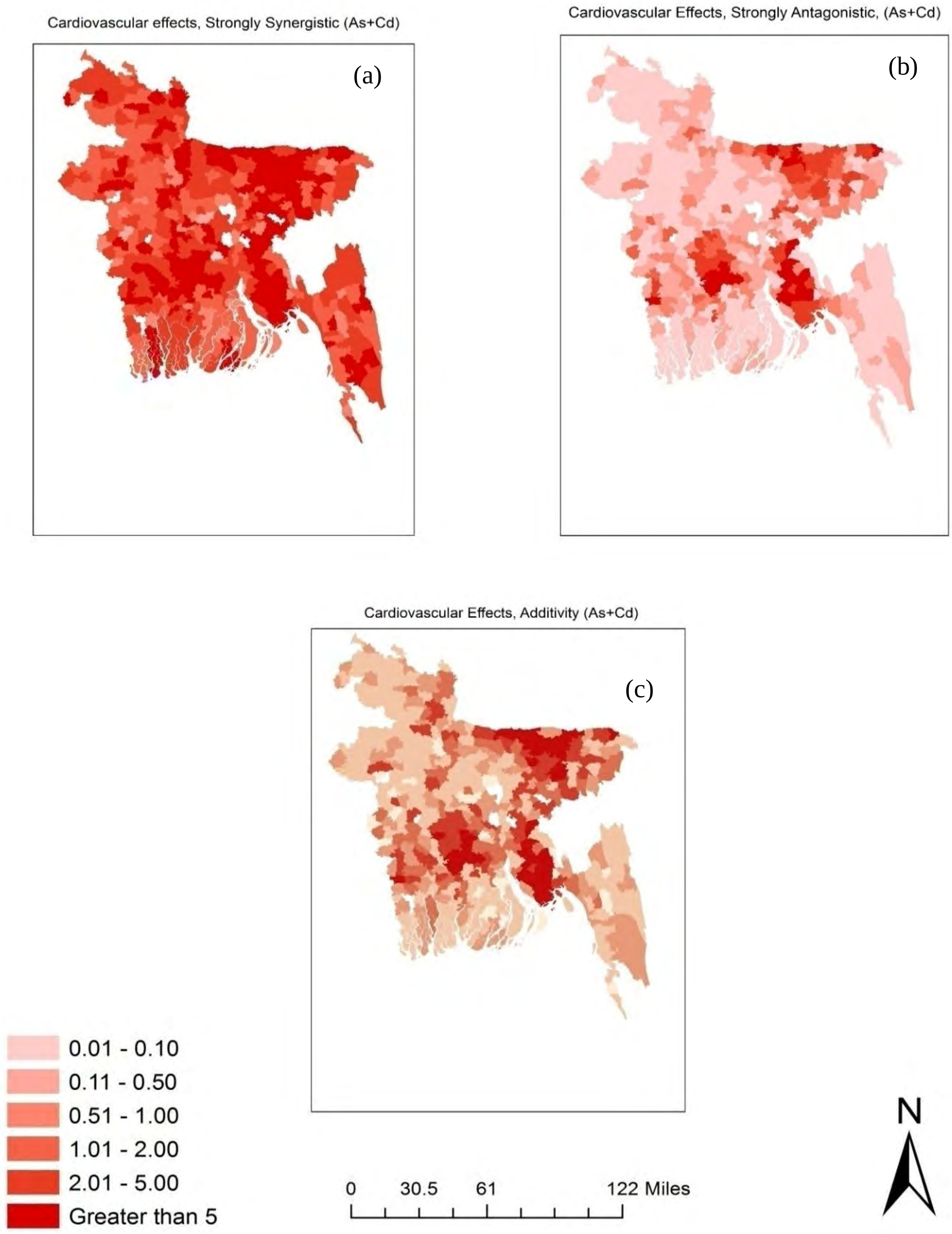


Figure 4.8: Range of HI scores for the cardiovascular effects of arsenic & cadmium, assuming (a) strong synergistic interaction, (b) Strong antagonistic interaction, and (c) no interaction (Additivity). On each map, results are shown only for Upazilas of Bangladesh.

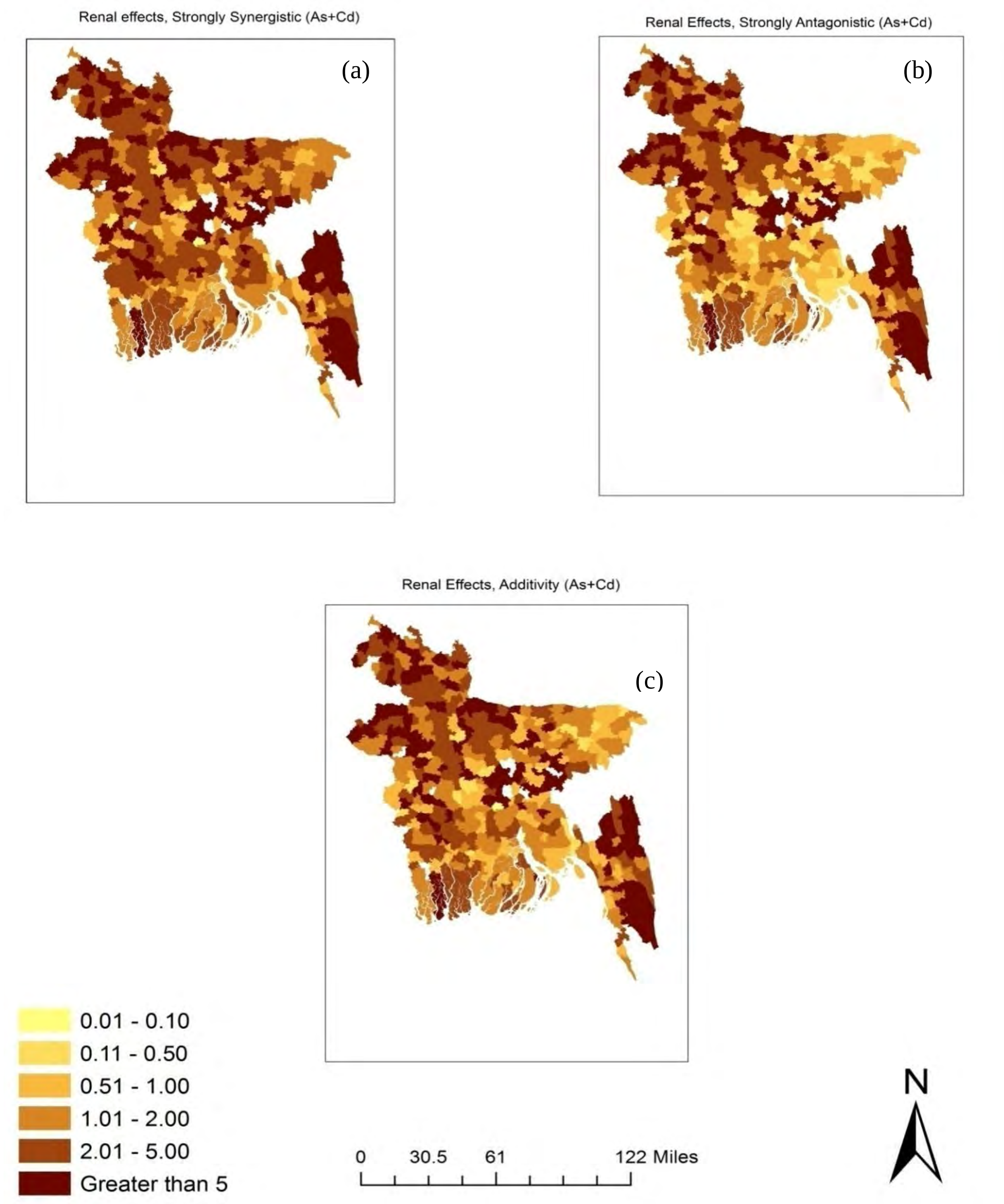


Figure 4.9: Range of HI scores for the renal effects of arsenic & cadmium, assuming (a) strong synergistic interaction, (b) Strong antagonistic interaction and (c) no interaction (Additivity) (c). On each map, results are shown only for Upazilas of Bangladesh.

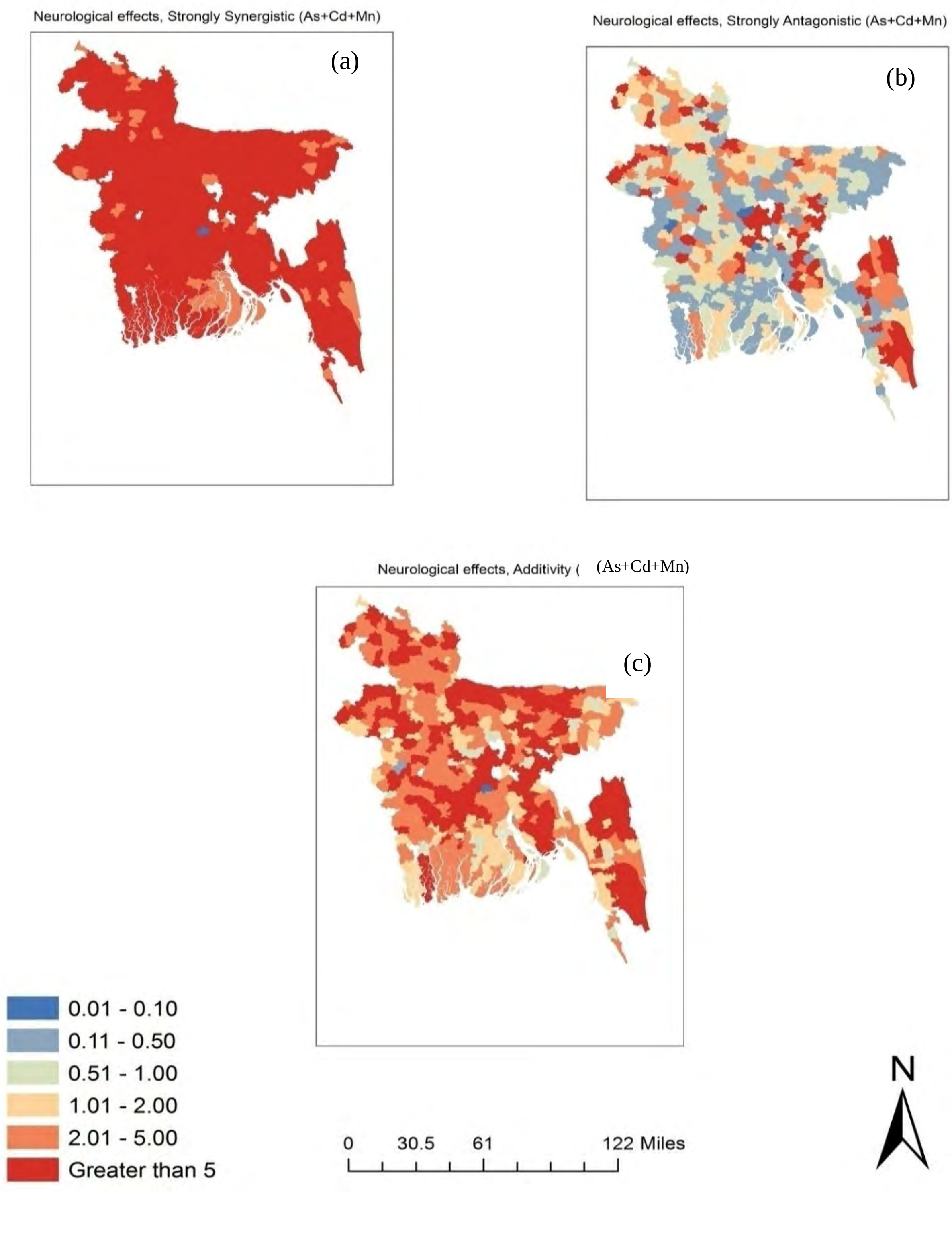


Figure 4.10: Range of *HI* scores for the neurological effects of arsenic & cadmium, assuming (a) strong synergistic interaction, (b) Strong antagonistic interaction, and (c) no interaction (Additivity). On each map, results are shown only for Upazilas of Bangladesh.

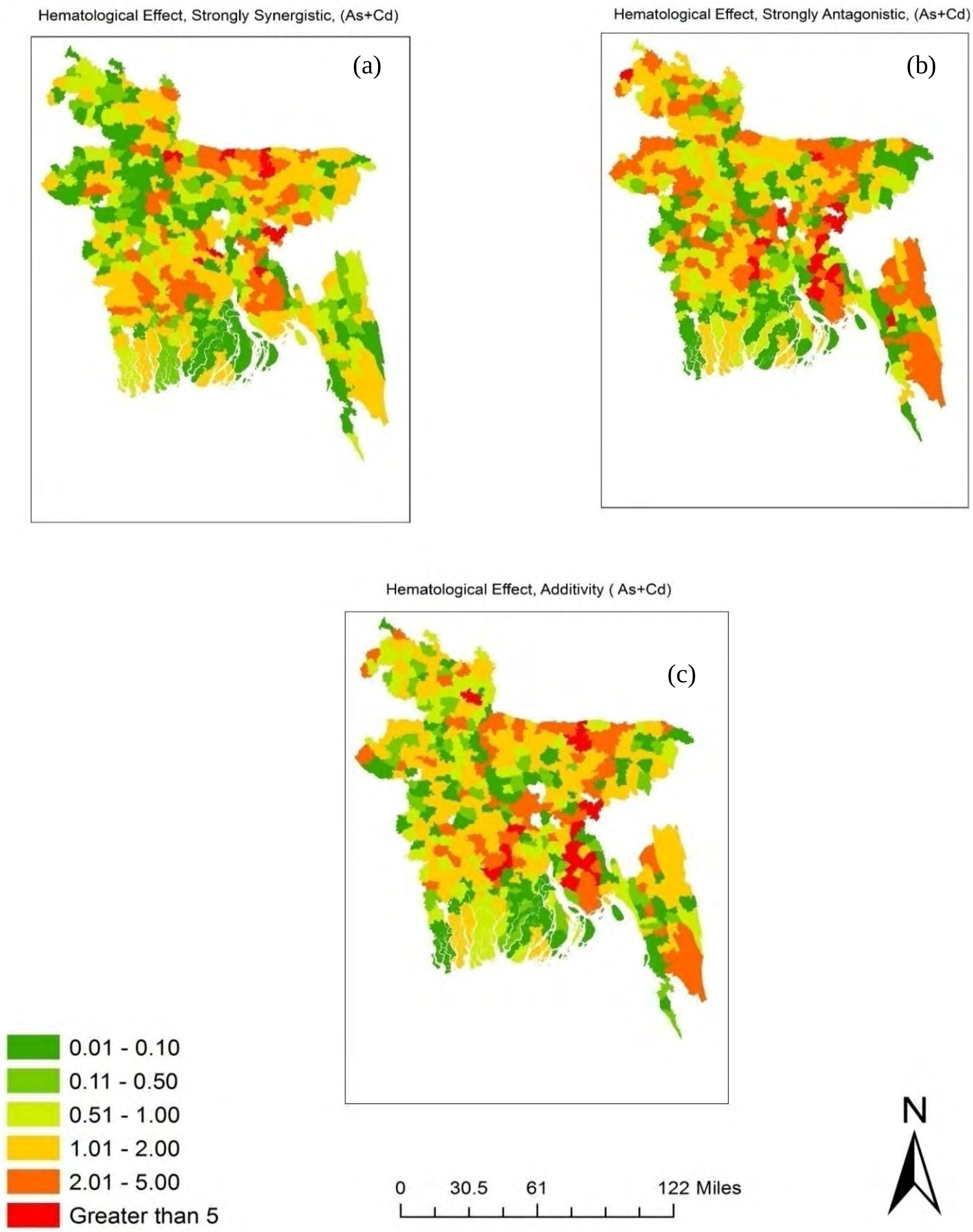


Figure 4.11: Range of *HI* scores for the hematological effects of arsenic & cadmium, assuming (a) strong synergistic interaction, (b) Strong antagonistic and (c) no interaction (Additivity). On each map, results are shown only for Upazilas of Bangladesh.

Chapter 5

CONCLUSIONS

5.1 Summery and Conclusions

Present study has utilized secondary data of Arsenic, Cadmium and manganese from potable drinking water sources of Bangladesh collected by UNICEF 2009 to assess the individual as well as combined mixture toxicity of different chemicals. ATSDR (2004) equations has been used to analyze the additive hazard index and interactive hazard index for illustrating different health effects which are going to help in scaling up risk assessment for complex mixtures of different types of chemicals. Finally, ArcGIS 10.2 has been used to demonstrate the geographic distribution of additive and interactive mixture toxicology between different chemicals of Bangladesh. Main outcome of this research has been summarized in the following paragraphs:

In base case scenario, the mixture toxicity of As, Mn and Cd has been assumed to be additive. The individual HI and summation of all component chemicals which constitutes the additive HI scores has been calculated using ATSDR (2004) equations. It has been found that, if there is a large difference between the potencies or the exposure concentrations of the component chemicals, HI may be dominated by the higher subset of component. For example, mixture of arsenic dominates the cardiovascular HI, cadmium dominates the both renal and hematological HI. For ternary mixtures of neurological effects, binary mixtures of arsenic and cadmium dominate the HI additivity. Moreover, the geospatial distribution of additive HI results found from this analysis was discussed earlier.

Again for interactive Hazard index it is established that, the greatest possibility for component chemical interactions is for those mixtures that happens contiguous to equitoxicity in drinking water (when $HQ_j : HQ_k$ near 1). For cardiovascular effects, the mixture toxicity ratios of arsenic and cadmium are close to equitoxicity ($HQ_j : HQ_k \leq 1.4$) and therefore possess much greater potential for interaction as the range of HI_{int} varies from 10% to 970% of the HI_{add}. Similarly for Hematological and Neurological health effects, the interaction range remains almost close to 10% to 960% and 10% to 990% respectively, indicating strong interaction as the relative toxicity ratio of component chemicals are close to equitoxicity ($HQ_j : HQ_k \leq 1.5$). In contrasts, for renal effects 90% of potable ground water samples, mixture toxicity ratio of Arsenic and Cadmium are likely to be additive ($HQ_j : HQ_k \leq 80$). So, the interaction of HI ranges between 60% to 170% of the HI_{add}. For this study, 10% values of mixture toxicity has been used which was discussed earlier.

The geographic distributions of interactive model results demonstrate three interactive hazard index (Additive, synergistic and antagonistic) scores for different health effects mapped at Upazila wise of Bangladesh. For cardiovascular effects, hazard index model exhibit that if arsenic and cadmium do interact with strong synergism, there is a strong likelihood of potential toxicity as HI > 5.0 at many places whereas for antagonistic effects there is little likelihood of potential toxicity (HI < 1.0). For renal effects the interaction of arsenic and cadmium are likely to be approximately additive as the toxicity ranges found from the analysis is not significant for interaction. For hematological effects, using the same interaction range, most of the Upazilas of Bangladesh were found to have significant interaction for both synergistic and antagonistic effects.

As mentioned earlier, the concentration of manganese is only been used for the analysis of neurological effects. When arsenic, cadmium and manganese interact with strong synergism, there is significant potential toxicity ($HI_{int} > 5.0$) in almost every upazilas of Bangladesh. Again for Antagonistic interaction, the interaction in overall Bangladesh is not a significant matter as mostly the hazard index value lies below 2.0 while at few locations, like lower hilly areas of the country, antagonistic mixture generated potential hazard index value $HI_{int} > 5.0$.

5.2 Limitations of the analysis

In this research, national data has been used to represent the potable drinking water resources that are a source of drinking water supply to a large percentage of people of Bangladesh. The analysis presented here uses a dataset of approximately 2896 potable drinking water sources in the Bangladesh that have been sampled for arsenic, cadmium, and manganese by UNICEF 2009.

There is little toxicological information available for analyzing potential toxicity interaction of chemicals on different health effects as the target-organ toxicity dose of manganese is not available for cardiovascular, renal, hematological except neurological health effect. So the interactions of mixture toxicity for cardiovascular, renal, hematological health effects has been conducted for binary chemicals (arsenic and cadmium) assuming there is no exposure to manganese.

Another limiting factor is the relative concentration of cadmium, which has been used to analyze the different health effects. Almost at 90% Upazilas of Bangladesh, Cd concentration exceeded the standard limit. Cadmium was measured in the laboratory and precision among laboratory replicates was high, analysis of field quality control samples revealed significant contamination of blanks and poor reproducibility among field replicates (UNICEF 2009). Cadmium levels were in fact very similar in blanks and field samples. Due to this incompatible consistency, the analysis of individual and combined hazard index gave over estimation at almost every upazilas. Consequently the cadmium data collected from different sources by UNICEF 2009 were considered as unreliable.

In addition, The assessment of HI interactive using ATSDR equation showed that, the interaction range of HIis strongly dependent on the ratio of mixture toxicity ($HQ_j : HQ_k$) with the bounded range of B ($-1 \leq B \leq +1$) and M (1 to 10). But the interaction (Synergistic, Antagonistic, Additive) on human body might also depend on weather of a country, genetic factor, weight, nutrient etc, which were not clearly investigated.

Furthermore the existing environmental data used to analyze this research has been collected from different potable water sources (rain water harvesting, dug wells, household water etc) of Bangladesh. So this investigation does not completely review the existing condition of ground water quality for different upazilas of Bangladesh.

5.3 Recommendations

Based on the analysis of complex mixture toxicology with existing environmental data to estimate HI_{int} : HI_{add} for 90% of drinking water wells shows that, for three health effects (Cardiovascular, Hematological and Neurological), the binary and ternary mixtures of chemicals are frequently occur close to equitoxicity. So the mixtures of component chemicals are showing strong interactive (Synergistic or antagonistic) relationship. In contrasts, for renal effects the mixture toxicity ratios are far from equitoxicity indicating that there is no significant interaction (additive) among component chemicals. So for Cardiovascular, Hematological and Neurological health effects, further study of specific mixtures and additional laboratory investigation is required to determine the possible interaction among chemicals that qualitative classify each mixtures as synergistic or antagonistic.

Again, it would always be hard to get impeccable knowledge on mixture toxicity. However, the analysis of hazard index model shows that in the deficiency of complete toxicological data, national drinking water data can be used to enhancement our understanding of the potential public health consequences of mixtures of chemicals in Bangladesh. Using this investigation, it would be possible to do some initial risk assessment on mixture toxicology without perfect information's. Surely it is going to help in setting priorities and making contaminant candidate list. Moreover this research has established that, national drinking water data of Bangladesh can be used to assess different proposed models of mixture risk.

REFERENCES

Altin, A., Filiz, Z. and Iscen, C. F., (2009) Assessment of seasonal variations of surface water quality characteristics for Porsuk stream, Environ. Monit.Assess.,158, 51–65.

ATSDR (1999a) Toxicological profile for cadmium. Atlanta, GA: Agency for Toxic Substances and Disease Registry.

ATSDR (2000a) Toxicological profile for arsenic. Atlanta, GA: Agency for Toxic Substances and Disease Registry.

ATSDR (2000b) Toxicological profile for manganese. Atlanta, GA: Agency for Toxic Substances and Disease Registry

ATSDR (2001) Guidance manual for the preparation of an interaction profile. Atlanta, GA: Agency for Toxic Substances and Disease Registry.

ATSDR (2004a) Interaction Profile for Arsenic, Cadmium, Chromium and Lead, Agency for Toxic Substances and Disease Registry, U.S. Department of Health and Human Services, Atlanta, GA.

ATSDR (2004b) Guidance manual for the assessment of the joint toxic action of chemical mixtures, Atlanta, GA: Agency for Toxic Substances and Disease Registry, US Department of Health and Human Services.

Beck, B. D., Slayton, T. M., Calabrese, E. J., Baldwin, L. A., and Rudel, R. (2001) The use of toxicology in the regulatory process, In A. W. Hayes (Ed.), Principles and Methods of Toxicology(pp. 23–75), Philadelphia: Taylor and Francis.

BGS and DPHE (2001) Arsenic contamination of groundwater in Bangladesh, BGS Technical Report, WC/00/19.

Bulut, V. N., Bayram, A., Gundogdu, A., Soylak, M. and Tufekci, M., (2010) Assessment of water quality parameters in the stream Galyan, Environ. Monit.Assess.,165, 1–13.

Calabrese, E. J. (1991) Quantitative analysis of combined effects of multiple agents inMultiple Chemical Interactions, (pp.21–92), Chelsea, MI Lewis.

Cassee, F. R., S¨uhnel, J., Groten, J. P., andFeron, V. J. (1999). Toxicology of chemical mixtures, In B. Ballantyne, T. Marrs, and T. Syversen (Eds.),General and Applied Toxicology (pp.303–319), London: Macmillan.

Chang, L. W., Ed. (1996) Toxicology of Metals, Boca Raton, FL: Lewis Publishers.

Das, P., Samantaray, S. and Rout, G. R. (1997) Studies on cadmium toxicity in plants: A review of Environ. Pollut., 98, 29–36.

EPA (1986) Guidance for conducting health risk assessment of chemical mixtures, Federal Register51(185), 34014–34025, Washington, DC: U.S. Environmental Protection Agency, Risk Assessment Forum

EPA (1990) Technical support document on health risk assessment of chemical mixtures, Washington, DC: U.S. Environmental Protection Agency, Office of Research and Development.

EPA (2000) Supplementary guidance for conducting health risk assessment of chemical mixtures, Washington, DC: U.S. Environmental Protection Agency, RiskAssessment Forum.

Feron, V. J., Cassee, F. R. and Groten, J. P. (1998) Toxicology of chemical mixtures: International perspective, Environmental Health Perspectives 106(Suppl 6), 1281–1289.

Jarup, L. (1998) Health effects of cadmium exposure — a review of the literature and a risk estimate. Scandinavian Journal of Work, Environment and Health, 24(Suppl. 1):1–51.

Hertzberg, R. C., andMacDonell, M. M. (2002) Synergy andother ineffective mixture risk definitions, Science of the TotalEnvironment,288(1–2), 31–42.

Hertzberg, R. C., andTeuschler, L. K. (2002) Evaluating quantitative formulas for dose-response assessment of chemical mixtures, Environmental Health Perspectives, 110(S6), 965–970.

Hertzberg, R. C. and MacDonell, M. M. (2002) Synergy and other ineffective mixture risk definitions, The Science of the Total Environment, 288, 31–42.

Ikem, A., Odueyungbo, S., Egiebor, N. O. and Nyavor, K., (2002) Chemical quality of bottled waters from three cities in eastern Alabama, Sci. Total Environ., 285, 165–175.

Khan, A. W., Ahmad, S. A. and Sayed, M. H. (1997) Arsenic contamination in ground water and its effect on human health with particular reference to Bangladesh, Journal of Preventive and Social Medicine, 16(1):65–73.

Kodell, R. L., and Pounds, J. G. (1991) Assessing the toxicity of mixtures of chemicals, In D. Krewskiand C. Franklin (Eds.), Statistics in Toxicology(pp. 559–591), New York: Gordon and Breach Science Publishers.

Kortenkamp, A., Backhaus, T., Faust, M. (2009) State of the Art Report on Mixture Toxicity. Directorate General for the Environment: Report to the EU Commission, The School of Pharmacy, University of London (ULSOP).

Krajnc, E. I. et al. (1987) Integrated criteria document. Cadmium Effects, Appendix.Bilthoven, National Institute of Public Health and Environmental Protection (Report No. 758476004)

La Point, T. W. and Waller, W. T. (2000) Field assessments in conjunction with whole effluent toxicity testing, Environmental Toxicology and Chemistry, vol. 19, no. 1, pp. 14-24.

Lerda, D. E. and Prosperi, C. H., (1996) Water mutagenicity and toxicology in Rio Tercero (Cordoba, Argentina), Water Res., 30, 819–824.

Melamed, R., Cao, X., Chen, M. and Ma, L. Q., (2003) Field assessment of lead immobilization in a contaminated soil after phosphate application, Sci. Total Environ., 305, 117–127.

Mohamed, A. R. and Ahmed, K. S. (2006) Market basket survey for some heavy metals in Egyptian fruits and vegetables, Food Chem. Toxicol., 44, 1273–1278.

Moon C, Marlowe M, Stellern J, et al. (1985) Main and interaction effects of metallic pollutants on cognitive functioning, J Learn Disabil 18(4):217–221.

Mumtaz, M. M., and Durkin, P. R. (1992) A weight-of-evidence scheme for assessing interactions in chemical mixtures, Toxicology and Industrial Health,8(6), 377–406.

Mumtaz, M. M., Poirier, K. A., and Colman, J. T. (1997) Risk assessment for chemical mixtures Fine-tuning the hazard index approach, Journal of Clean Technology, Environ-mental Toxicology and Occupational Medicine, 6(2), 189–204.

Ryker, S. J. and Small M. J., (2008) Combining Occurrence and Toxicity Information to Identify Priorities for Drinking-Water Mixture Research, Risk Analysis, Vol. 28, No. 3.

Saha, N., Zaman, M. R., (2011) Concentration of selected toxic metals in ground-water and some cereals grown in Shibganj area of Chapai-nawabganj, Rajshahi, Bangladesh, Current Science, Vol. 101, No. 3

Safe Drinking Water Act Amendments (1996), 42 U.S. Code of Federal Regulations, 300j–18.

Schreiber, Z. (2000) Chemical mixtures risk assessment: A conceptual model and reconstructive toxicology, Department of civil engineering, Environmental health engineering program, Evanston, IL: Northwestern University.

Seth, H. F., Richard, O., Donald, M. M. and Bibudhendra, S., (2002) The concentrations of arsenic and other toxic elements in Bangladesh's drinking water, Environ. Health Perspect., 110, 1147– 1153.

Smith, A. H.,Lingas, E. O. and Rahman, M. (2000) Contamination of drinking-water by arsenic in Bangladesh: a public health emergency, Bulletin of the World Health Organization, 78(9):1093 – 1103WMO.

Teuschler, L. K., Klaunig, J., Carney, E., et al. (2002). Support of science based decisions concerning the evaluation of the toxicology of mixtures: A new beginning, Regulatory Toxicology and Pharmacology36, 34–39.

Tripathi, R. M., Raghunath, R. and Krishnamoorthy, T. M. (1997) Dietary intake of heavy metals in Bombay City, India. Sci. Total Environ.,208, 149–159.

Thorpe, K., Gross-Sorokin, M., Johnson, I., Brighty, G., and Tyler, C. R. (2006) An assessment of the model of Concentration Addition for predicting the estrogenic activity of chemical mixtures in wastewater treatment work effluents, Environmental Health Perspectives, vol. 114, no. suppl 1, pp. 90-97.

Tseng W-P. (1977) Effects and dose-response relationships of skin cancer and Blackfoot disease with arsenic, Environ Health Perspect 19:109–119.

Teuschler, L. K., Groten, J. P., Hertzberg, R. C., Mumtaz, M. and Rice, G. (2001) Environmental chemical mixtures risk assessment: Current approaches and emerging issues, Comments on Toxicology7(5–6), 453–49

U.S. EPA. (1990) Technical Support Document on Health Risk Assessment of Chemical Mixtures, U.S.Environmental Protection Agency, Office of Research and Development, EPA/600/8–90/064, Washington, DC.

U.S. EPA. (2000) Supplementary Guidance for Conducting Health Risk Assessment of Chemical Mixtures, U.S. Environmental Protection Agency, Risk Assessment Forum,EPA/630/R-00/002, Washington, DC.

UNICEF (2009) Bangladesh National Drinking water Quality Survey, Dhaka, Bangladesh. Bangladesh Bureau of Statistics, Planning Division, Ministry of Planning, Government of the People's Republic of Bangladesh

U.S. EPA. (1986) Guidance for conducting health risk assessment of chemical mixtures, U.S. Environmental Protection Agency, Risk Assessment Forum, EPA/630/R-98/002, Washington, DC.Federal Register,51(185), 34014–34025.

APPENDIX

Appendix-T-1 Bangladesh Drinking Water Quality Standard in ECR, 1997

Sl. No.	Water Quality parameter	Unit	Bangladesh Standard
01.	Arsenic	mg/l	0.05
02.	BOD5	mg/l	0.2
03.	Cadmium	mg/l	0.005
04.	Calcium	mg/l	75
05.	Chloride	mg/l	150-600
06.	Chlorine (residual)	mg/l	0.2
07.	Chromium (total)	mg/l	0.05
08.	COD	mg/l	4
09.	Coliform (faecal)	N/100ml	0
10.	Coliform (total)	N/100ml	0
11.	Color	Hazen unit	15
12.	Dissolve oxygen (DO)	mg/l	6
13.	Hardness (as CaCO3)	mg/l	200-500
14.	Iron	mg/l	0.3-1.0
15.	Lead	mg/l	0.05
16.	Magnesium	mg/l	30-35
17.	Manganese	mg/l	0.1
18.	Mercury	mg/l	0.001
19.	Nickel	mg/l	0.1
20.	Odor	mg/l	Odorless
21.	Oil and grease	mg/l	0.01
22.	pH		6.5-8.5
23.	Sodium	mg/l	200
24.	Suspended solid	mg/l	10
25.	Sulfide	mg/l	0
26.	Sulfate	mg/l	400
27.	Total Dissolve Solid (TDS)	mg/l	1000
28.	Turbidity	JTU	10
29.	Zinc	mg/l	5

Appendix-T-2 Hazard index calculation for Neurolodical effects.

Neurological effects							
Upozilas	Dose of As	Dose of Cd	Avg_HQp..Mn	Avg_HIadd,P	SS Avg_Hint, P	SA Avg_Hint, P	Additive Avg_Hint, P
Nawabganj	0.001083	0.236667	0.493877551	34.40659184	56.93480527	21.05604304	34.40659184
Savar	0.001042	0.121458	0.111904898	17.56228585	25.12227824	12.28321995	17.56228585
Tejgaon	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>
Gazipur S.	0.0005	0.13825	0.045204082	19.84282313	24.79637585	15.8800351	19.84282313
Kaliakair	0.0005	0.118	0.055306122	16.96006803	21.87243401	13.15354895	16.96006803
Kaliganj	0.00055	0.10495	0.264816327	15.31005442	26.6461889	8.931636313	15.31005442
Kapasia	0.0005	0.06295	0.055714286	9.096190476	12.88651903	6.424005313	9.096190476
Sreepur	0.0005	0.154767	0.05966	22.21685048	27.89223486	17.70028788	22.21685048
Daulatpur	0.002875	0.003125	0.265306122	0.985544218	9.315781499	0.104351414	0.985544218
Ghior	0.0262	0.00272	0.436734694	3.320544218	17.16872128	0.653727042	3.320544218
Harirampur	0.028125	0.003525	0.335357143	3.5175	17.83540454	0.712168499	3.5175
Manikganj S.	0.0065	0.003988	0.33755102	1.526312925	14.58675317	0.160031164	1.526312925
Saturia	0.00225	0.0107	0.524489796	2.267346939	15.21328683	0.355007479	2.267346939
Shivalaya	0.048333	0.002967	0.293877551	5.320877551	18.11924443	1.593593343	5.320877551
Singair	0.018643	0.027857	0.503206939	6.258302177	46.88409108	0.896625085	6.258302177
Sadarpur	0.054583	0.009567	0.369387755	6.934482993	40.32524361	1.297609555	6.934482993
Gopalganj S.	0.175417	0.016867	0.033605306	19.14955769	87.39917812	4.310877554	19.14955769
Kashiani	0.1006	0.01248	0.181469388	11.54527891	57.92755439	2.530333257	11.54527891
Kotalipara	0.001643	0.007329	0.022390612	1.225866803	5.350830105	0.306393115	1.225866803
Muksudpur	0.0855	0.011125	0.10377551	9.835918367	51.63642537	2.042188457	9.835918367
Tungipara	0.040143	0.022886	0.035043673	7.127615102	69.89701799	0.774189268	7.127615102
Kalkini	0.0196	0.03482	0.087020408	6.927972789	51.89839154	1.025049877	6.927972789
Agailjhara	0.022833	0.013617	0.122653061	4.242510204	39.75729877	0.513396738	4.242510204
Babuganj	0.0044	0.00478	0.024163265	1.126068027	10.0106296	0.143185315	1.126068027
Bakerganj	0.0009	0.01122	0.010693878	1.699265306	4.427900121	0.679169369	1.699265306
Banaripara	0.001571	0.011986	0.01002898	1.871933741	6.302770613	0.584239023	1.871933741
Barisal S.	0.001	0.007729	0.01172	1.211100952	3.960984312	0.393054772	1.211100952
Gaurnadi	0.00225	0.008667	0.023129388	1.475557959	7.0879676	0.336874178	1.475557959
Hizla	0.0016	0.0093	0.088571429	1.56952381	5.885923641	0.430899109	1.56952381
Mehendiganj	0.0005	0.0052	0.014489796	0.804965986	2.207219824	0.305736789	0.804965986
Muladi	0.016333	0.006733	0.235646122	2.753027075	23.03010433	0.352418163	2.753027075
Wazirpur	0.0014	0.01028	0.010367347	1.612272109	5.51026675	0.498131354	1.612272109
Jhalakati S.	0.0005	0.004867	0.003945714	0.746850476	2.211955258	0.263619607	0.746850476
Kathalia	0.0012	0.00518	0.029877551	0.884163265	3.830734654	0.220192388	0.884163265
Nalchity	0.0015	0.012143	0.011895102	1.889466531	6.127818536	0.613526428	1.889466531
Rajapur	0.001786	0.004743	0.012244898	0.859911565	5.172708819	0.158195466	0.859911565
Bhandaria	0.008583	0.011533	0.13088449	2.59588449	20.58919256	0.364851647	2.59588449

Neurological effects							
Upozilas	Dose of As	Dose of Cd	Avg_HQp..Mn	Avg_HIadd,P	SS Avg_Hint, P	SA Avg_Hint, P	Additive Avg_Hint, P
Kawkhali	0.002625	0.013125	0.02122449	2.14622449	8.997485704	0.551474552	2.14622449
Mathbaria	0.008214	0.010043	0.096559592	2.313559592	19.17817846	0.314203225	2.313559592
Nazirpur	0.0158	0.00524	0.018857143	2.272190476	19.42626831	0.289641545	2.272190476
Nesarabad	0.00075	0.0064	0.006683673	0.992397959	3.121395427	0.332231326	0.992397959
Pirojpur S.	0.013	0.017587	0.023520408	3.774044218	32.3284965	0.474006696	3.774044218
Bhola S.	0.000643	0.016786	0.015743265	2.474981361	4.772093636	1.30966671	2.474981361
Burhanuddin	0.000688	0.013925	0.037295918	2.092105442	4.420627216	1.001352586	2.092105442
Charfasson	0.000667	0.008067	0.01034	1.226292381	3.206083625	0.489582954	1.226292381
Daulatkhan	0.0005	0.0143	0.008734694	2.099210884	3.966825693	1.133218726	2.099210884
Lalmohan	0.000667	0.013433	0.014149796	1.996673605	4.216767451	0.970968123	1.996673605
Manpura	0.0006	0.01844	0.016	2.707428571	4.957811643	1.503260397	2.707428571
Tazumuddin	0.0005	0.04305	0.011836735	6.209455782	8.948205685	4.336979822	6.209455782
Amtali	0.001318	0.010091	0.00282	1.569915238	5.40153835	0.468012649	1.569915238
Bamna	0.0024	0.00704	0.028816327	1.263102041	7.012938882	0.252942992	1.263102041
Barguna S.	0.001	0.013867	0.004421633	2.080659728	5.325710658	0.832939745	2.080659728
Betagi	0.0006	0.01016	0.012081633	1.520653061	3.429793461	0.695727249	1.520653061
Patharghata	0.001083	0.01395	0.024081633	2.120081633	5.325191726	0.877340852	2.120081633
Bauphal	0.001045	0.009627	0.019777551	1.494587075	4.393848653	0.535754636	1.494587075
Dashina	0.000687	0.005875	0.004540816	0.909255102	2.885850709	0.299944006	0.909255102
Galachipa	0.00575	0.03	0.00755102	4.840884354	20.63179086	1.163747593	4.840884354
Kalapara	0.005143	0.011857	0.004956327	2.188622993	14.81364159	0.334990259	2.188622993
Mirzaganj	0.0005	0.01626	0.013061224	2.383537415	4.295001641	1.34396892	2.383537415
Patuakhali S.	0.0005	0.00683	0.006693878	1.030027211	2.569316469	0.42905471	1.030027211
Alikadam	0.00125	0.081	0.681632653	12.37210884	33.22543764	4.820018985	12.37210884
Bandarban S.	0.001833	0.0596	0.048299184	8.737156327	15.74225446	4.926669469	8.737156327
Lama	0.002219	0.075956	0.107908163	11.17009864	19.8683745	6.330802234	11.17009864
Naikhongchhari	0.00075	0.036567	0.099387755	5.394673469	9.712857403	3.007803225	5.394673469
Rowangghhari	0.001	0.102333	0.018911429	14.73314952	20.66438648	10.56528335	14.73314952
Ruma	0.001667	0.142067	0.019727755	20.47377537	29.89309408	14.11697406	20.47377537
Thanchi	0.001	0.11575	0.015816327	16.64676871	22.94181528	12.14162226	16.64676871
Anwara	0.002364	0.053382	0.111873878	7.963016735	16.09719271	3.989464843	7.963016735
Banshkhali	0.001364	0.005591	0.168571429	1.097190476	6.120312869	0.200691802	1.097190476
Boalkhali	0.002292	0.026283	0.127584898	4.100584898	10.92311674	1.567677811	4.100584898
Chandanaish	0.001333	0.084867	0.012925306	12.26373483	19.06159352	7.957005382	12.26373483
Fatikchhari	0.008375	0.005	0.242857143	1.754761905	15.79429727	0.199739533	1.754761905
Hathazari	0.000625	0.00835	0.041428571	1.293809524	3.277564164	0.516817111	1.293809524
Kotwali	0.008	0.010769	0.033751837	2.33408517	19.62303298	0.309924394	2.33408517
Lohagara	0.006833	0.0428	0.255782449	7.020830068	24.72765612	2.088105109	7.020830068
Mirsharai	0.0145	0.0084	0.066122449	2.64707483	24.92096936	0.318604914	2.64707483

Neurological effects							
Upozilas	Dose of As	Dose of Cd	Avg_HQp..Mn	Avg_HIadd,P	SS Avg_Hint, P	SA Avg_Hint, P	Additive Avg_Hint, P
Patiya	0.00335	0.01018	0.107387755	1.880721088	9.884816238	0.383439415	1.880721088
Rangunia	0.0005	0.0038	0.001632653	0.592108844	2.031245326	0.178609798	0.592108844
Raozan	0.0015	0.1514	0.10789102	21.87931959	31.10261433	15.40490711	21.87931959
Sandwip	0.00425	0.0056	0.136122449	1.340884354	10.56632073	0.179006921	1.340884354
Satkania	0.0022	0.00939	0.060204082	1.611156463	7.008048351	0.398116756	1.611156463
Sitakunda	0.004667	0.018917	0.091972653	3.238877415	14.66034792	0.780116399	3.238877415
Chakaria	0.000563	0.01185	0.153061224	1.899537415	6.141698569	0.615641455	1.899537415
Cox Bazar S	0.000667	0.007067	0.12244898	1.195544218	4.575903874	0.323595523	1.195544218
Kutubdia	0.0015	0.0064	0.191836735	1.248979592	6.893724597	0.231156513	1.248979592
Maheshkhali	<Null>	<Null>	<Null>	<Null>	#VALUE!	<Null>	<Null>
Ramu	0.00075	0.00395	0.062380816	0.698095102	2.969749404	0.167004114	0.698095102
Teknaf	0.002667	0.012089	0.157369796	2.138369796	9.298457593	0.506175012	2.138369796
Ukhia	0.0005	0.006162	0.066632653	0.994537415	3.073830149	0.32709921	0.994537415
Akhaura	0.00075	0.295	0.371020408	42.58530612	63.11684277	28.95754894	42.58530612
Bancharampur	0.015167	0.1545	0.073809388	23.58971415	69.31074159	8.305667459	23.58971415
Brahmanbaria S.	0.0755	0.103262	0.219974286	22.16216476	187.2467066	2.881907339	22.16216476
Kasba	0.0005	0.163	0.071428571	23.4047619	29.63559939	18.49482662	23.4047619
Nabinagar	0.002	0.07	0.530612245	10.72108844	26.99053661	4.392613524	10.72108844
Nasirnagar	0.001594	0.149825	0.17946449	21.73484544	32.54853017	14.52582555	21.73484544
Sarail	0.002167	0.256667	0.044625714	36.91772095	50.5064964	27.11853506	36.91772095
Chandpur S.	0.00175	0.007933	0.035748163	1.335700544	5.671598534	0.341123447	1.335700544
Faridganj	0.0035	0.011267	0.028299184	1.971203946	10.58818645	0.404192415	1.971203946
Haimchar	0.002	0.0003	0.000408163	0.233741497	1.379732573	0.0407343	0.233741497
Haziganj	0.495	0.004	0.053979592	47.76826531	76.84692459	29.97539112	47.76826531
Kachua	0.265	0.009667	0.040748163	26.6598434	72.83124722	9.959869206	26.6598434
Matlab	0.011125	0.004506	0.26676	1.969998095	16.67363917	0.238969244	1.969998095
Shahrasti	0.194	0.020483	0.036530612	21.43886395	103.3271504	4.568906943	21.43886395
Barura	0.018278	0.012978	0.479682449	4.074444354	36.42433009	0.473419619	4.074444354
Brahmanpara	<Null>	<Null>	<Null>	<Null>	#VALUE!	<Null>	<Null>
Burichang	0.001773	0.009618	0.125973878	1.66883102	6.746293055	0.421412687	1.66883102
Chandhina	0.38	0.076675	0.009897959	47.15394558	329.4701851	6.778603541	47.15394558
Chauddagram	0.0005	0.0032	1.673469388	2.178231293	13.48448319	0.393668691	2.178231293
Comilla S.	0.000875	0.01305	0.12372449	2.071343537	5.95319408	0.732443945	2.071343537
Daudkandi	0.039942	0.007181	0.374819592	5.204676735	30.67867184	0.940187841	5.204676735
Debidwar	0.0005	0.0106	0.088979592	1.650884354	4.391218982	0.633867202	1.650884354
Homna	0.041	0.006878	0.660317551	5.547650884	33.33313898	0.945324796	5.547650884
Laksam	0.210056	0.014189	0.19410449	22.22643782	79.85260208	6.59226274	22.22643782
Muradnagar	0.19425	0.0055	0.046870612	19.3325849	46.71770457	8.20358239	19.3325849
Nangalkot	0.069833	0.00905	0.070952245	8.014571293	42.23162154	1.647805752	8.014571293

Neurological effects							
Upozilas	Dose of As	Dose of Cd	Avg_HQp..Mn	Avg_HIadd,P	SS Avg_Hint, P	SA Avg_Hint, P	Additive Avg_Hint, P
Dighinala	0.001045	0.034327	0.095881224	5.099262177	9.67665564	2.694201801	5.099262177
Khagrachhari	0.0005	0.107333	0.078571429	15.45947619	20.90044103	11.45074526	15.45947619
Lakshmichhari	0.0005	0.0498	0.035183673	7.197088435	10.24256233	5.062127304	7.197088435
Mahalchhari	0.0005	0.0086	0.002857143	1.279047619	2.978861195	0.562061673	1.279047619
Manikchhari	0.000667	0.0737	0.099047755	10.69114299	16.10980802	7.111365608	10.69114299
Matiranga	0.002333	0.045433	0.060272245	6.772891293	14.40547794	3.26692075	6.772891293
Panchhari	0.0005	0.110125	0.015408163	15.79517007	19.82305972	12.61346115	15.79517007
Ramgarh	0.000833	0.041011	0.035237959	5.973285578	9.644649927	3.72530005	5.973285578
Chhagalnaiya	0.005	0.019279	0.127492653	3.357825986	15.48683964	0.787364407	3.357825986
Daganbhuiyan	0.0005	0.0085	0.000816327	1.262721088	3.009630756	0.535075095	1.262721088
Feni S.	0.008167	0.002656	0.047301633	1.204539728	9.617567157	0.170017551	1.204539728
Parshuram	0.001722	0.012022	0.079319592	1.960748163	6.568865863	0.60568354	1.960748163
Sonagazi	0.025333	0.002967	0.077278776	2.913802585	13.76287984	0.676320166	2.913802585
Lakshmipur S.	0.236583	0.009583	0.076870612	23.9775849	67.86824271	8.759579261	23.9775849
Raipur	0.014429	0.007914	0.031895102	2.536657007	24.34358671	0.293501038	2.536657007
Ramganj	0.178083	0.006633	0.043401224	17.95125837	49.11894351	6.744758106	17.95125837
Ramgati	0.005625	0.008	0.167142857	1.845714286	14.10894961	0.256511944	1.845714286
Begumganj	0.08925	0.010514	0.072157551	10.07415755	50.49166293	2.157647303	10.07415755
Chatkhil	0.041125	0.00425	0.120204082	4.644013605	20.37534302	1.152556832	4.644013605
Companiganj	0.03825	0.004383	0.297755102	4.566755102	21.14879678	1.031010745	4.566755102
Hatiya	0.0005	0.0041	0.033877551	0.667210884	2.137091745	0.211964148	0.667210884
Noakhali S.	0.052458	0.005658	0.175782449	5.980068163	26.76429613	1.453699134	5.980068163
Senbagh	0.297833	0.008117	0.086258367	29.61087741	70.0696825	12.85632946	29.61087741
Bagaichhari	0.0013	0.06254	0.028163265	9.086258503	14.81791415	5.63750365	9.086258503
Barkal	0.00225	0.069025	0.826734694	10.90173469	34.11719187	3.676179206	10.90173469
Belaichhari	0.0005	0.0193	0.005306122	2.810068027	4.928775932	1.624831983	2.810068027
Juraichhari	0.001	0.008333	0.05966	1.345326667	4.203363632	0.439698258	1.345326667
Kaptai	0.001357	0.0078	0.13364449	1.377168299	5.831660321	0.330644897	1.377168299
Kawkhali	0.0005	0.0089	0.187755102	1.506802721	6.373379077	0.384272635	1.506802721
Langadu	0.0005	0.045367	0.194557959	6.723177007	13.68821226	3.381476479	6.723177007
Nannerchar	0.000714	0.053514	0.293702449	8.006559592	17.8422811	3.702601341	8.006559592
Rajasthali	0.0023	0.0136	0.129428571	2.291333333	8.527216232	0.633300741	2.291333333
Rangamati S.	0.0009	0.0324	0.035591837	4.749877551	8.298725107	2.746852708	4.749877551
Dhamrai	0.014409	0.144818	0.262782857	22.32335429	63.07235132	8.300196917	22.32335429
Dohar	0.02775	0.15	0.7	24.77142857	94.76980315	6.928656195	24.77142857
Keraniganj	0.037333	0.155	0.321768571	26.02014952	120.7577331	6.105626241	26.02014952
Gazaria	0.0005	0.089	0.008571429	12.77047619	16.52621234	9.901638344	12.77047619
Lohajang	0.0014	0.01204	0.174693878	2.028027211	7.399825906	0.566048295	2.028027211
Munshiganj S.	0.00075	0.01345	0.449234694	2.442091837	13.61151287	0.486638946	2.442091837

Neurological effects							
Upozilas	Dose of As	Dose of Cd	Avg_HQp..Mn	Avg_HIadd,P	SS Avg_Hint, P	SA Avg_Hint, P	Additive Avg_Hint, P
Sirajdikhan	0.007714	0.041764	0.350962041	7.051914422	27.06552209	1.912004575	7.051914422
Sreenagar	0.0005	0.0001	0.000408163	0.062312925	0.423802755	0.009859673	0.062312925
Tongibari	0.010611	0.009078	0.286757551	2.594186122	22.77747007	0.308753338	2.594186122
Araihazar	<Null>	<Null>	<Null>	<Null>	#VALUE!	<Null>	<Null>
Bandar	0.0005	0.0216	0.049591837	3.18292517	5.635664579	1.800978739	3.18292517
Narayanganj S.	0.0121	0.00616	0.127673469	2.160054422	19.14620028	0.269501232	2.160054422
Rupganj	0.001	0.0047	0.355102041	1.121768707	8.951739954	0.150485613	1.121768707
Sonargaon	0.0005	0.017	0.02877551	2.504965986	4.495847869	1.403970324	2.504965986
Belabo	0.000917	0.060317	0.353401224	9.057448844	20.65975557	4.096626942	9.057448844
Manohardi	0.03675	0.00505	0.588163265	4.809591837	26.79616794	0.879557315	4.809591837
Narsingdi S.	0.032667	0.048633	0.375102041	10.43381633	80.82377867	1.519989337	10.43381633
Palash	0.000556	0.033511	0.111337959	4.951576054	9.258868306	2.67670045	4.951576054
Raipur	0.000938	0.004962	0.154591837	0.952782313	5.156412405	0.18192715	0.952782313
Shibpur	0.010667	0.004933	0.345578367	2.066197415	18.4079463	0.234781941	2.066197415
Goalandaghat	0.022167	0.006667	0.532653061	3.59622449	28.20450565	0.467443788	3.59622449
Alfadanga	0.0355	0.00694	0.295428571	4.667809524	28.7167811	0.819703961	4.667809524
Bhanga	0.1875	0.005	0.174489796	18.74591837	42.36016449	8.553810917	18.74591837
Boalmari	0.045571	0.015646	0.349300408	6.924538503	55.69215731	0.960177859	6.924538503
Char Bhadrasan	0.054333	0.004667	0.557823265	6.39910898	27.22471568	1.531858422	6.39910898
Faridpur S.	0.02565	0.00499	0.291510204	3.44722449	21.28222073	0.588759523	3.44722449
Madhukhali	0.06425	0.009175	0.365816327	7.795578231	40.49557166	1.626863324	7.795578231
Nagarkanda	0.045875	0.007837	0.222959184	5.711578231	33.10073704	1.089801404	5.711578231
Madaripur S.	0.085682	0.016964	0.327198367	10.91081741	69.6278097	1.916710484	10.91081741
Rajoir	0.1915	0.0046	0.129693878	19.02493197	41.58751038	8.962928057	19.02493197
Shibchar	0.0149	0.01444	0.376326531	3.858231293	33.08903372	0.475823238	3.858231293
Baliakandi	0.022	0.01144	0.478367347	4.207891156	36.98207398	0.49900661	4.207891156
Pangsha	0.002056	0.009422	0.51156449	2.053374014	14.4273495	0.307665379	2.053374014
Rajbari S.	0.047	0.002125	0.218469388	4.998231293	14.64539905	1.731320718	4.998231293
Bhedarganj	0.0131	0.01588	0.229142857	3.745333333	30.54302129	0.506012331	3.745333333
Damudya	0.0095	0.01894	0.185632653	3.796108844	25.19143057	0.632739853	3.796108844
Gosairhat	0.007417	0.023867	0.299795918	4.415748299	22.60164636	0.909586301	4.415748299
Shariatpur S.	0.0344	0.00792	0.172734694	4.580353741	31.29713935	0.751149468	4.580353741
Zanjira	0.010667	0.013067	0.176496735	3.059115782	24.92388947	0.415408157	3.059115782
Baksiganj	0.0024	0.0731	0.308163265	10.97959184	22.802104	5.318793792	10.97959184
Dewanganj	0.002083	0.008067	0.595033878	1.945843401	15.44130799	0.257901918	1.945843401
Islampur	0.03745	0.08633	0.262040816	16.16156463	104.7338028	2.778533959	16.16156463
Jamalpur S.	0.00545	0.02699	0.300979592	4.675741497	19.17225708	1.176489676	4.675741497
Madarganj	0.014875	0.08175	0.27755102	13.37278912	51.27681185	3.758463683	13.37278912
Melandaha	0.01325	0.0285	0.340816327	5.67414966	35.96013594	0.973635382	5.67414966

Neurological effects							
Upozilas	Dose of As	Dose of Cd	Avg_HQp..Mn	Avg_HIadd,P	SS Avg_Hint, P	SA Avg_Hint, P	Additive Avg_Hint, P
Sarishabari	0.006333	0.072933	0.194693878	11.21683673	29.35196008	4.443974801	11.21683673
Jhenaigati	0.00075	0.054975	0.344897959	8.269897959	19.48303152	3.634165261	8.269897959
Nakla	0.008	0.072729	0.305306122	11.45706803	33.42464605	4.070492263	11.45706803
Nalitabari	0.038833	0.045333	0.709387755	10.88391156	89.61253152	1.449734814	10.88391156
Sherpur S.	0.00125	0.0296	0.654489796	5.002108844	22.01205215	1.23970711	5.002108844
Sreebardi	0.0005	0.089143	0.180583265	12.9629166	21.20311004	8.016028809	12.9629166
Astagram	0.006833	0.092767	0.065986531	13.96917701	35.33676887	5.723833523	13.96917701
Bajitpur	0.050667	0.004633	0.236530612	5.723816327	23.11601675	1.501367994	5.723816327
Bhairab	0.013125	0.04035	0.590204082	7.604489796	40.20053346	1.505587565	7.604489796
Hossainpur	0.000875	0.003675	0.414795918	1.023129252	9.002890062	0.125153604	1.023129252
Itna	0.033833	0.008133	0.011836735	4.395884354	33.24841036	0.605409536	4.395884354
Karimganj	0.0242	0.02378	0.168326531	5.870231293	52.82433562	0.739829687	5.870231293
Katiadi	0.02875	0.009125	0.152755102	4.194421769	33.30379531	0.596426426	4.194421769
Kishoreganj S.	0.001278	0.032944	0.366893469	5.194893469	15.60588597	1.80743771	5.194893469
Kuliarchar	0.00375	0.0028	0.597959184	1.355102041	12.93130972	0.142100953	1.355102041
Mithamain	0.031786	0.004729	0.088688163	3.791497687	20.79816921	0.76790285	3.791497687
Nikli	0.005167	0.064467	0.027755102	9.729421769	25.97058316	3.755827853	9.729421769
Pakundia	0.000733	0.00988	0.147864082	1.629102177	5.723952915	0.481284785	1.629102177
Tarail	0.006727	0.006036	0.460816327	1.963768707	18.63847812	0.207204694	1.963768707
Bhaluka	0.000571	0.0047	0.02635551	0.752165034	2.317053225	0.251801257	0.752165034
Dhobaura	0.065571	0.067214	0.156035102	16.00289224	148.1437633	1.89825561	16.00289224
Gaffargaon	0.00175	0.013438	0.493877551	2.580258503	14.80699469	0.481789475	2.580258503
Gauripur	0.002625	0.00585	0.113061224	1.19877551	7.545079452	0.199208814	1.19877551
Haluaghat	0.019375	0.02785	0.098163265	5.921972789	48.28386569	0.814523514	5.921972789
Ishwarganj	0.0049	0.005	0.075755102	1.256707483	10.78075426	0.161738121	1.256707483
Muktagachha	0.000857	0.018929	0.399650204	3.185412109	13.59087026	0.810782789	3.185412109
Mymensingh S.	0.007333	0.025467	0.328027347	4.664551156	22.99289424	0.990755682	4.664551156
Nandail	0.005167	0.035933	0.271428571	5.896809524	19.97561532	1.7912857	5.896809524
Phulbari	0.006389	0.0075	0.062766531	1.742671293	14.75909296	0.232705272	1.742671293
Phulpur	0.009333	0.045033	0.384421633	7.70656449	31.37881104	1.984354253	7.70656449
Trishal	0.0008	0.03142	0.089795918	4.654557823	8.646967669	2.512670271	4.654557823
Atpara	0.037833	0.007567	0.040952245	4.725095102	31.92167895	0.761721211	4.725095102
Barhatta	0.16	0.0035	0.106122449	15.84421769	33.40245977	7.719103905	15.84421769
Durgapur	0.092	0.011533	0.461496735	10.87097293	52.49961185	2.433965078	10.87097293
Kalmakanda	0.083357	0.018814	0.056035102	10.68251129	77.68566056	1.567209789	10.68251129
Kendua	0.009625	0.053775	0.138571429	8.737380952	33.59738081	2.451955996	8.737380952
Khaliajuri	0.04625	0.003525	0.047857143	4.956190476	19.00490157	1.385043205	4.956190476
Madan	0.052667	0.010844	0.040861633	6.605909252	45.68036113	1.025739693	6.605909252
Mohanganj	0.11525	0.1913	0.011020408	38.31578231	307.0836362	4.809541292	38.31578231

Neurological effects							
Upozilas	Dose of As	Dose of Cd	Avg_HQp..Mn	Avg_HIadd,P	SS Avg_Hint, P	SA Avg_Hint, P	Additive Avg_Hint, P
Netrokona S.	0.010885	0.013308	0.067158367	3.004967891	25.71146947	0.397203875	3.004967891
Purbadhala	0.025667	0.004767	0.03088449	3.15636068	20.40810213	0.533918235	3.15636068
Basail	0.01825	0.00355	0.408163265	2.653401361	17.9330252	0.398421437	2.653401361
Bhuapur	0.001063	0.00785	0.457653061	1.680319728	12.18478903	0.254339002	1.680319728
Delduar	0.000667	0.00375	0.20966	0.808898095	5.729605515	0.122458556	0.808898095
Ghatail	0.00195	0.01732	0.136571429	2.796571429	8.644259561	0.918979013	2.796571429
Gopalpur	0.002375	0.03335	0.246938776	5.237414966	14.09601627	1.963386859	5.237414966
Kalihati	0.0018	0.0106	0.309387755	1.995102041	10.34674075	0.398640305	1.995102041
Madhupur	0.00092	0.034928	0.103265306	5.180598639	9.723923464	2.768345808	5.180598639
Mirzapur	0.0005	0.00285	0.334693878	0.789455782	7.062382153	0.097450582	0.789455782
Nagarpur	0.006188	0.0684	0.186938776	10.54770068	28.11568192	4.109075234	10.54770068
Sakhipur	0.00075	0.0158	0.514897959	2.843469388	15.74386035	0.570893646	2.843469388
Tangail S.	0.000889	0.006867	0.458095102	1.523761769	11.74595928	0.218836397	1.523761769
Abhaynagar	0.0135	0.03896	0.377183673	7.228612245	39.12208292	1.444782452	7.228612245
Bagherpara	0.015333	0.097767	0.163265306	15.59026531	56.59292935	4.594672011	15.59026531
Chaugachha	0.028833	0.0051	0.102313061	3.57688449	21.47875887	0.665444483	3.57688449
Jessore S.	0.005313	0.020888	0.247602041	3.737602041	17.21016997	0.847089321	3.737602041
Jhikargachha	0.036833	0.009733	0.054693878	4.953027211	38.22738412	0.70779281	4.953027211
Keshabpur	0.024063	0.016994	0.050510204	4.769938776	46.44872784	0.539835396	4.769938776
Manirampur	0.013786	0.012543	0.107171837	3.211981361	29.14129262	0.401115488	3.211981361
Sharsha	0.0065	0.0153	0.053061224	2.857823129	18.19681046	0.501436521	2.857823129
Harinakunda	0.002167	0.009633	0.539931837	2.122455646	15.13285	0.313084336	2.122455646
Jhenaidaha S.	0.015333	0.00365	0.341428571	2.323142857	16.75004879	0.328074556	2.323142857
Kaliganj	0.0033	0.0747	0.227673469	11.21338776	23.21374008	5.450832725	11.21338776
Kotchandpur	0.012056	0.015311	0.16644	3.50191619	28.44771803	0.482399406	3.50191619
Maheshpur	0.005375	0.0166	0.157142857	3.04047619	15.84009427	0.629088356	3.04047619
Shailkupa	0.008375	0.08755	0.200255102	13.50501701	37.11685645	5.137845271	13.50501701
Magura S.	0.006125	0.025275	0.207653061	4.40170068	19.48002658	1.057676319	4.40170068
Mohammadpur	0.000889	0.058222	0.421904898	8.824000136	22.08616392	3.667072312	8.824000136
Shalikha	0.01825	0.0229	0.167244898	5.176768707	43.11808338	0.703902785	5.176768707
Sreepur	0.0005	0.062833	0.247346939	9.271108844	18.4582769	4.765660607	9.271108844
Kalia	0.006	0.034517	0.057278776	5.559707347	21.42990756	1.548215471	5.559707347
Lohagara	0.0024	0.0224	0.165387755	3.593959184	10.81066991	1.213297571	3.593959184
Narail S.	0.024944	0.033322	0.433106531	7.569011293	59.80585858	1.059415445	7.569011293
Bagerhat S.	0.0016	0.0163	0.032244898	2.513197279	7.029820205	0.942589465	2.513197279
Chitalmari	0.003	0.0034	0.053061224	0.824489796	6.853621416	0.108909374	0.824489796
Fakirhat	0.017625	0.024888	0.07005102	5.30405102	43.90180452	0.712689573	5.30405102
Kachua	0.049	0.0056	0.016530612	5.483197279	27.49403903	1.139828129	5.483197279
Mollahat	0.014833	0.007911	0.023265306	2.56607483	24.73554213	0.291338311	2.56607483

Neurological effects							
Upozilas	Dose of As	Dose of Cd	Avg_HQp..Mn	Avg_HIadd,P	SS Avg_Hint, P	SA Avg_Hint, P	Additive Avg_Hint, P
Mongla	0.0015	0.022	0.05755102	3.343265306	7.895643939	1.450646515	3.343265306
Morrelganj	0.002278	0.021867	0.014512653	3.355322177	10.07164376	1.164600251	3.355322177
Rampal	0.0063	0.01288	0.241632653	2.681632653	17.52548813	0.432144941	2.681632653
Batiaghata	0.002438	0.006687	0.031734694	1.219210884	6.993995007	0.236834975	1.219210884
Dacope	0.0108	0.01965	0.023795918	3.859510204	29.09984226	0.550035004	3.859510204
Dighalia	0.002	0.006267	0.318299184	1.404061088	9.960425803	0.202428065	1.404061088
Dumuria	0.00565	0.01663	0.013918367	2.927727891	17.13539029	0.530379711	2.927727891
Kotwali	0.0005	0.009433	0.005782449	1.400972925	3.088413415	0.653612252	1.400972925
Koyra	0.0035	0.052467	0.092244898	7.920863946	18.60143662	3.481978723	7.920863946
Paikgachha	0.00225	0.0038	0.09244898	0.849591837	6.117188213	0.122894451	0.849591837
Phultala	0.000875	0.01195	0.040306122	1.830782313	4.470980416	0.765457858	1.830782313
Rupsa	0.013333	0.004367	0.042176735	1.935843401	15.96805108	0.265177301	1.935843401
Terokhada	0.037812	0.0146	0.174132653	5.860989796	50.45243376	0.771910053	5.860989796
Mathbaria	0.0016	0.0159	0.09044898	2.514258503	7.16644484	0.899895454	2.514258503
Assasuni	0.010056	0.010856	0.015464898	2.524036327	23.2619682	0.294472183	2.524036327
Debhata	0.001556	0.014833	0.197641633	2.464832109	8.55919985	0.72252188	2.464832109
Kalaroa	0.119	0.017725	0.05244898	13.91792517	81.13908762	2.510105863	13.91792517
Kaliganj	0.006917	0.009233	0.063537551	2.041299456	16.65339882	0.283357029	2.041299456
Satkhira S.	0.00925	0.0048	0.012755102	1.579421769	15.20246201	0.178636404	1.579421769
Shyamnagar	0.0026	0.00816	0.146122449	1.559455782	8.335631503	0.301177861	1.559455782
Tala	0.014667	0.0146	0.042040816	3.524612245	32.6908696	0.421041111	3.524612245
Alamdanga	0.005607	0.033264	0.315451837	5.601451837	20.80756543	1.550977045	5.601451837
Chuadanga S.	0.0005	0.0456	0.125306122	6.687210884	11.80128096	3.834293127	6.687210884
Damurhula	0.019	0.0038	0.254421633	2.606802585	16.47746536	0.430192078	2.606802585
Jibannagar	0.0005	0.00335	0.039591837	0.565782313	2.076472038	0.156707842	0.565782313
Bheramara	0.024938	0.0059	0.244540816	3.462445578	23.43759432	0.551953225	3.462445578
Daulatpur	0.00425	0.008281	0.314795918	1.902557823	13.86478893	0.264413615	1.902557823
Khoksa	<Null>	<Null>	<Null>	<Null>	#VALUE!	<Null>	<Null>
Kumarkhali	0.0266	0.00804	0.331428571	4.013333333	30.26017979	0.570062481	4.013333333
Kushtia S.	0.0005	0.069767	0.48843551	10.50276884	26.57946712	4.299454739	10.50276884
Mirpur	0.0005	0.0019	0.106122449	0.425170068	3.056832466	0.061430192	0.425170068
Gangni	0.011909	0.005464	0.263562041	2.178323946	18.80006276	0.261587369	2.178323946
Meherpur S.	0.000667	0.006083	0.176462449	1.108986259	5.584825905	0.234774966	1.108986259
Adamdighi	0.00095	0.01282	0.146367347	2.068272109	6.449292544	0.677617717	2.068272109
Bogra S.	0.0005	0.019229	0.496909796	3.291528844	16.29798301	0.72917652	3.291528844
Dhunat	0.009	0.022	0.357142857	4.357142857	25.96641847	0.770649771	4.357142857
Dupchanchia	0.000667	0.010833	0.173242449	1.784337687	6.451074707	0.519374826	1.784337687
Gabtali	0.000875	0.015625	0.245918367	2.561394558	9.181412519	0.754321058	2.561394558
Kahaloo	0.0005	0.013433	0.157823265	2.124442313	6.560761147	0.722440944	2.124442313

Neurological effects							
Upozilas	Dose of As	Dose of Cd	Avg_HQp..Mn	Avg_HIadd,P	SS Avg_Hint, P	SA Avg_Hint, P	Additive Avg_Hint, P
Nandigram	0.0005	0.010033	0.13088449	1.611789252	5.237770204	0.51911738	1.611789252
Sariakandi	0.000625	0.00615	0.619387755	1.557482993	13.92377634	0.196849734	1.557482993
Sherpur	0.0005	0.018229	0.283206939	2.934968844	10.68403017	0.865925579	2.934968844
Shibganj	0.0016	0.02876	0.093306122	4.354258503	9.658950663	1.984876487	4.354258503
Sonatala	0.00275	0.01955	0.124489796	3.179251701	10.54168895	0.992670625	3.179251701
Akkelpur	0.0045	0.023443	0.215043673	3.992615102	15.70400584	1.054281781	3.992615102
Joypurhat S.	0.001786	0.009671	0.225073061	1.776739728	8.479690656	0.38039164	1.776739728
Kalai	0.0005	0.01085	0.104591837	1.702210884	4.788238216	0.623083056	1.702210884
Khetlal	0.0009	0.01264	0.128163265	2.019591837	5.991236642	0.692639691	2.019591837
Panchbibi	0.000583	0.018767	0.146122449	2.882646259	7.341612598	1.166432276	2.882646259
Biral	0.0005	0.021525	0.097346939	3.219965986	6.664041975	1.577576691	3.219965986
Birampur	0.0005	0.01625	0.061428571	2.43047619	4.885346816	1.215053351	2.43047619
Birganj	0.004	0.0451	0.091020408	6.914829932	18.39374489	2.713123445	6.914829932
Bochaganj	0.0014	0.01208	0.058040816	1.917088435	5.74598753	0.661738269	1.917088435
Chirirbandar	0.0006	0.01556	0.165632653	2.445632653	7.185760637	0.867656967	2.445632653
Dinajpur S.	0.0005	0.0655	0.180204082	9.584965986	16.97942286	5.493956205	9.584965986
Ghoraghat	0.0005	0.016367	0.057415102	2.443177007	4.828533803	1.241064044	2.443177007
Hakimpur	0.000667	0.020411	0.154648571	3.134029524	7.89417164	1.27855875	3.134029524
Kaharole	0.001333	0.024333	0.066258367	3.669353605	8.01594198	1.70401345	3.669353605
Khansama	0.0031	0.02514	0.13555102	4.022217687	12.45286688	1.343148565	4.022217687
Nawabganj	0.0005	0.020133	0.029342449	2.953104354	5.064622619	1.730055831	2.953104354
Parbatipur	0.001056	0.042722	0.226984082	6.430698367	14.06941239	2.993814612	6.430698367
Phulbari	0.0005	0.026417	0.262040816	4.083517007	11.81246034	1.486087495	4.083517007
Atwari	0.00125	0.0243	0.033469388	3.623945578	7.707045483	1.747498438	3.623945578
Boda	0.001375	0.0565	0.045306122	8.247687075	13.91013156	4.944008922	8.247687075
Debiganj	0.0018	0.02602	0.071183673	3.959755102	9.410078075	1.706633922	3.959755102
Panchagarh S.	0.00075	0.0855	0.027755102	12.31346939	16.87700453	9.016002784	12.31346939
Tentulia	0.000583	0.010983	0.033401224	1.657925034	3.608840846	0.770067939	1.657925034
Baliadangi	0.00075	0.133833	0.018843673	19.20927224	24.75319259	14.95297662	19.20927224
Haripur	0.002	0.076	0.142857143	11.19047619	19.76291275	6.356327551	11.19047619
Pirganj	0.0017	0.01346	0.072897959	2.157659864	6.755861745	0.713398935	2.157659864
Ranisankail	0.000937	0.016825	0.134030612	2.626840136	6.953639333	1.00648605	2.626840136
Thakurgaon S.	0.001833	0.023758	0.088469388	3.657040816	9.148472633	1.49203209	3.657040816
Atgharia	0.0005	0.011314	0.366239184	2.030143946	11.23573023	0.407787906	2.030143946
Bera	0.0125	0.023	0.244897959	4.721088435	32.54474955	0.756921024	4.721088435
Bhangura	0.0005	0.0132	0.399727755	2.333061088	12.49844092	0.482715351	2.333061088
Chatmohar	0.001063	0.0116	0.320408163	2.078789116	10.17967513	0.456103857	2.078789116
Faridpur	0.0008	0.087	0.533061224	13.03782313	30.81733781	5.708398018	13.03782313
Ishwardi	0.0065	0.0246	0.218843673	4.352177007	20.22277326	0.99798683	4.352177007

Neurological effects							
Upozilas	Dose of As	Dose of Cd	Avg_HQp..Mn	Avg_HIadd,P	SS Avg_Hint, P	SA Avg_Hint, P	Additive Avg_Hint, P
Pabna S.	0.0005	0.04355	0.261428571	6.53047619	15.18212401	2.905943608	6.53047619
Santhia	0.0078	0.0212	0.327918367	4.099346939	23.12206849	0.763724012	4.099346939
Sujanagar	0.002571	0.013986	0.111020408	2.353877551	8.986068871	0.643338342	2.353877551
Belkuchi	0.002429	0.021857	0.436384898	3.790146803	15.73242339	0.94674701	3.790146803
Chauhali	0.001042	0.044108	0.482244898	6.88262585	20.76001857	2.409190833	6.88262585
Kamarkhanda	0.010437	0.019625	0.324081633	4.121653061	27.89684911	0.650967935	4.121653061
Kazipur	0.00425	0.0025	0.604081633	1.365986395	13.02177271	0.143395652	1.365986395
Raiganj	0.015929	0.021057	0.563265306	5.088455782	40.20804587	0.672020612	5.088455782
Shahjadpur	0.001	0.015	0.142857143	2.380952381	6.849313673	0.841429339	2.380952381
Sirajganj S.	0.008917	0.0644	0.501292653	10.55053075	35.25995041	3.237716902	10.55053075
Tarash	0.0005	0.021183	0.33244898	3.406210884	12.55768778	0.992929341	3.406210884
Ullahpara	0.025	0.018975	0.491836735	5.583503401	49.60867591	0.671338903	5.583503401
Atrai	0.002375	0.0995	0.18877551	14.6292517	25.41076544	8.440305969	14.6292517
Badalgachhi	0.006833	0.0444	0.51755102	7.511170068	27.77972184	2.066673098	7.511170068
Dhamoirhat	0.0005	0.063057	0.152594694	9.208356599	15.71761199	5.461697769	9.208356599
Mahadevpur	0.000714	0.0166	0.507405306	2.946833878	15.77621622	0.610456678	2.946833878
Manda	0.002	0.061	0.097959184	9.002721088	16.56022681	4.938220272	9.002721088
Naogaon S.	0.006625	0.058975	0.395918367	9.451870748	28.5768778	3.189084087	9.451870748
Niamatpur	0.0005	0.01675	0.168061224	2.608537415	7.473811725	0.952683422	2.608537415
Patnitala	0.0008	0.053	0.108	7.755619048	12.90699854	4.673536285	7.755619048
Porsha	0.0005	0.0528	0.054530612	7.645006803	11.15270248	5.243688934	7.645006803
Raninagar	0.001188	0.047712	0.125510204	7.054653061	12.88156635	3.872578522	7.054653061
Sapahar	0.0005	0.035833	0.00721102	5.173830068	7.786488339	3.466205099	5.173830068
Bagatipara	0.000833	0.008767	0.297959184	1.629721088	8.980397793	0.32193097	1.629721088
Baraigram	0.0005	0.044263	0.450510204	6.821414966	20.41400671	2.395471783	6.821414966
Gurudaspur	0.0005	0.0061	0.269387755	1.188435374	7.636168263	0.206009918	1.188435374
Lalpur	0.0005	0.007233	0.456462449	1.537367211	11.93421503	0.223994453	1.537367211
Natore S.	0.0008	0.04896	0.283673469	7.35414966	16.66712006	3.343220983	7.35414966
Singra	0.00055	0.04417	0.218897959	6.581278912	14.10792022	3.154846299	6.581278912
Bholahat	0.000625	0.024	0.265306122	3.753401361	11.34557208	1.310095136	3.753401361
Gomastapur	0.0005	0.05255	0.004591837	7.559353741	10.67143786	5.382003036	7.559353741
Nachole	0.001133	0.043913	0.02688449	6.408074966	11.01916849	3.779231711	6.408074966
Nawabganj S.	0.0005	0.0114	0.14122449	1.817414966	5.754415247	0.601586575	1.817414966
Shibganj	0.0015	0.098	0.407142857	14.55	29.13906826	7.402531316	14.55
Bagha	0.000917	0.01205	0.625170204	2.433932109	17.10542284	0.389198118	2.433932109
Bagmara	0.022643	0.015857	0.183323673	4.605085578	42.57645174	0.562113858	4.605085578
Boalia	<Null>	<Null>	<Null>	<Null>	#VALUE!	<Null>	<Null>
Charghat	0.001417	0.013033	0.476870612	2.473680136	14.17192821	0.468403635	2.473680136
Durgapur	0.0005	0.00915	0.232653061	1.587414966	7.513565768	0.366816817	1.587414966

Neurological effects							
Upozilas	Dose of As	Dose of Cd	Avg_HQp..Mn	Avg_HIadd,P	SS Avg_Hint, P	SA Avg_Hint, P	Additive Avg_Hint, P
Godagari	0.000625	0.008617	0.080102041	1.37062585	3.955177745	0.481510698	1.37062585
Mohanpur	0.02375	0.05045	0.213265306	9.682312925	64.69304564	1.627433153	9.682312925
Paba	0.00085	0.06236	0.188040816	9.177564626	16.6431188	5.117850311	9.177564626
Puthia	<Null>	<Null>	<Null>	<Null>	#VALUE!	<Null>	<Null>
Tanore	0.0005	0.01364	0.139020408	2.135210884	6.145094768	0.772561634	2.135210884
Gaibandha S.	0.0245	0.008633	0.81088449	4.377503537	37.37534934	0.516980418	4.377503537
Gobindaganj	0.0116	0.18946	0.404897959	28.57537415	64.65115698	12.94212221	28.57537415
Palashbari	0.0071	0.02321	0.159020408	4.15092517	21.08381383	0.892938481	4.15092517
Phulchhari	0.00475	0.014317	0.645578367	3.143245034	21.53718547	0.467032039	3.143245034
Sadullapur	0.010944	0.025278	0.177823265	4.831251837	30.02570886	0.866232021	4.831251837
Sughatta	0.0005	0.015	0.000816327	2.191292517	4.257179278	1.134423228	2.191292517
Sundarganj	0.017	0.204614	0.405247755	31.2548668	80.66415652	12.60345327	31.2548668
Bhurungamari	0.001	0.027567	0.165442041	4.198822993	9.733290211	1.836825921	4.198822993
Charrajibpur	0.00075	0.026167	0.449795918	4.259367347	16.41541542	1.19297176	4.259367347
Chilmari	0.002375	0.009975	0.290204082	1.941394558	10.63234548	0.361655832	1.941394558
Kurigram S.	0.0082	0.05692	0.474367347	9.386748299	32.13094796	2.811016059	9.386748299
Nageshwari	0.016	0.027667	0.500680408	5.976918503	42.08146886	0.904628062	5.976918503
Phulbari	0.00875	0.021167	0.410952245	4.268142721	25.88915156	0.732532937	4.268142721
Rajarhat	0.0075	0.01925	0.576734694	4.041020408	25.64418155	0.647350249	4.041020408
Raomari	0.001583	0.022933	0.807482857	4.234387619	24.10083274	0.824017336	4.234387619
Ulipur	0.010714	0.013929	0.472653061	3.482891156	28.13428442	0.442428984	3.482891156
Aditmari	0.006	0.05178	0.191265306	8.159836735	24.40218347	2.850244736	8.159836735
Hatibandha	0.003583	0.029667	0.049251837	4.628632789	14.52513058	1.562547074	4.628632789
Kaliganj	0.0011	0.0103	0.04122449	1.617414966	4.651517548	0.582863653	1.617414966
Lalhonirhat S.	0.002429	0.079757	0.181282857	11.80647333	21.83925689	6.404432087	11.80647333
Patgram	0.000625	0.023925	0.003877551	3.481258503	6.188245213	1.980800977	3.481258503
Dimla	0.0005	0.0138	0.007755102	2.026802721	3.885500004	1.079254586	2.026802721
Domar	0.001125	0.038325	0.034642857	5.616785714	9.966605556	3.209344156	5.616785714
Jaldhaka	0.000714	0.036914	0.048163265	5.389591837	8.753251587	3.326808287	5.389591837
Kishoreganj	0.000667	0.035167	0.024421633	5.111802585	8.115003818	3.245095501	5.111802585
Nilphahari S.	0.0019	0.0133	0.184816327	2.265768707	8.544589222	0.609933453	2.265768707
Saidpur	0.000917	0.009333	0.660748163	2.081367211	16.66083818	0.292408865	2.081367211
Badarganj	0.0005	0.061027	1.299925714	10.06568762	46.12258948	2.319373369	10.06568762
Gangachhara	0.0005	0.0136	0.031326531	2.021802721	3.902881645	1.053938839	2.021802721
Kaunia	0.008	0.0099	0.558425714	2.73461619	23.90629518	0.314437996	2.73461619
Mithapukur	0.006875	0.016	0.183163265	3.123639456	18.99709698	0.557512041	3.123639456
Pirgachha	0.003214	0.013271	0.287638367	2.489590748	12.45318326	0.506408561	2.489590748
Pirganj	0.0005	0.014	0.034285714	2.081904762	4.012084198	1.085715878	2.081904762
Rangpur S.	0.0048	0.10766	0.078857143	15.916	32.61400314	7.963498568	15.916

Neurological effects							
Upozilas	Dose of As	Dose of Cd	Avg_HQp..Mn	Avg_HIadd,P	SS Avg_Hint, P	SA Avg_Hint, P	Additive Avg_Hint, P
Taraganj	0.003722	0.039344	0.110748163	6.085795782	16.5565032	2.32698217	6.085795782
Ajmiriganj	0.0606	0.0181	0.064244898	8.421387755	69.21570851	1.112153128	8.421387755
Bahubal	0.00275	0.007925	0.085	1.479047619	8.005566907	0.293618334	1.479047619
Baniachong	0.072778	0.0122	0.302993061	8.977088299	51.82381079	1.727046808	8.977088299
Chunarughat	0.021714	0.029714	0.091311837	6.40416898	53.52949012	0.854794881	6.40416898
Habiganj S.	0.026136	0.010745	0.082077959	4.106220816	36.66069371	0.519049423	4.106220816
Lakhai	0.00225	0.0053	0.128571429	1.1	6.928654978	0.179496221	1.1
Madhabpur	0.0095	0.02134	0.179673469	4.133006803	25.87517383	0.731369546	4.133006803
Nabiganj	0.005	0.0028	0.026734694	0.90292517	8.406110088	0.109984008	0.90292517
Barlekha	0.010857	0.006471	0.056035102	2.014463673	18.91206882	0.243323939	2.014463673
Kamalganj	0.006556	0.006889	0.144807347	1.753331156	14.77269727	0.223626392	1.753331156
Kulaura	0.014727	0.0116	0.041373061	3.101087347	29.80056655	0.359199322	3.101087347
Maulvibazar S.	0.036417	0.005383	0.051632653	4.288918367	24.16146326	0.835795589	4.288918367
Rajnagar	0.0005	0.00955	0.002653061	1.414557823	3.168591692	0.644385005	1.414557823
Sreemangal	0.019167	0.0124	0.165986531	3.762843673	34.61140595	0.459962077	3.762843673
Bishwamvarpur	0.006333	0.015133	0.767074694	3.532074694	26.26465534	0.480574167	3.532074694
Chhatak	0.025429	0.0089	0.062215918	3.755454014	32.10008439	0.492954153	3.755454014
Derai	0.0645	0.0028	0.024693878	6.56755102	19.15727786	2.337158374	6.56755102
Dharampasha	0.199	0.027967	0.095646122	23.04331279	129.70504	4.31714405	23.04331279
Dowarabazar	0.075833	0.010133	0.050952245	8.72071415	47.33635296	1.714715026	8.72071415
Jagannathpur	0.035667	0.011056	0.109750612	5.086036327	41.06229097	0.711418261	5.086036327
Jamalganj	0.071333	0.01275	0.063265306	8.678312925	55.37559496	1.468843972	8.678312925
Sullah	0.03325	0.010583	0.05789102	4.73641483	39.47144884	0.630105494	4.73641483
Sunamganj S.	0.067267	0.00814	0.053197143	7.622435238	38.84607007	1.604737322	7.622435238
Tahirpur	0.0083	0.00994	0.056979592	2.267455782	19.43110155	0.299767307	2.267455782
Balaganj	0.038083	0.00445	0.058571429	4.321238095	21.0553825	0.970477883	4.321238095
Beanibazar	0.0072	0.01048	0.075428571	2.258285714	17.73082998	0.32515285	2.258285714
Bishwanath	0.008	0.003	0.228571429	1.419047619	12.02562962	0.169929693	1.419047619
Companiganj	0.008227	0.006727	0.719703265	2.464227075	24.31401513	0.249767832	2.464227075
Fenchuganj	0.021857	0.005171	0.260058367	3.080391701	20.88851097	0.482540003	3.080391701
Golabganj	0.005063	0.0093	0.125204082	1.935965986	13.26304317	0.307401727	1.935965986
Gowainghat	0.03975	0.006275	0.091530612	4.773673469	27.3891214	0.925328878	4.773673469
Jaintiapur	0.0805	0.002433	0.051836735	8.06607483	19.47059249	3.464553785	8.06607483
Kanaighat	0.00125	0.007025	0.025816327	1.148435374	4.332234459	0.327138829	1.148435374
Sylhet S.	0.000808	0.004962	0.073877551	0.859687075	3.430853074	0.218871698	0.859687075
Zakiganj	0.003167	0.0064	0.105850204	1.321754966	8.646153883	0.215100905	1.321754966

Upozilas	Concentration of samples		Cardiovascular effects				Renal effects				Hematological effects			
	As	Cd	HI	SS	SA	Additive	HI	SS	SA	Additive	HI	SS	SA	AddItive
Nawabganj	0.001083	0.236667	1.455525714	4.74472953	0.446507033	1.455525714	33.80991524	34.3100848	33.31704	33.80991524	8.503964	12.15897	5.947657	8.503964
Savar	0.001042	0.121458	0.79328381	3.63988988	0.172889627	0.79328381	17.35147365	17.7038947	17.00607	17.35147365	4.387405	7.139917	2.696014	4.387405
Gazipur S.	0.0005	0.13825	0.837619048	2.43309993	0.288358756	0.837619048	19.75015873	20.0096944	19.49399	19.75015873	4.96131	6.82046	3.608934	4.96131
Kaliakair	0.0005	0.118	0.721904762	2.2642008	0.230167963	0.721904762	16.85730159	17.0972067	16.62076	16.85730159	4.238095	5.979369	3.003904	4.238095
Kaliganj	0.00055	0.10495	0.652095238	2.27986452	0.186514679	0.652095238	14.99303175	15.2305139	14.75925	14.99303175	3.774405	5.53185	2.575292	3.774405
Kapasia	0.0005	0.06295	0.407333333	1.78880317	0.092755004	0.407333333	8.993015873	9.16869988	8.820698	8.993015873	2.272024	3.631412	1.421511	2.272024
Sreepur	0.0005	0.154767	0.932001905	2.56917013	0.338096547	0.932001905	22.10973016	22.3842336	21.83859	22.10973016	5.551202	7.50046	4.108527	5.551202
Daulatpur	0.002875	0.003125	0.291666667	0.87977186	0.096694891	0.291666667	0.44734127	0.55066253	0.363406	0.44734127	0.248512	2.455571	0.02515	0.248512
Ghior	0.0262	0.00272	2.510780952	3.60312891	1.749596297	2.510780952	0.396888889	0.76762184	0.205206	0.396888889	1.344762	4.430048	0.408209	1.344762
Harirampur	0.028125	0.003525	2.698714286	4.01142126	1.815580644	2.698714286	0.5125	0.93619456	0.280557	0.5125	1.465179	5.325886	0.403078	1.465179
Manikganj S.	0.0065	0.003988	0.64183619	1.50497891	0.273727222	0.64183619	0.571777778	0.75363075	0.433806	0.571777778	0.451952	3.839162	0.053205	0.451952
Saturia	0.00225	0.0107	0.275428571	1.86715416	0.040629156	0.275428571	1.529285714	1.68928221	1.384443	1.529285714	0.489286	3.286019	0.072854	0.489286
Shivalaya	0.048333	0.002967	4.620097143	6.10357655	3.49717865	4.620097143	0.439200952	1.02305136	0.188551	0.439200952	2.407536	6.191892	0.9361	2.407536
Singair	0.018643	0.027857	1.934706667	6.85786985	0.545809409	1.934706667	3.985489841	4.75877967	3.337858	3.985489841	1.882655	18.75644	0.188969	1.882655
Sadarpur	0.054583	0.009567	5.253049524	8.38255897	3.291898023	5.253049524	1.384042222	2.30955291	0.829413	1.384042222	2.940869	12.86364	0.672338	2.940869
Gopalganj S.	0.175417	0.016867	16.80276381	23.7914089	11.86700935	16.80276381	2.465259365	4.88698977	1.243609	2.465259365	8.955583	28.38265	2.825757	8.955583
Kashiani	0.1006	0.01248	9.652266667	14.3187149	6.506607077	9.652266667	1.814793651	3.32503604	0.990508	1.814793651	5.23619	18.9296	1.448403	5.23619
Kotalipara	0.001643	0.007329	0.19835619	1.29919448	0.030284287	0.19835619	1.047521587	1.16086132	0.945248	1.047521587	0.339988	2.362016	0.048938	0.339988
Muksudpur	0.0855	0.011125	8.206428571	12.2885297	5.480352121	8.206428571	1.616428571	2.921045	0.894489	1.616428571	4.46875	16.5736	1.204912	4.46875
Tungipara	0.040143	0.022886	3.95392	9.00936972	1.735247176	3.95392	3.282172381	4.3706137	2.464792	3.282172381	2.728929	22.4949	0.331055	2.728929
Kalkini	0.0196	0.03482	2.065638095	8.03758455	0.530863559	2.065638095	4.980507937	5.86031229	4.232788	4.980507937	2.176905	21.26338	0.222867	2.176905
Agailjhara	0.022833	0.013617	2.252382857	5.22272713	0.971375377	2.252382857	1.952534286	2.5836344	1.475592	1.952534286	1.573607	13.21597	0.187367	1.573607
Babuganj	0.0044	0.00478	0.446361905	1.34603271	0.148019397	0.446361905	0.684253968	0.84234191	0.555835	0.684253968	0.380238	3.756931	0.038484	0.380238
Bakerganj	0.0009	0.01122	0.149828571	1.46267668	0.015347617	0.149828571	1.603142857	1.70478556	1.50756	1.603142857	0.443571	1.729173	0.113786	0.443571
Banaripara	0.001571	0.011986	0.218110476	1.8489564	0.025729206	0.218110476	1.712784444	1.85278826	1.58336	1.712784444	0.502881	2.589241	0.097669	0.502881
Barisal S.	0.001	0.007729	0.13940381	1.18780923	0.016360727	0.13940381	1.104460317	1.19413395	1.021521	1.104460317	0.323655	1.65406	0.06333	0.323655
Gaurnadi	0.00225	0.008667	0.263811429	1.59326796	0.043681585	0.263811429	1.238857143	1.38366532	1.109204	1.238857143	0.416679	3.118248	0.055679	0.416679
Hizla	0.0016	0.0093	0.20552381	1.54369941	0.027362863	0.20552381	1.329079365	1.45425936	1.214675	1.329079365	0.408333	2.455711	0.067897	0.408333
Mehendiganj	0.0005	0.0052	0.077333333	0.72643237	0.008232624	0.077333333	0.743015873	0.79474374	0.694655	0.743015873	0.209524	0.90359	0.048584	0.209524
Muladi	0.016333	0.006733	1.593998095	3.2317407	0.786210951	1.593998095	0.967042222	1.35363263	0.69086	0.967042222	1.018226	7.199254	0.144013	1.018226
Wazirpur	0.0014	0.01028	0.19207619	1.60321054	0.023012114	0.19207619	1.469015873	1.5915083	1.355951	1.469015873	0.43381	2.283375	0.082418	0.43381
Jhalakati S.	0.0005	0.004867	0.075430476	0.69574992	0.008177876	0.075430476	0.695444444	0.74554593	0.64871	0.695444444	0.197631	0.884884	0.044139	0.197631
Kathalia	0.0012	0.00518	0.143885714	0.92569838	0.022364843	0.143885714	0.740380952	0.82188361	0.666961	0.740380952	0.242143	1.711202	0.034264	0.242143
Nalchity	0.0015	0.012143	0.212245714	1.84085085	0.024471425	0.212245714	1.735190476	1.8727273	1.607755	1.735190476	0.505107	2.513489	0.101506	0.505107
Rajapur	0.001786	0.004743	0.197198095	0.96277481	0.040390638	0.197198095	0.678138413	0.77468398	0.593625	0.678138413	0.25444	2.233798	0.028982	0.25444
Bhandaria	0.008583	0.011533	0.883331429	2.96235113	0.263397004	0.883331429	1.65029619	1.98958094	1.36887	1.65029619	0.820607	8.20593	0.082062	0.820607
Kawkhali	0.002625	0.013125	0.325	2.26221277	0.04669101	0.325	1.875833333	2.06699402	1.702352	1.875833333	0.59375	3.881222	0.090832	0.59375
Mathbaria	0.008214	0.010043	0.839674286	2.68404046	0.262683412	0.839674286	1.437321905	1.7484937	1.181528	1.437321905	0.749821	7.482042	0.075144	0.749821
Nazirpur	0.0158	0.00524	1.534704762	2.90165766	0.811714883	1.534704762	0.753587302	1.09586788	0.518214	0.753587302	0.939524	5.911379	0.149323	0.939524
Nesarabad	0.00075	0.0064	0.108	0.95478933	0.012216307	0.108	0.91452381	0.98505726	0.849041	0.91452381	0.264286	1.275879	0.054744	0.264286
Pirojpur S.	0.013	0.017587	1.338592381	4.50483184	0.397757258	1.338592381	2.516555556	3.03202147	2.088723	2.516555556	1.247155	12.47079	0.124723	1.247155
Bhola S.	0.000643	0.016786	0.157158095	1.48485024	0.016633776	0.157158095	2.398204127	2.50228684	2.298451	2.398204127	0.630119	1.696101	0.234096	0.630119
Burhanuddin	0.000688	0.013925	0.145095238	1.43534204	0.014667325	0.145095238	1.989504127	2.08784917	1.895791	1.989504127	0.530083	1.606745	0.17488	0.530083
Charfasson	0.000667	0.008067	0.109620952	1.06457596	0.011287831	0.109620952	1.152640317	1.22687098	1.082901	1.152640317	0.319869	1.26792	0.080696	0.319869
Daulatkhan	0.0005	0.0143	0.129333333	1.19216472	0.014030872	0.129333333	2.043015873	2.12764859	1.96175	2.043015873	0.534524	1.382182	0.206714	0.534524

Upozilas	Concentration of samples		Cardiovascular effects				Renal effects				Hematological effects			
	As	Cd	HI	SS	SA	Additive	HI	SS	SA	Additive	HI	SS	SA	AddItive
Lalmohan	0.000667	0.013433	0.14028381	1.38850152	0.014173227	0.14028381	1.919211746	2.01432398	1.828591	1.919211746	0.511512	1.554207	0.168346	0.511512
Manpura	0.0006	0.01844	0.162514286	1.46501492	0.01802773	0.162514286	2.63447619	2.73967914	2.533313	2.63447619	0.687143	1.723067	0.274026	0.687143
Tazumuddin	0.0005	0.04305	0.293619048	1.60330215	0.053771615	0.293619048	6.15015873	6.29573919	6.007945	6.15015873	1.56131	2.745226	0.887973	1.56131
Amtali	0.001318	0.010091	0.183186667	1.55506112	0.021579444	0.183186667	1.441989841	1.55964453	1.333211	1.441989841	0.423155	2.174358	0.082351	0.423155
Bamna	0.0024	0.00704	0.2688	1.38964757	0.051994075	0.2688	1.00647619	1.1423785	0.886741	1.00647619	0.365714	3.091482	0.043263	0.365714
Barguna S.	0.001	0.013867	0.174478095	1.727939	0.017617871	0.174478095	1.98131746	2.10023644	1.869132	1.98131746	0.542869	1.997386	0.147546	0.542869
Betagi	0.0006	0.01016	0.1152	1.15191646	0.011520835	0.1152	1.451619048	1.53024546	1.377033	1.451619048	0.391429	1.296885	0.118142	0.391429
Patharghata	0.001083	0.01395	0.182857143	1.7941963	0.018636052	0.182857143	1.993200952	2.11746382	1.87623	1.993200952	0.549786	2.105241	0.143577	0.549786
Bauphal	0.001045	0.009627	0.154535238	1.40167009	0.017037633	0.154535238	1.37561746	1.47758573	1.280686	1.37561746	0.393583	1.818486	0.085185	0.393583
Dashina	0.000687	0.005875	0.099	0.8758838	0.011189841	0.099	0.83950381	0.90417923	0.779455	0.83950381	0.242536	1.169434	0.050301	0.242536
Galachipa	0.00575	0.03	0.719047619	5.11658967	0.101049627	0.719047619	4.287539683	4.71483529	3.898969	4.287539683	1.345238	8.591327	0.210639	1.345238
Kalapara	0.005143	0.011857	0.55756381	2.51045351	0.123833164	0.55756381	1.695489841	1.95581907	1.469812	1.695489841	0.668369	6.147086	0.072671	0.668369
Mirzaganj	0.0005	0.01626	0.140533333	1.24283556	0.015890773	0.140533333	2.323015873	2.41314782	2.23625	2.323015873	0.604524	1.480589	0.246827	0.604524
Patuakhali S.	0.0005	0.00683	0.086647619	0.85670216	0.008763617	0.086647619	0.975873016	1.03490015	0.920213	0.975873016	0.267738	0.993095	0.072182	0.267738
Alikadam	0.00125	0.081	0.581904762	3.72944794	0.090794444	0.581904762	11.5718254	11.8881318	11.26393	11.5718254	2.952381	5.63996	1.545499	2.952381
Bandarban S.	0.001833	0.0596	0.515142857	4.55601817	0.058246511	0.515142857	8.514867619	8.84526644	8.19681	8.514867619	2.215857	5.427382	0.904676	2.215857
Lama	0.002219	0.075956	0.645367619	5.60250012	0.074341697	0.645367619	10.85156159	11.2617494	10.45631	10.85156159	2.818381	6.759705	1.175091	2.818381
Naikhongchhari	0.00075	0.036567	0.280382857	2.08543577	0.03769694	0.280382857	5.224095238	5.38905767	5.064182	5.224095238	1.341679	2.815681	0.639313	1.341679
Rowangghhari	0.001	0.102333	0.679998095	3.36200845	0.137536064	0.679998095	14.61931746	14.936433	14.30893	14.61931746	3.702369	6.220652	2.203553	3.702369
Ruma	0.001667	0.142067	0.970573333	5.3309915	0.176704952	0.970573333	20.29581492	20.7787314	19.82412	20.29581492	5.153202	9.086261	2.922599	5.153202
Thanchi	0.001	0.11575	0.756666667	3.48577733	0.164251583	0.756666667	16.53603175	16.873079	16.20572	16.53603175	4.181548	6.816266	2.565237	4.181548
Anwara	0.002364	0.053382	0.530182857	5.16423063	0.054430927	0.530182857	7.626750476	7.98321763	7.2862	7.626750476	2.019071	5.808233	0.701874	2.019071
Banshkhali	0.001364	0.005591	0.161853333	1.01200607	0.025885716	0.161853333	0.799147302	0.88954814	0.717934	0.799147302	0.264631	1.920181	0.03647	0.264631
Boalkhali	0.002292	0.026283	0.368474286	3.54145523	0.038338279	0.368474286	3.755441905	4.004029	3.522288	3.755441905	1.047821	4.277871	0.256653	1.047821
Chandanaish	0.001333	0.084867	0.611906667	3.95981997	0.094557271	0.611906667	12.12428032	12.4586655	11.79887	12.12428032	3.09444	5.943962	1.610973	3.09444
Fatikchhari	0.008375	0.005	0.826190476	1.91654072	0.356157683	0.826190476	0.716944444	0.94853429	0.541899	0.716944444	0.577381	4.851262	0.068718	0.577381
Hathazari	0.000625	0.00835	0.107238095	1.05746721	0.01087505	0.107238095	1.193055556	1.26604892	1.124271	1.193055556	0.327976	1.23121	0.087368	0.327976
Kotwali	0.008	0.010769	0.823441905	2.76406688	0.245311202	0.823441905	1.540968254	1.85746464	1.2784	1.540968254	0.76556	7.655394	0.076558	0.76556
Lohagara	0.006833	0.0428	0.895333333	6.96870196	0.115031721	0.895333333	6.116454921	6.67048567	5.60844	6.116454921	1.853952	10.68805	0.321587	1.853952
Mirsharai	0.0145	0.0084	1.428952381	3.27616551	0.623260608	1.428952381	1.204603175	1.60044669	0.906665	1.204603175	0.990476	8.219692	0.119353	0.990476
Patiya	0.00335	0.01018	0.377219048	1.99019632	0.071497575	0.377219048	1.455349206	1.64820839	1.285057	1.455349206	0.523095	4.358759	0.062777	0.523095
Rangunia	0.0005	0.0038	0.069333333	0.58684224	0.008191488	0.069333333	0.543015873	0.5874918	0.501907	0.543015873	0.159524	0.823194	0.030914	0.159524
Raozan	0.0015	0.1514	1.008	5.02334362	0.202268465	1.008	21.62904762	22.1014918	21.1667	21.62904762	5.478571	9.237197	3.249335	5.478571
Sandwip	0.00425	0.0056	0.436761905	1.45007852	0.13155216	0.436761905	0.801349206	0.96787162	0.663477	0.801349206	0.402381	4.023647	0.04024	0.402381
Satkania	0.0022	0.00939	0.263180952	1.68273222	0.041161756	0.263180952	1.342126984	1.49075167	1.20832	1.342126984	0.440119	3.128429	0.061918	0.440119
Sitakunda	0.004667	0.018917	0.552573333	3.4336181	0.088925815	0.552573333	2.703910159	3.01158949	2.427665	2.703910159	0.897845	6.55162	0.123042	0.897845
Chakaria	0.000563	0.01185	0.121333333	1.19456429	0.012323973	0.121333333	1.693035873	1.77506524	1.614797	1.693035873	0.450024	1.338522	0.151302	0.450024
Cox Bazar S	0.000667	0.007067	0.103906667	0.98068239	0.011009268	0.103906667	1.009783175	1.07941081	0.944647	1.009783175	0.284155	1.212658	0.066584	0.284155
Kutubdia	0.0015	0.0064	0.179428571	1.14701061	0.028068278	0.179428571	0.914761905	1.01607989	0.823547	0.914761905	0.3	2.132832	0.042197	0.3
Maheshkhali	<Null>	<Null>	#VALUE!	#VALUE!	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>
Ramu	0.00075	0.00395	0.094	0.67211269	0.013146605	0.094	0.56452381	0.62050793	0.513591	0.56452381	0.176786	1.123212	0.027825	0.176786
Teknaf	0.002667	0.012089	0.32308	2.13455996	0.04890033	0.32308	1.727846667	1.91322835	1.560427	1.727846667	0.55875	3.849323	0.081106	0.55875
Ukhia	0.0005	0.006162	0.082830476	0.80706253	0.008501061	0.082830476	0.880444444	0.93659864	0.827657	0.880444444	0.243881	0.956751	0.062167	0.243881
Akhaura	0.00075	0.295	1.757142857	4.36279743	0.707699835	1.757142857	42.14309524	42.6069287	41.68431	42.14309524	10.57143	13.80972	8.092497	10.57143
Bancharampur	0.015167	0.1545	2.327333333	21.7423048	0.249121724	2.327333333	22.07624349	23.6297243	20.62489	22.07624349	6.240095	27.22831	1.430085	6.240095

Upozilas	Concentration of samples		Cardiovascular effects				Renal effects				Hematological effects			
	As	Cd	HI	SS	SA	Additive	HI	SS	SA	Additive	HI	SS	SA	AddItive
Brahmanbaria.S	0.0755	0.103262	7.780544762	26.3324103	2.298949325	7.780544762	14.77568254	17.7841797	12.27612	14.77568254	7.283167	72.81809	0.728452	7.283167
Kasba	0.0005	0.163	0.979047619	2.63648026	0.363565871	0.979047619	23.28587302	23.5675385	23.00757	23.28587302	5.845238	7.837672	4.359306	5.845238
Nabinagar	0.002	0.07	0.59047619	5.08311485	0.06859222	0.59047619	10.00063492	10.3743989	9.640337	10.00063492	2.595238	6.168962	1.091798	2.595238
Nasirnagar	0.001594	0.149825	1.007952381	5.23335477	0.194133218	1.007952381	21.40407746	21.8887506	20.93014	21.40407746	5.426798	9.320026	3.159877	5.426798
Sarail	0.002167	0.256667	1.673049524	7.60676407	0.367974435	1.673049524	36.66740222	37.4061471	35.94325	36.66740222	9.269869	15.02833	5.7179	9.269869
Chandpur S.	0.00175	0.007933	0.211998095	1.40070784	0.032086058	0.211998095	1.13384127	1.25548705	1.023982	1.13384127	0.366655	2.525849	0.053224	0.366655
Faridganj	0.0035	0.011267	0.39771619	2.16898846	0.07292716	0.39771619	1.61068254	1.81769658	1.427245	1.61068254	0.56906	4.627285	0.069982	0.56906
Haimchar	0.002	0.0003	0.192190476	0.29633034	0.124648656	0.192190476	0.043492063	0.0755594	0.025034	0.043492063	0.105952	0.424713	0.026432	0.105952
Haziganj	0.495	0.004	47.16571429	52.1967695	42.61958406	47.16571429	0.728571429	4.84247415	0.109617	0.728571429	23.71429	33.86662	16.60536	23.71429
Kachua	0.265	0.009667	25.29333524	31.3595634	20.40056489	25.29333524	1.465126984	4.27720884	0.501869	1.465126984	12.9643	27.21153	6.176538	12.9643
Matlab	0.011125	0.004506	1.085272381	2.1873773	0.53846044	1.085272381	0.647246032	0.90866339	0.461037	0.647246032	0.69069	4.83909	0.098583	0.69069
Shahrasti	0.194	0.020483	18.59323619	26.7631782	12.91731608	18.59323619	2.987730159	5.74796114	1.552991	2.987730159	9.969631	33.12728	3.000353	9.969631
Barura	0.018278	0.012978	1.814921905	4.51643131	0.729323949	1.814921905	1.85980254	2.40439559	1.438559	1.85980254	1.333881	11.95248	0.148859	1.333881
Brahmanpara	<Null>	<Null>	#VALUE!	#VALUE!	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>
Burichang	0.001773	0.009618	0.223817143	1.6245309	0.030836048	0.223817143	1.374562857	1.50878578	1.252281	1.374562857	0.427929	2.67477	0.068463	0.427929
Chandhina	0.38	0.076675	36.62861905	60.4293667	22.20204856	36.62861905	11.07420635	17.8613684	6.866106	11.07420635	20.83363	98.74815	4.395426	20.83363
Chauddagram	0.0005	0.0032	0.065904762	0.51808888	0.008383576	0.065904762	0.457301587	0.49826178	0.419709	0.457301587	0.138095	0.786426	0.024249	0.138095
Comilla S.	0.000875	0.01305	0.157904762	1.57345581	0.015846593	0.157904762	1.864563492	1.97236195	1.762657	1.864563492	0.507738	1.797058	0.143456	0.507738
Daudkandi	0.039942	0.007181	3.845034286	6.17171308	2.395491896	3.845034286	1.038537143	1.72211373	0.6263	1.038537143	2.158464	9.578405	0.486403	2.158464
Debidwar	0.0005	0.0106	0.108190476	1.0641355	0.010999707	0.108190476	1.514444444	1.58755107	1.444704	1.514444444	0.402381	1.192693	0.135752	0.402381
Homna	0.041	0.006878	3.944064762	6.2315648	2.496266563	3.944064762	0.995587302	1.67980537	0.590065	0.995587302	2.198024	9.379183	0.51511	2.198024
Laksam	0.210056	0.014189	20.08641333	26.8975995	15.00000028	20.08641333	2.093684444	4.70017448	0.932628	2.093684444	10.50942	28.18607	3.918525	10.50942
Muradnagar	0.19425	0.0055	18.53142857	22.3976838	15.33256061	18.53142857	0.847380952	2.80289339	0.256183	0.847380952	9.446429	18.2245	4.896432	9.446429
Nangalkot	0.069833	0.00905	6.70247619	10.0284618	4.479569034	6.70247619	1.315026349	2.37911737	0.726864	1.315026349	3.648595	13.50256	0.985906	3.648595
Dighinala	0.001045	0.034327	0.295678095	2.60560938	0.033552817	0.295678095	4.904188889	5.09349639	4.721917	4.904188889	1.275726	3.111569	0.523041	1.275726
Khagrachhari	0.0005	0.107333	0.660950476	2.174193	0.20092767	0.660950476	15.33344444	15.5623279	15.10793	15.33344444	3.857131	5.532402	2.68915	3.857131
Lakshmichhari	0.0005	0.0498	0.332190476	1.66818117	0.066150197	0.332190476	7.114444444	7.27089353	6.961362	7.114444444	1.802381	3.049251	1.065369	1.802381
Mahalchhari	0.0005	0.0086	0.096761905	0.96734279	0.009678954	0.096761905	1.228730159	1.2947524	1.166075	1.228730159	0.330952	1.087804	0.100689	0.330952
Manikchhari	0.000667	0.0737	0.484666667	2.29292791	0.102446212	0.484666667	10.52878317	10.7484833	10.31357	10.52878317	2.663905	4.391354	1.615991	2.663905
Matiranga	0.002333	0.045433	0.481807619	4.78467046	0.048517152	0.481807619	6.491169206	6.81844158	6.179605	6.491169206	1.733702	5.355062	0.561287	1.733702
Panchhari	0.0005	0.110125	0.676904762	2.19782701	0.208478672	0.676904762	15.73230159	15.9641209	15.50385	15.73230159	3.956845	5.649683	2.771239	3.956845
Ramgarh	0.000833	0.041011	0.313681905	2.32193057	0.042376951	0.313681905	5.85897873	6.04307691	5.680489	5.85897873	1.504345	3.146314	0.719272	1.504345
Chhagalnaiya	0.005	0.019279	0.58635619	3.54321233	0.097034428	0.58635619	2.755730159	3.07767586	2.467462	2.755730159	0.926631	6.931175	0.123882	0.926631
Daganbhuiyan	0.0005	0.0085	0.096190476	0.9617962	0.009620133	0.096190476	1.214444444	1.28009188	1.152164	1.214444444	0.327381	1.082505	0.099009	0.327381
Feni S.	0.008167	0.002656	0.792986667	1.49037101	0.421927055	0.792986667	0.38202127	0.55755979	0.261748	0.38202127	0.483762	3.010889	0.077726	0.483762
Parshuram	0.001722	0.012022	0.232697143	1.9014082	0.02847782	0.232697143	1.717975238	1.86503838	1.582508	1.717975238	0.511357	2.770761	0.094373	0.511357
Sonagazi	0.025333	0.002967	2.429620952	3.56471943	1.655967065	2.429620952	0.431899365	0.80490439	0.231751	0.431899365	1.312298	4.601773	0.374231	1.312298
Lakshmipur S.	0.236583	0.009583	22.58647429	28.3273926	18.00902848	22.58647429	1.444105714	4.01501504	0.519411	1.444105714	11.60811	25.29748	5.326544	11.60811
Raipur	0.014429	0.007914	1.419413333	3.1868729	0.632197855	1.419413333	1.135152063	1.52000445	0.847741	1.135152063	0.969738	7.861892	0.119614	0.969738
Ramganj	0.178083	0.006633	16.99818857	21.1222012	13.67937043	16.99818857	1.004105714	2.90263024	0.34735	1.004105714	8.717036	18.43147	4.122661	8.717036
Ramgati	0.005625	0.008	0.581428571	2.0081615	0.168342628	0.581428571	1.144642857	1.37278843	0.954413	1.144642857	0.553571	5.529085	0.055424	0.553571
Begumganj	0.08925	0.010514	8.56008	12.573126	5.827903867	8.56008	1.530333333	2.84702267	0.822586	1.530333333	4.6255	16.26982	1.315027	4.6255
Chatkhil	0.041125	0.00425	3.940952381	5.65091223	2.748424508	3.940952381	0.620198413	1.20125935	0.320202	0.620198413	2.110119	6.935192	0.64203	2.110119
Companiganj	0.03825	0.004383	3.667902857	5.35945013	2.510240984	3.667902857	0.638285714	1.19738782	0.340248	0.638285714	1.977964	6.856968	0.570565	1.977964
Hatiya	0.0005	0.0041	0.071047619	0.61915638	0.008152648	0.071047619	0.585873016	0.63200264	0.54311	0.585873016	0.170238	0.840893	0.034465	0.170238

Upozilas	Concentration of samples		Cardiovascular effects				Renal effects				Hematological effects			
	As	Cd	HI	SS	SA	Additive	HI	SS	SA	Additive	HI	SS	SA	AddItive
Noakhali S.	0.052458	0.005658	5.028331429	7.26574576	3.479906643	5.028331429	0.824939048	1.57653408	0.431659	0.824939048	2.700071	9.070661	0.803733	2.700071
Senbagh	0.297833	0.008117	28.41143048	34.2165776	23.59117823	28.41143048	1.254121587	4.230423	0.371788	1.254121587	14.47242	27.58999	7.591551	14.47242
Bagaichhari	0.0013	0.06254	0.481180952	3.60250393	0.064270606	0.481180952	8.934698413	9.2187557	8.659394	8.934698413	2.295476	4.840091	1.08866	2.295476
Barkal	0.00225	0.069025	0.608714286	5.49060308	0.067484951	0.608714286	9.861428571	10.2555899	9.482416	9.861428571	2.572321	6.455227	1.025036	2.572321
Belaichhari	0.0005	0.0193	0.157904762	1.30699156	0.019077333	0.157904762	2.757301587	2.85534405	2.662626	2.757301587	0.713095	1.630977	0.311779	0.713095
Juraichhari	0.001	0.008333	0.142855238	1.25227274	0.016296465	0.142855238	1.190746032	1.2837219	1.104504	1.190746032	0.345226	1.689542	0.070541	0.345226
Kaptai	0.001357	0.0078	0.173809524	1.29839485	0.023266998	0.173809524	1.114716508	1.22032082	1.018251	1.114716508	0.34319	2.076926	0.056709	0.34319
Kawkhali	0.0005	0.0089	0.09847619	0.9835365	0.009859888	0.09847619	1.271587302	1.33872111	1.20782	1.271587302	0.341667	1.103667	0.105771	0.341667
Langadu	0.0005	0.045367	0.306859048	1.62590593	0.057913852	0.306859048	6.48115873	6.63056011	6.335124	6.48115873	1.64406	2.850047	0.948381	1.64406
Nannerchar	0.000714	0.053514	0.373794286	2.20895528	0.063252601	0.373794286	7.64508381	7.8392084	7.455766	7.64508381	1.945214	3.556815	1.063834	1.945214
Rajasthali	0.0023	0.0136	0.296761905	2.24759057	0.039183128	0.296761905	1.943587302	2.12501249	1.777651	1.943587302	0.595238	3.54535	0.099936	0.595238
Rangamati S.	0.0009	0.0324	0.270857143	2.30635561	0.031809315	0.270857143	4.628857143	4.79939276	4.464381	4.628857143	1.2	2.820558	0.510537	1.2
Dhamrai	0.014409	0.144818	2.199817143	20.4757436	0.23633796	2.199817143	20.69286	22.1591528	19.32359	20.69286	5.858214	25.75748	1.332377	5.858214
Dohar	0.02775	0.15	3.5	25.3583745	0.483075127	3.5	21.43738095	23.5345995	19.52705	21.43738095	6.678571	41.82703	1.066375	6.678571
Keraniganj	0.037333	0.155	4.441238095	27.9670827	0.705278989	4.441238095	22.15470889	24.6440346	19.91683	22.15470889	7.313476	52.72423	1.014466	7.313476
Gazaria	0.0005	0.089	0.556190476	2.01751699	0.153330975	0.556190476	12.71444444	12.9230181	12.50924	12.71444444	3.202381	4.75645	2.156071	3.202381
Lohajang	0.0014	0.01204	0.202133333	1.79186255	0.022801908	0.202133333	1.720444444	1.85260089	1.597715	1.720444444	0.496667	2.38704	0.10334	0.496667
Munshiganj S.	0.00075	0.01345	0.148285714	1.48057013	0.014851477	0.148285714	1.921666667	2.02273406	1.825649	1.921666667	0.516071	1.660779	0.160364	0.516071
Sirajdikhan	0.007714	0.041764	0.973318095	7.05762741	0.134230395	0.973318095	5.968734603	6.5521676	5.437253	5.968734603	1.858905	11.63177	0.297077	1.858905
Sreenagar	0.0005	0.0001	0.048190476	0.07933272	0.029273192	0.048190476	0.014444444	0.02334547	0.008937	0.014444444	0.027381	0.129125	0.005806	0.027381
Tongibari	0.010611	0.009078	1.062445714	2.86623804	0.39382315	1.062445714	1.300225714	1.64318247	1.028849	1.300225714	0.8295	7.846941	0.087686	0.8295
Araihazar	<Null>	<Null>	#VALUE!	#VALUE!	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>
Bandar	0.0005	0.0216	0.171047619	1.34752325	0.021711898	0.171047619	3.085873016	3.18949331	2.985619	3.085873016	0.795238	1.743177	0.362788	0.795238
Narayanganj S.	0.0121	0.00616	1.187580952	2.59327059	0.543849348	1.187580952	0.88384127	1.19656828	0.652846	0.88384127	0.79619	6.242618	0.101547	0.79619
Rupganj	0.001	0.0047	0.122095238	0.82252508	0.01812376	0.122095238	0.671746032	0.74246006	0.607767	0.671746032	0.215476	1.45624	0.031883	0.215476
Sonargaon	0.0005	0.017	0.144761905	1.25984154	0.016633845	0.144761905	2.428730159	2.52085143	2.339975	2.428730159	0.630952	1.517435	0.262351	0.630952
Belabo	0.000917	0.060317	0.432001905	2.74604039	0.067961726	0.432001905	8.617005397	8.8507659	8.389419	8.617005397	2.197845	4.17917	1.155857	2.197845
Manohardi	0.03675	0.00505	3.528857143	5.34259023	2.330860538	3.528857143	0.733095238	1.30451233	0.411977	0.733095238	1.930357	7.374141	0.505317	1.930357
Narsingdi S.	0.032667	0.048633	3.389045714	11.9896875	0.957959147	3.389045714	6.957941905	8.31066876	5.825398	6.957941905	3.292464	32.80979	0.330399	3.292464
Palash	0.000556	0.033511	0.24444381	1.62954893	0.036668292	0.24444381	4.787462222	4.92321805	4.65545	4.787462222	1.223298	2.390913	0.625893	1.223298
Raipur	0.000938	0.004962	0.117687619	0.84338256	0.016422412	0.117687619	0.709154921	0.77931976	0.645307	0.709154921	0.221881	1.406297	0.035008	0.221881
Shibpur	0.010667	0.004933	1.044093333	2.2023942	0.494975373	1.044093333	0.708100635	0.97290898	0.515368	0.708100635	0.684131	5.124806	0.091327	0.684131
Goalandaghat	0.022167	0.006667	2.14924	3.94631201	1.170518844	2.14924	0.959465714	1.4212905	0.647703	0.959465714	1.293679	7.706965	0.217155	1.293679
Alfadanga	0.0355	0.00694	3.420609524	5.60013638	2.089336532	3.420609524	1.002698413	1.62932799	0.617067	1.002698413	1.938333	9.022384	0.416424	1.938333
Bhanga	0.1875	0.005	17.88571429	21.4970315	14.88106742	17.88571429	0.773809524	2.63981067	0.226827	0.773809524	9.107143	17.24562	4.809339	9.107143
Boalmari	0.045571	0.015646	4.429500952	8.46475652	2.317902309	4.429500952	2.249609841	3.25069534	1.556819	2.249609841	2.728833	17.50029	0.425509	2.728833
Char Bhadrasan	0.054333	0.004667	5.20124	7.22687081	3.743376386	5.20124	0.683962857	1.4080216	0.332243	0.683962857	2.753964	8.25782	0.918441	2.753964
Faridpur S.	0.02565	0.00499	2.471371429	4.04132487	1.511305558	2.471371429	0.721	1.1729421	0.443194	0.721	1.399643	6.496781	0.301534	1.399643
Madhukhali	0.06425	0.009175	6.17147619	9.41768871	4.044210796	6.17147619	1.331111111	2.34360096	0.75604	1.331111111	3.387202	13.21443	0.868228	3.387202
Nagarkanda	0.045875	0.007837	4.413830476	7.00238634	2.782180035	4.413830476	1.134134921	1.9047662	0.675286	1.134134921	2.464417	10.62428	0.571648	2.464417
Madaripur S.	0.085682	0.016964	8.257127619	13.5598246	5.02810017	8.257127619	2.450629206	3.97020398	1.512664	2.450629206	4.685952	21.97071	0.999428	4.685952
Rajoir	0.1915	0.0046	18.26438095	21.7482024	15.33862915	18.26438095	0.717936508	2.5875624	0.199196	0.717936508	9.283333	17.0372	5.058359	9.283333
Shibchar	0.0149	0.01444	1.501561905	4.28861953	0.52573751	1.501561905	2.067587302	2.57641364	1.659251	2.067587302	1.225238	11.90229	0.126128	1.225238
Baliakandi	0.022	0.01144	2.160609524	4.7550837	0.981735298	2.160609524	1.641269841	2.21496935	1.216164	1.641269841	1.45619	11.52867	0.183932	1.45619
Pangsha	0.002056	0.009422	0.249649524	1.6591774	0.037563726	0.249649524	1.346652698	1.49030763	1.216845	1.346652698	0.434405	2.975466	0.063421	0.434405

Upozilas	Concentration of samples		Cardiovascular effects				Renal effects				Hematological effects			
	As	Cd	HI	SS	SA	Additive	HI	SS	SA	Additive	HI	SS	SA	AddItive
Rajbari S.	0.047	0.002125	4.488333333	5.7012715	3.533446202	4.488333333	0.318492063	0.84279879	0.120358	0.318492063	2.313988	5.255005	1.018941	2.313988
Bhedarganj	0.0131	0.01588	1.338361905	4.25974177	0.420497928	1.338361905	2.272730159	2.7670869	1.866693	2.272730159	1.190952	11.8785	0.119406	1.190952
Damudya	0.0095	0.01894	1.012990476	4.20171393	0.244221696	1.012990476	2.708730159	3.15837417	2.3231	2.708730159	1.12881	10.78265	0.118172	1.12881
Gosairhat	0.007417	0.023867	0.84276381	4.59506803	0.154568079	0.84276381	3.411926032	3.85053746	3.023276	3.411926032	1.205583	9.804825	0.148236	1.205583
Shariatpur S.	0.0344	0.00792	3.321447619	5.66487095	1.947443177	3.321447619	1.142349206	1.78817674	0.729772	1.142349206	1.920952	9.822529	0.375673	1.920952
Zanjira	0.010667	0.013067	1.090573333	3.48936928	0.340849621	1.090573333	1.870100635	2.2745449	1.537572	1.870100635	0.974631	9.726198	0.097665	0.974631
Baksiganj	0.0024	0.0731	0.646285714	5.84306486	0.071483927	0.646285714	10.44361905	10.8625811	10.04082	10.44361905	2.725	6.859135	1.082589	2.725
Dewanganj	0.002083	0.008067	0.244478095	1.48097123	0.040358339	0.244478095	1.153089841	1.28749084	1.032719	1.153089841	0.387298	2.89075	0.051889	0.387298
Islampur	0.03745	0.08633	4.059980952	18.2790682	0.901766172	4.059980952	12.34474603	14.2402985	10.70151	12.34474603	4.866548	44.75982	0.529119	4.866548
Jamalpur S.	0.00545	0.02699	0.67327619	4.66298809	0.097212521	0.67327619	3.857444444	4.25252601	3.499068	3.857444444	1.223452	8.039179	0.186193	1.223452
Madarganj	0.014875	0.08175	1.883809524	13.7630497	0.257845347	1.883809524	11.68329365	12.8163959	10.65037	11.68329365	3.627976	22.51325	0.584643	3.627976
Melandaha	0.01325	0.0285	1.424761905	6.16743423	0.329139543	1.424761905	4.075634921	4.72513117	3.515416	4.075634921	1.64881	15.4614	0.17583	1.64881
Sarishabari	0.006333	0.072933	1.019902857	9.81112987	0.106022635	1.019902857	10.42101048	11.1092991	9.775365	10.42101048	2.906321	11.83728	0.713568	2.906321
Jhenaigati	0.00075	0.054975	0.385571429	2.30733939	0.064431495	0.385571429	7.853809524	8.05549386	7.657175	7.853809524	1.999107	3.679242	1.08621	1.999107
Nakla	0.008	0.072729	1.177499048	10.634893	0.130373103	1.177499048	10.39239683	11.1680448	9.67062	10.39239683	2.978417	13.86602	0.639763	2.978417
Nalitabari	0.038833	0.045333	3.957426667	12.3616896	1.266916278	3.957426667	6.488470794	7.92933776	5.309429	6.488470794	3.468226	34.50667	0.348587	3.468226
Sherpur S.	0.00125	0.0296	0.288190476	2.78263254	0.029847186	0.288190476	4.228968254	4.42188266	4.04447	4.228968254	1.116667	3.141993	0.396864	1.116667
Sreebardi	0.0005	0.089143	0.557007619	2.01875015	0.153687908	0.557007619	12.73487302	12.9436128	12.5295	12.73487302	3.207488	4.762546	2.160185	3.207488
Astagram	0.006833	0.092767	1.180859048	11.667118	0.119517785	1.180859048	13.25459778	14.0588614	12.49634	13.25459778	3.638488	13.54068	0.97769	3.638488
Bajitpur	0.050667	0.004633	4.851902857	6.81152567	3.456048246	4.851902857	0.677941905	1.36640702	0.33636	0.677941905	2.578179	7.969942	0.834009	2.578179
Bhairab	0.013125	0.04035	1.480571429	7.86376172	0.27875867	1.480571429	5.768452381	6.52817678	5.097142	5.768452381	2.066071	17.13295	0.249149	2.066071
Hossainpur	0.000875	0.003675	0.104333333	0.66120123	0.016463134	0.104333333	0.525277778	0.58394114	0.472508	0.525277778	0.172917	1.239292	0.024127	0.172917
Itna	0.033833	0.008133	3.268664762	5.63830426	1.894925996	3.268664762	1.172597778	1.818373	0.756163	1.172597778	1.90156	9.967901	0.362757	1.90156
Karimganj	0.0242	0.02378	2.440647619	7.01609345	0.849013892	2.440647619	3.404825397	4.23633302	2.736526	3.404825397	2.001667	19.49221	0.205552	2.001667
Katiadi	0.02875	0.009125	2.790238095	5.20570766	1.495556249	2.790238095	1.312698413	1.92464926	0.89532	1.312698413	1.69494	10.40708	0.276045	1.69494
Kishoreganj S.	0.001278	0.032944	0.309965714	2.937667	0.032705798	0.309965714	4.706691429	4.91228618	4.509701	4.706691429	1.237429	3.349723	0.457121	1.237429
Kuliarchar	0.00375	0.0028	0.373142857	0.94851409	0.146793383	0.373142857	0.401190476	0.51538977	0.312295	0.401190476	0.278571	2.53709	0.030587	0.278571
Mithamain	0.031786	0.004729	3.054260952	4.70105529	1.984343811	3.054260952	0.685662222	1.19383518	0.3938	0.685662222	1.682512	6.713883	0.421641	1.682512
Nikli	0.005167	0.064467	0.860478095	8.40138147	0.088131048	0.860478095	9.211211746	9.79498082	8.662235	9.211211746	2.54844	9.930199	0.65402	2.54844
Pakundia	0.000733	0.00988	0.126266667	1.24646972	0.012790741	0.126266667	1.41166127	1.49763644	1.330622	1.41166127	0.387762	1.448686	0.10379	0.387762
Tarail	0.006727	0.006036	0.675158095	1.86103108	0.244938658	0.675158095	0.86442127	1.08645286	0.687765	0.86442127	0.535905	5.126183	0.056025	0.535905
Bhaluka	0.000571	0.0047	0.081238095	0.70895167	0.009308996	0.081238095	0.671609841	0.72438608	0.622679	0.671609841	0.195048	0.961339	0.039574	0.195048
Dhobaura	0.065571	0.067214	6.628937143	19.4403223	2.260395019	6.628937143	9.62281619	11.9185167	7.769305	9.62281619	5.522929	54.14887	0.563313	5.522929
Gaffargaon	0.00175	0.013438	0.243455238	2.06908433	0.028645741	0.243455238	1.920269841	2.07670898	1.775615	1.920269841	0.563262	2.889394	0.109803	0.563262
Gauripur	0.002625	0.00585	0.283428571	1.25177467	0.064174294	0.283428571	0.836547619	0.96734892	0.723433	0.836547619	0.333929	3.101368	0.035955	0.333929
Haluaghat	0.019375	0.02785	2.004380952	6.96140062	0.577117052	2.004380952	3.984722222	4.77435362	3.325688	3.984722222	1.917262	19.14148	0.192038	1.917262
Ishwarganj	0.0049	0.005	0.495238095	1.44922366	0.169235969	0.495238095	0.71584127	0.88704826	0.577679	0.71584127	0.411905	4.035709	0.042041	0.411905
Muktagachha	0.000857	0.018929	0.189784762	1.85536825	0.019412996	0.189784762	2.704414921	2.83225401	2.582346	2.704414921	0.716845	2.083725	0.24661	0.716845
Mymensingh S.	0.007333	0.025467	0.843906667	4.80644847	0.148171455	0.843906667	3.640470794	4.08993572	3.2404	3.640470794	1.258726	9.894141	0.160134	1.258726
Nandail	0.005167	0.035933	0.697426667	5.68925453	0.0854952	0.697426667	5.134926032	5.57537949	4.729268	5.134926032	1.529369	8.305314	0.281623	1.529369
Phulbari	0.006389	0.0075	0.651333333	2.04016111	0.207941965	0.651333333	1.073456825	1.31110736	0.878883	1.073456825	0.572095	5.694352	0.057477	0.572095
Phulpur	0.009333	0.045033	1.146188571	7.83024318	0.167778728	1.146188571	6.436248571	7.10450724	5.830847	6.436248571	2.05275	13.67916	0.308044	2.05275
Trishal	0.0008	0.03142	0.255733333	2.10128007	0.031123665	0.255733333	4.488825397	4.64703498	4.336002	4.488825397	1.160238	2.636033	0.510674	1.160238
Atpara	0.037833	0.007567	3.646382857	6.00287061	2.214958278	3.646382857	1.093010476	1.76652895	0.676282	1.093010476	2.071821	9.770748	0.439316	2.071821
Barhatta	0.16	0.0035	15.25809524	18.0244587	12.9163086	15.25809524	0.550793651	2.08765478	0.145318	0.550793651	7.744048	13.83588	4.334403	7.744048

Upozilas	Concentration of samples		Cardiovascular effects				Renal effects				Hematological effects			
	As	Cd	HI	SS	SA	Additive	HI	SS	SA	Additive	HI	SS	SA	AddItive
Durgapur	0.092	0.011533	8.827807619	13.1223429	5.938740379	8.827807619	1.676777778	3.06282513	0.917971	1.676777778	4.792845	17.42375	1.318394	4.792845
Kalmakanda	0.083357	0.018814	8.046270476	13.6529689	4.742006606	8.046270476	2.714176825	4.26731503	1.726321	2.714176825	4.64131	23.46285	0.918122	4.64131
Kendua	0.009625	0.053775	1.223952381	9.01593285	0.166156898	1.223952381	7.685198413	8.4241571	7.01106	7.685198413	2.378869	14.62718	0.386884	2.378869
Khaliajuri	0.04625	0.003525	4.424904762	6.03303411	3.245428717	4.424904762	0.518253968	1.1126916	0.241385	0.518253968	2.328274	6.597066	0.821708	2.328274
Madan	0.052667	0.010844	5.077870476	8.41907999	3.062658699	5.077870476	1.56586254	2.51369425	0.975427	1.56586254	2.895238	13.88311	0.603784	2.895238
Mohanganj	0.11525	0.1913	12.06933333	45.2566175	3.218729438	12.06933333	27.36515873	32.3801736	23.12687	27.36515873	12.32024	121.5208	1.249072	12.32024
Netrokona S.	0.010885	0.013308	1.112712381	3.55671349	0.348110368	1.112712381	1.904598413	2.31694556	1.565637	1.904598413	0.993619	9.914732	0.099577	0.993619
Purbadhala	0.025667	0.004767	2.47171619	3.99758154	1.528269245	2.47171619	0.689148254	1.13369563	0.418918	0.689148254	1.392488	6.294634	0.308044	1.392488
Basail	0.01825	0.00355	1.758380952	2.87532709	1.075322381	1.758380952	0.512936508	0.83448063	0.315291	0.512936508	0.995833	4.622111	0.214552	0.995833
Bhuapur	0.001063	0.00785	0.146095238	1.22227424	0.017462381	0.146095238	1.121766032	1.21502703	1.035663	1.121766032	0.330976	1.736415	0.063087	0.330976
Delduar	0.000667	0.00375	0.084952381	0.62773239	0.011496789	0.084952381	0.535926032	0.58728837	0.489056	0.535926032	0.16569	1.015231	0.027041	0.16569
Ghatail	0.00195	0.01732	0.284685714	2.55161437	0.031762619	0.284685714	2.474904762	2.66186193	2.301079	2.474904762	0.711429	3.356489	0.150792	0.711429
Gopalpur	0.002375	0.03335	0.416761905	4.13265438	0.042028795	0.416761905	4.765039683	5.04919759	4.496874	4.765039683	1.304167	4.766252	0.356853	1.304167
Kalihati	0.0018	0.0106	0.232	1.75363395	0.030692836	0.232	1.514857143	1.65656491	1.385272	1.514857143	0.464286	2.771761	0.07777	0.464286
Madhupur	0.00092	0.034928	0.287207619	2.39371214	0.034460374	0.287207619	4.990006349	5.16894117	4.817266	4.990006349	1.291238	2.972321	0.560941	1.291238
Mirzapur	0.0005	0.00285	0.063904762	0.47542242	0.008589874	0.063904762	0.407301587	0.44605729	0.371913	0.407301587	0.125595	0.76366	0.020656	0.125595
Nagarpur	0.006188	0.0684	0.980190476	9.34534531	0.102807691	0.980190476	9.773393016	10.4327152	9.155738	9.773393016	2.737524	11.40796	0.656913	2.737524
Sakhipur	0.00075	0.0158	0.161714286	1.59193903	0.016427457	0.161714286	2.257380952	2.3667037	2.153108	2.257380952	0.6	1.783841	0.201812	0.6
Tangail S.	0.000889	0.006867	0.123906667	1.05551749	0.014545341	0.123906667	0.981282222	1.06097934	0.907572	0.981282222	0.287583	1.470217	0.056253	0.287583
Abhaynagar	0.0135	0.03896	1.508342857	7.72506956	0.294508439	1.508342857	5.57	6.32864858	4.902295	5.57	2.034286	17.30799	0.239099	2.034286
Bagherpara	0.015333	0.097767	2.018954286	15.8442629	0.257265134	2.018954286	13.9715819	15.2254355	12.82099	13.9715819	4.221821	24.09347	0.739776	4.221821
Chaugachha	0.028833	0.0051	2.775142857	4.43771022	1.735448575	2.775142857	0.737724762	1.228248	0.443101	0.737724762	1.555143	6.8376	0.353702	1.555143
Jessore S.	0.005313	0.020888	0.62536	3.8203007	0.10236763	0.62536	2.985686667	3.33093982	2.676219	2.985686667	0.999	7.401419	0.134839	0.999
Jhikargachha	0.036833	0.009733	3.563521905	6.3063886	2.013622877	3.563521905	1.402121587	2.13139731	0.922374	1.402121587	2.10156	11.6314	0.37971	2.10156
Keshabpur	0.024063	0.016994	2.388822857	5.93124308	0.962104329	2.388822857	2.435353333	3.15064312	1.882456	2.435353333	1.752786	15.67786	0.195962	1.752786
Manirampur	0.013786	0.012543	1.384626667	3.84091287	0.49914983	1.384626667	1.796233651	2.25405312	1.431402	1.796233651	1.10444	10.59642	0.115113	1.10444
Sharsha	0.0065	0.0153	0.70647619	3.21882014	0.15505949	0.70647619	2.187777778	2.5199798	1.899369	2.187777778	0.855952	7.823207	0.093651	0.855952
Harinakunda	0.002167	0.009633	0.261426667	1.70907486	0.039988829	0.261426667	1.376830794	1.52607263	1.242184	1.376830794	0.447226	3.112668	0.064257	0.447226
Jhenaidaha S.	0.015333	0.00365	1.481142857	2.54831682	0.860875752	1.481142857	0.52629619	0.81786245	0.338673	0.52629619	0.8605	4.485414	0.165082	0.8605
Kaliganj	0.0033	0.0747	0.741142857	7.21604925	0.076120979	0.741142857	10.67247619	11.1706759	10.1965	10.67247619	2.825	8.11734	0.983158	2.825
Kotchandpur	0.012056	0.015311	1.235681905	4.02625771	0.379237962	1.235681905	2.191113016	2.65570448	1.807798	2.191113016	1.120917	11.20153	0.112168	1.120917
Maheshpur	0.005375	0.0166	0.606761905	3.2311754	0.113939964	0.606761905	2.373134921	2.68492724	2.09755	2.373134921	0.84881	7.025316	0.102554	0.84881
Shailkupa	0.008375	0.08755	1.297904762	12.2081185	0.1379866	1.297904762	12.50980159	13.3784026	11.6976	12.50980159	3.525595	15.16028	0.819894	3.525595
Magura S.	0.006125	0.025275	0.727761905	4.56734352	0.115961803	0.727761905	3.61265873	4.01988895	3.246682	3.61265873	1.194345	8.636965	0.165158	1.194345
Mohammadpur	0.000889	0.058222	0.41736381	2.65934003	0.065502173	0.41736381	8.317710794	8.54384888	8.097558	8.317710794	2.12169	4.039774	1.114312	2.12169
Shalikha	0.01825	0.0229	1.868952381	6.05267323	0.577097568	1.868952381	3.277222222	3.97670378	2.700776	3.277222222	1.686905	16.85117	0.168869	1.686905
Sreepur	0.0005	0.062833	0.406664762	1.78775162	0.092505148	0.406664762	8.976301587	9.15182384	8.804146	8.976301587	2.267845	3.626282	1.418291	2.267845
Kalia	0.006	0.034517	0.768668571	5.74449778	0.102855183	0.768668571	4.932904762	5.40002442	4.506192	4.932904762	1.518464	9.185111	0.25103	1.518464
Lohagara	0.0024	0.0224	0.356571429	3.24747541	0.039151392	0.356571429	3.200761905	3.4364236	2.981261	3.200761905	0.914286	4.192951	0.199363	0.914286
Narail S.	0.024944	0.033322	2.566030476	8.57964151	0.767457754	2.566030476	4.768204444	5.75163644	3.952923	4.768204444	2.377881	23.77878	0.237788	2.377881
Bagerhat S.	0.0016	0.0163	0.24552381	2.29377635	0.026280653	0.24552381	2.329079365	2.49296653	2.175966	2.329079365	0.658333	2.872455	0.150882	0.658333
Chitalmari	0.003	0.0034	0.305142857	0.93936198	0.099122772	0.305142857	0.486666667	0.59651282	0.397048	0.486666667	0.264286	2.622897	0.02663	0.264286
Fakirhat	0.017625	0.024888	1.820788571	6.26528307	0.529149439	1.820788571	3.56102381	4.27356601	2.967286	3.56102381	1.728143	17.26506	0.172978	1.728143
Kachua	0.049	0.0056	4.698666667	6.8621855	3.217264883	4.698666667	0.815555556	1.53116101	0.434396	0.815555556	2.533333	8.77012	0.731778	2.533333
Mollahat	0.014833	0.007911	1.457872381	3.23890406	0.656207111	1.457872381	1.134851746	1.52581667	0.844065	1.134851746	0.988869	7.918598	0.123489	0.988869

Upozilas	Concentration of samples		Cardiovascular effects				Renal effects				Hematological effects			
	As	Cd	HI	SS	SA	Additive	HI	SS	SA	Additive	HI	SS	SA	AddItive
Mongla	0.0015	0.022	0.268571429	2.67313326	0.026983545	0.268571429	3.143333333	3.32663388	2.970133	3.143333333	0.857143	3.060723	0.240039	0.857143
Morrelganj	0.002278	0.021867	0.341906667	3.14070507	0.037220995	0.341906667	3.124580317	3.35131255	2.913188	3.124580317	0.88944	4.014174	0.197078	0.88944
Rampal	0.0063	0.01288	0.6736	2.83361951	0.160126283	0.6736	1.842	2.14366086	1.58279	1.842	0.76	7.217749	0.080025	0.76
Batiaghata	0.002438	0.006687	0.270401905	1.34492777	0.054365143	0.270401905	0.956059683	1.08985015	0.838693	0.956059683	0.354917	3.079206	0.040909	0.354917
Dacope	0.0108	0.01965	1.140857143	4.4978057	0.289375555	1.140857143	2.810571429	3.30069721	2.393225	2.810571429	1.216071	11.83044	0.125002	1.216071
Dighalia	0.002	0.006267	0.226287619	1.21513071	0.042140394	0.226287619	0.895920635	1.01272782	0.792586	0.895920635	0.31906	2.624632	0.038786	0.31906
Dumuria	0.00565	0.01663	0.63312381	3.2795724	0.122225007	0.63312381	2.377507937	2.69795584	2.095121	2.377507937	0.862976	7.284997	0.102228	0.862976
Kotwali	0.0005	0.009433	0.101521905	1.01074676	0.010197111	0.101521905	1.347730159	1.41679362	1.282033	1.347730159	0.360702	1.131733	0.114962	0.360702
Koyra	0.0035	0.052467	0.633144762	6.31103289	0.063519284	0.633144762	7.496396825	7.92866079	7.0877	7.496396825	2.040488	7.202555	0.578071	2.040488
Paikgachha	0.00225	0.0038	0.236	0.89328748	0.062349469	0.236	0.543571429	0.6422571	0.460049	0.543571429	0.242857	2.390047	0.024677	0.242857
Phultala	0.000875	0.01195	0.151619048	1.4990519	0.01533525	0.151619048	1.707420635	1.81070764	1.610025	1.707420635	0.468452	1.737782	0.12628	0.468452
Rupsa	0.013333	0.004367	1.29476381	2.43869795	0.687421466	1.29476381	0.628089841	0.91548338	0.430916	0.628089841	0.790869	4.941778	0.126569	0.790869
Terokhada	0.037812	0.0146	3.684571429	7.30987607	1.857222541	3.684571429	2.097718095	2.96896884	1.482138	2.097718095	2.322	15.86525	0.339842	2.322
Mathbaria	0.0016	0.0159	0.243238095	2.25691113	0.026214932	0.243238095	2.271936508	2.43386986	2.120777	2.271936508	0.644048	2.849986	0.145544	0.644048
Assasuni	0.010056	0.010856	1.019748571	3.06577509	0.339192249	1.019748571	1.554049524	1.91433973	1.261568	1.554049524	0.866571	8.555747	0.087771	0.866571
Debhata	0.001556	0.014833	0.232950476	2.13539569	0.025412585	0.232950476	2.119493968	2.2738468	1.975619	2.119493968	0.603845	2.736048	0.133269	0.603845
Kalaroa	0.119	0.017725	11.43461905	17.6042729	7.427203249	11.43461905	2.569920635	4.47319439	1.47646	2.569920635	6.299702	25.15449	1.577701	6.299702
Kaliganj	0.006917	0.009233	0.711521905	2.37804973	0.212890174	0.711521905	1.321195873	1.59380628	1.095214	1.321195873	0.659131	6.591307	0.065913	0.659131
Satkhira S.	0.00925	0.0048	0.908380952	1.99763035	0.41306739	0.908380952	0.688650794	0.92965363	0.510125	0.688650794	0.611905	4.839874	0.077363	0.611905
Shyamnagar	0.0026	0.00816	0.294247619	1.58150229	0.054746466	0.294247619	1.166539683	1.3185017	1.032092	1.166539683	0.415238	3.413516	0.050512	0.415238
Tala	0.014667	0.0146	1.480285714	4.28130203	0.511817615	1.480285714	2.090370476	2.59722612	1.682429	2.090370476	1.219857	11.90491	0.124995	1.219857
Alamdanga	0.005607	0.033264	0.72408	5.49269856	0.095452507	0.72408	4.75378	5.19676022	4.34856	4.75378	1.455	8.650142	0.244739	1.455
Chuadanga S.	0.0005	0.0456	0.308190476	1.62815753	0.05833672	0.308190476	6.514444444	6.6642246	6.368031	6.514444444	1.652381	2.86056	0.954485	1.652381
Damurhula	0.019	0.0038	1.831238095	3.01464338	1.112381314	1.831238095	0.548888889	0.88712795	0.339612	0.548888889	1.040476	4.906756	0.220633	1.040476
Jibannagar	0.0005	0.00335	0.066761905	0.53579724	0.008318729	0.066761905	0.478730159	0.52059813	0.440229	0.478730159	0.143452	0.795837	0.025858	0.143452
Bheramara	0.024938	0.0059	2.408761905	4.13757556	1.40230283	2.408761905	0.850773968	1.32386548	0.546745	0.850773968	1.398238	7.262619	0.269196	1.398238
Daulatpur	0.00425	0.008281	0.452081905	1.85129638	0.110397261	0.452081905	1.184349206	1.38339206	1.013945	1.184349206	0.498131	4.782113	0.051888	0.498131
Khoksa	<Null>	<Null>	#VALUE!	#VALUE!	<Null>	<Null>	<Null>	<Null>	<Null>	#VALUE!	<Null>	<Null>	<Null>	<Null>
Kumarkhali	0.0266	0.00804	2.57927619	4.74280634	1.402685496	2.57927619	1.157015873	1.712288	0.781811	1.157015873	1.55381	9.282545	0.260093	1.55381
Kushtia S.	0.0005	0.069767	0.446287619	1.84960355	0.107683962	0.446287619	9.966873016	10.1517353	9.785377	9.966873016	2.515488	3.928958	1.610524	2.515488
Mirpur	0.0005	0.0019	0.05847619	0.35047392	0.009756688	0.05847619	0.271587302	0.30356121	0.242981	0.271587302	0.091667	0.690551	0.012168	0.091667
Gangni	0.011909	0.005464	1.165413333	2.45146419	0.554031442	1.165413333	0.784352063	1.07902002	0.570155	0.784352063	0.762238	5.687859	0.102149	0.762238
Meherpur S.	0.000667	0.006083	0.09828381	0.88858368	0.010870903	0.09828381	0.869211746	0.93398007	0.808935	0.869211746	0.249012	1.157178	0.053585	0.249012
Adamdighi	0.00095	0.01282	0.163733333	1.61656015	0.016583735	0.163733333	1.831730159	1.94322141	1.726636	1.831730159	0.503095	1.878379	0.134746	0.503095
Bogra S.	0.0005	0.019229	0.157499048	1.30564675	0.018998975	0.157499048	2.74715873	2.84502386	2.65266	2.74715873	0.71056	1.627493	0.310229	0.71056
Dhunat	0.009	0.022	0.982857143	4.57575538	0.211114468	0.982857143	3.145714286	3.61382213	2.738242	3.145714286	1.214286	10.96706	0.134447	1.214286
Dupchanchia	0.000667	0.010833	0.125426667	1.2540255	0.012545079	0.125426667	1.547783175	1.63343306	1.466624	1.547783175	0.418655	1.41718	0.123676	0.418655
Gabtali	0.000875	0.015625	0.172619048	1.72382831	0.017285559	0.172619048	2.232420635	2.35008833	2.120644	2.232420635	0.599702	1.934057	0.185953	0.599702
Kahaloo	0.0005	0.013433	0.124379048	1.16657757	0.013261139	0.124379048	1.91915873	2.00123898	1.840445	1.91915873	0.50356	1.338245	0.189481	0.50356
Nandigram	0.0005	0.010033	0.104950476	1.03918567	0.010599263	0.104950476	1.433444444	1.50461604	1.365639	1.433444444	0.382131	1.163155	0.125541	0.382131
Sariakandi	0.000625	0.00615	0.094666667	0.87591773	0.010231301	0.094666667	0.878769841	0.94172481	0.820023	0.878769841	0.249405	1.109843	0.056046	0.249405
Sherpur	0.0005	0.018229	0.151784762	1.28600385	0.017914887	0.151784762	2.604301587	2.69963342	2.512336	2.604301587	0.674845	1.578283	0.288552	0.674845
Shibganj	0.0016	0.02876	0.31672381	3.16203929	0.031724455	0.31672381	4.109079365	4.32493367	3.903998	4.109079365	1.103333	3.546512	0.343251	1.103333
Sonatala	0.00275	0.01955	0.373619048	3.07661975	0.04537161	0.373619048	2.793730159	3.03063594	2.575343	2.793730159	0.829167	4.446285	0.154627	0.829167
Akkelpur	0.0045	0.023443	0.562531429	3.99976575	0.079115035	0.562531429	3.350428571	3.68459473	3.046569	3.350428571	1.051536	6.721154	0.164515	1.051536

Upozilas	Concentration of samples		Cardiovascular effects				Renal effects				Hematological effects			
	As	Cd	HI	SS	SA	Additive	HI	SS	SA	Additive	HI	SS	SA	AddItive
Joypurhat S.	0.001786	0.009671	0.225358095	1.63422238	0.03107672	0.225358095	1.382138413	1.51722896	1.259076	1.382138413	0.43044	2.693173	0.068796	0.43044
Kalai	0.0005	0.01085	0.109619048	1.07459108	0.01118224	0.109619048	1.55015873	1.62410208	1.479582	1.55015873	0.41131	1.20567	0.140317	0.41131
Khetlal	0.0009	0.01264	0.157942857	1.56620336	0.015927655	0.157942857	1.806	1.9136896	1.70437	1.806	0.494286	1.806272	0.135261	0.494286
Panchbibi	0.000583	0.018767	0.16276381	1.44456309	0.018339149	0.16276381	2.681185079	2.78575521	2.58054	2.681185079	0.698012	1.716773	0.2838	0.698012
Biral	0.0005	0.021525	0.170619048	1.3462846	0.02162311	0.170619048	3.07515873	3.17860196	2.975082	3.07515873	0.79256	1.739538	0.361102	0.79256
Birampur	0.0005	0.01625	0.14047619	1.2425986	0.015880881	0.14047619	2.321587302	2.41169206	2.234849	2.321587302	0.604167	1.48009	0.246618	0.604167
Birganj	0.004	0.0451	0.638666667	6.11618444	0.066691107	0.638666667	6.444126984	6.87442711	6.040761	6.444126984	1.80119	7.423263	0.437043	1.80119
Bochaganj	0.0014	0.01208	0.202361905	1.79595819	0.022801389	0.202361905	1.72615873	1.85852632	1.603219	1.72615873	0.498095	2.389351	0.103835	0.498095
Chirirbandar	0.0006	0.01556	0.146057143	1.38221951	0.015433648	0.146057143	2.223047619	2.31985551	2.13028	2.223047619	0.584286	1.577401	0.216425	0.584286
Dinajpur S.	0.0005	0.0655	0.421904762	1.81164993	0.09825498	0.421904762	9.357301587	9.53647442	9.181495	9.357301587	2.363095	3.743015	1.491904	2.363095
Ghoraghat	0.0005	0.016367	0.141144762	1.24535869	0.015996872	0.141144762	2.338301587	2.42872394	2.251246	2.338301587	0.608345	1.485927	0.249059	0.608345
Hakimpur	0.000667	0.020411	0.180158095	1.62634614	0.019956969	0.180158095	2.916068889	3.03277279	2.803856	2.916068889	0.760726	1.911052	0.30282	0.760726
Kaharole	0.001333	0.024333	0.265998095	2.65365528	0.026663217	0.265998095	3.476566032	3.65775556	3.304352	3.476566032	0.932512	2.974314	0.292363	0.932512
Khansama	0.0031	0.02514	0.438895238	3.80914688	0.050570124	0.438895238	3.592412698	3.87689746	3.328803	3.592412698	1.045476	5.197151	0.210311	1.045476
Nawabganj	0.0005	0.020133	0.162664762	1.32232086	0.020010139	0.162664762	2.876301587	2.97640072	2.779569	2.876301587	0.742845	1.671759	0.330083	0.742845
Parbatipur	0.001056	0.042722	0.344697143	2.7963366	0.042489921	0.344697143	6.103478095	6.31537821	5.898688	6.103478095	1.576071	3.540578	0.701581	1.576071
Phulbari	0.0005	0.026417	0.198573333	1.4185697	0.027796568	0.198573333	3.774015873	3.8884273	3.662971	3.774015873	0.967274	1.974455	0.473862	0.967274
Atwari	0.00125	0.0243	0.257904762	2.56156365	0.025966509	0.257904762	3.471825397	3.64702529	3.305042	3.471825397	0.927381	2.866963	0.299981	0.927381
Boda	0.001375	0.0565	0.453809524	3.65646624	0.056322982	0.453809524	8.071865079	8.34989483	7.803093	8.071865079	2.083333	4.652696	0.932852	2.083333
Debiganj	0.0018	0.02602	0.320114286	3.18257093	0.032198232	0.320114286	3.717714286	3.9361316	3.511417	3.717714286	1.015	3.652429	0.282066	1.015
Panchagarh S.	0.00075	0.0855	0.56	2.60235438	0.120506263	0.56	12.21452381	12.4654105	11.96869	12.21452381	3.089286	5.054204	1.888267	3.089286
Tentulia	0.000583	0.010983	0.11828381	1.1777477	0.011879505	0.11828381	1.569185079	1.64965639	1.492639	1.569185079	0.420012	1.318766	0.133769	0.420012
Baliadangi	0.00075	0.133833	0.836188571	3.029147	0.230827797	0.836188571	19.1192381	19.4324854	18.81104	19.1192381	4.815464	7.14887	3.243687	4.815464
Haripur	0.002	0.076	0.624761905	5.2050638	0.074989943	0.624761905	10.85777778	11.2469415	10.48208	10.85777778	2.809524	6.464986	1.22095	2.809524
Pirganj	0.0017	0.01346	0.238819048	2.05400424	0.027767488	0.238819048	1.923396825	2.07761815	1.780623	1.923396825	0.561667	2.830866	0.111439	0.561667
Ranisankail	0.000937	0.016825	0.185380952	1.85085	0.018567738	0.185380952	2.403868889	2.5302143	2.283832	2.403868889	0.645512	2.075999	0.200716	0.645512
Thakurgaon S.	0.001833	0.023758	0.310331429	3.0477152	0.031599277	0.310331429	3.394581905	3.60553457	3.195972	3.394581905	0.935786	3.571183	0.245211	0.935786
Atgharia	0.0005	0.011314	0.112270476	1.09317792	0.011530291	0.112270476	1.616444444	1.69191562	1.54434	1.616444444	0.427881	1.229684	0.148885	0.427881
Bera	0.0125	0.023	1.321904762	5.24396881	0.333227039	1.321904762	3.28968254	3.85989022	2.80371	3.28968254	1.416667	13.75432	0.145914	1.416667
Bhangura	0.0005	0.0132	0.123047619	1.15930866	0.013060125	0.123047619	1.885873016	1.96725337	1.807859	1.885873016	0.495238	1.326391	0.184908	0.495238
Chatmohar	0.001063	0.0116	0.16752381	1.5924609	0.017623181	0.16752381	1.657480317	1.7700399	1.552079	1.657480317	0.464905	1.951382	0.110761	0.464905
Faridpur	0.0008	0.087	0.573333333	2.7372824	0.120086664	0.573333333	12.4288254	12.6902667	12.17277	12.4288254	3.145238	5.205062	1.900558	3.145238
Ishwardi	0.0065	0.0246	0.759619048	4.5423487	0.12703144	0.759619048	3.516349206	3.93121544	3.145264	3.516349206	1.188095	8.967866	0.157403	1.188095
Pabna S.	0.0005	0.04355	0.29647619	1.60821467	0.05465572	0.29647619	6.221587302	6.36800083	6.07854	6.221587302	1.579167	2.767889	0.900964	1.579167
Santhia	0.0078	0.0212	0.864	4.27490721	0.174622738	0.864	3.031047619	3.45727403	2.657368	3.031047619	1.128571	9.824533	0.129642	1.128571
Sujanagar	0.002571	0.013986	0.324777143	2.36065575	0.044682581	0.324777143	1.99881619	2.19371045	1.821237	1.99881619	0.621929	3.881336	0.099655	0.621929
Belkuchi	0.002429	0.021857	0.356230476	3.20665058	0.039574051	0.356230476	3.123199683	3.35754495	2.905211	3.123199683	0.896274	4.197179	0.191392	0.896274
Chauhali	0.001042	0.044108	0.35128381	2.79312093	0.044180083	0.35128381	6.301473651	6.51526947	6.094693	6.301473651	1.624905	3.588763	0.735717	1.624905
Kamarkhanda	0.010437	0.019625	1.106142857	4.44097874	0.275514046	1.106142857	2.806884762	3.28775019	2.396351	2.806884762	1.197893	11.58313	0.123883	1.197893
Kazipur	0.00425	0.0025	0.419047619	0.96647098	0.181692891	0.419047619	0.358492063	0.47527411	0.270405	0.358492063	0.291667	2.435843	0.034924	0.291667
Raiganj	0.015929	0.021057	1.637373333	5.44523025	0.492355935	1.637373333	3.013199683	3.63824055	2.495539	3.013199683	1.51056	15.10527	0.151059	1.51056
Shahjadpur	0.001	0.015	0.180952381	1.80375812	0.018153079	0.180952381	2.143174603	2.26671633	2.026366	2.143174603	0.583333	2.058379	0.165313	0.583333
Sirajganj S.	0.008917	0.0644	1.217238095	10.0903219	0.146840565	1.217238095	9.202830794	9.97684253	8.488868	9.202830794	2.724619	14.47848	0.51273	2.724619
Tarash	0.0005	0.021183	0.168664762	1.3405717	0.021220649	0.168664762	3.026301587	3.12893347	2.927036	3.026301587	0.780345	1.722927	0.353433	0.780345
Ullahpara	0.025	0.018975	2.489380952	6.37240612	0.972476866	2.489380952	2.718650794	3.4854298	2.12056	2.718650794	1.868155	17.10022	0.204091	1.868155

Upozilas	Concentration of samples		Cardiovascular effects				Renal effects				Hematological effects			
	As	Cd	HI	SS	SA	Additive	HI	SS	SA	Additive	HI	SS	SA	AddItive
Atrai	0.002375	0.0995	0.794761905	6.34871683	0.099491992	0.794761905	14.21503968	14.6998678	13.7462	14.21503968	3.666667	8.129467	1.653792	3.666667
Badalgachhi	0.006833	0.0444	0.90447619	7.15968005	0.114261695	0.90447619	6.345026349	6.90886706	5.827201	6.345026349	1.911095	10.78953	0.338503	1.911095
Dhamoirhat	0.0005	0.063057	0.407944762	1.78976459	0.092983697	0.407944762	9.008301587	9.18413339	8.835836	9.008301587	2.275845	3.636102	1.424457	2.275845
Mahadevpur	0.000714	0.0166	0.162857143	1.57802925	0.016807324	0.162857143	2.371655238	2.48086385	2.267254	2.371655238	0.626857	1.778875	0.220898	0.626857
Manda	0.002	0.061	0.539047619	4.87137782	0.059648901	0.539047619	8.714920635	9.06428969	8.379017	8.714920635	2.27381	5.720131	0.903862	2.27381
Naogaon S.	0.006625	0.058975	0.967952381	8.68213556	0.107914902	0.967952381	8.427103175	9.0629609	7.835857	8.427103175	2.421726	11.411	0.513957	2.421726
Niamatpur	0.0005	0.01675	0.143333333	1.25420997	0.016380387	0.143333333	2.393015873	2.48447001	2.304928	2.393015873	0.622024	1.505005	0.257085	0.622024
Patnitala	0.0008	0.053	0.379047619	2.39992336	0.059867369	0.379047619	7.57168254	7.77634049	7.372411	7.57168254	1.930952	3.663572	1.017744	1.930952
Porsha	0.0005	0.0528	0.349333333	1.69622535	0.071944319	0.349333333	7.543015873	7.7040577	7.38534	7.543015873	1.909524	3.183143	1.145497	1.909524
Raninagar	0.001188	0.047712	0.385782857	3.13960762	0.047403507	0.385782857	6.816377143	7.0539095	6.586843	6.816377143	1.760571	3.96604	0.781538	1.760571
Sapahar	0.0005	0.035833	0.252379048	1.52954685	0.041643173	0.252379048	5.11915873	5.25212705	4.989557	5.11915873	1.30356	2.415167	0.703582	1.30356
Bagatipara	0.000833	0.008767	0.129430476	1.21952555	0.013736693	0.129430476	1.252693016	1.33936888	1.171626	1.252693016	0.352774	1.511179	0.082353	0.352774
Baraigram	0.0005	0.044263	0.300550476	1.61518588	0.055925816	0.300550476	6.323444444	6.47103772	6.179218	6.323444444	1.604631	2.800165	0.919532	1.604631
Gurudaspur	0.0005	0.0061	0.08247619	0.80220377	0.008479544	0.08247619	0.871587302	0.92746712	0.819074	0.871587302	0.241667	0.953357	0.06126	0.241667
Lalpur	0.0005	0.007233	0.088950476	0.88439615	0.008946429	0.088950476	1.033444444	1.0941372	0.976118	1.033444444	0.282131	1.014845	0.078434	0.282131
Natore S.	0.0008	0.04896	0.355961905	2.35350135	0.053838456	0.355961905	6.994539683	7.19134945	6.803116	6.994539683	1.786667	3.474995	0.918614	1.786667
Singra	0.00055	0.04417	0.304780952	1.73185954	0.053636815	0.304780952	6.310174603	6.46489844	6.159154	6.310174603	1.60369	2.874839	0.894597	1.60369
Bholahat	0.000625	0.024	0.196666667	1.63136955	0.023708777	0.196666667	3.428769841	3.5510106	3.310737	3.428769841	0.886905	2.032586	0.386995	0.886905
Gomastapur	0.0005	0.05255	0.347904762	1.69390294	0.071454934	0.347904762	7.507301587	7.66796575	7.350004	7.507301587	1.900595	3.172012	1.138792	1.900595
Nachole	0.001133	0.043913	0.35883619	2.96502051	0.043427494	0.35883619	6.273645397	6.49625633	6.058663	6.273645397	1.622274	3.704583	0.71041	1.622274
Nawabganj S.	0.0005	0.0114	0.112761905	1.09651148	0.011596091	0.112761905	1.628730159	1.70448105	1.556346	1.628730159	0.430952	1.234125	0.150487	0.430952
Shibganj	0.0015	0.098	0.702857143	4.48439696	0.11016156	0.702857143	14.00047619	14.3815815	13.62947	14.00047619	3.571429	6.805217	1.874312	3.571429
Bagha	0.000917	0.01205	0.156190476	1.53685651	0.015873613	0.156190476	1.721719683	1.8279593	1.621655	1.721719683	0.474024	1.795512	0.125145	0.474024
Bagmara	0.022643	0.015857	2.247087619	5.55975621	0.908205787	2.247087619	2.272473968	2.94310162	1.754658	2.272473968	1.64456	14.66791	0.184387	1.64456
Boalia	<Null>	<Null>	#VALUE!	#VALUE!	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>
Charghat	0.001417	0.013033	0.209426667	1.89857458	0.023101294	0.209426667	1.862306984	2.00046663	1.733689	1.862306984	0.53294	2.464634	0.11524	0.53294
Durgapur	0.0005	0.00915	0.099904762	0.99653975	0.010015618	0.099904762	1.307301587	1.37534747	1.242622	1.307301587	0.350595	1.11685	0.110057	0.350595
Godagari	0.000625	0.008617	0.10876381	1.07647601	0.010989159	0.10876381	1.231198413	1.30531491	1.16129	1.231198413	0.337512	1.24567	0.091448	0.337512
Mohanpur	0.02375	0.05045	2.550190476	10.9614415	0.593304398	2.550190476	7.21468254	8.37216556	6.217226	7.21468254	2.932738	27.59059	0.311735	2.932738
Paba	0.00085	0.06236	0.437295238	2.61556536	0.073111201	0.437295238	8.90884127	9.13751644	8.685889	8.90884127	2.267619	4.17234	1.232425	2.267619
Puthia	<Null>	<Null>	#VALUE!	#VALUE!	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>
Tanore	0.0005	0.01364	0.125561905	1.1728906	0.013441826	0.125561905	1.948730159	2.03142713	1.8694	1.948730159	0.510952	1.348759	0.193565	0.510952
Gaibandha S.	0.0245	0.008633	2.382664762	4.5903739	1.236738335	2.382664762	1.241063492	1.7849506	0.862903	1.241063492	1.474988	9.594553	0.226753	1.474988
Gobindaganj	0.0116	0.18946	2.187390476	21.8713264	0.218764834	2.187390476	27.06939683	28.5630309	25.65387	27.06939683	7.31881	24.70303	2.168356	7.31881
Palashbari	0.0071	0.02321	0.808819048	4.45002735	0.147007692	0.808819048	3.317968254	3.7409519	2.942811	3.317968254	1.167024	9.426112	0.144486	1.167024
Phulchhari	0.00475	0.014317	0.534192381	2.8051834	0.101726504	0.534192381	2.046793651	2.31920769	1.806377	2.046793651	0.737512	6.166113	0.088212	0.737512
Sadullapur	0.010944	0.025278	1.186731429	5.34897315	0.263290064	1.186731429	3.614617143	4.16906049	3.133909	3.614617143	1.423929	13.08884	0.154908	1.423929
Sughatta	0.0005	0.015	0.133333333	1.21130521	0.014676547	0.133333333	2.143015873	2.22965348	2.059745	2.143015873	0.559524	1.417469	0.220863	0.559524
Sundarganj	0.017	0.204614	2.788270476	27.0542702	0.28736507	2.788270476	29.23596825	31.1234801	27.46293	29.23596825	8.117167	32.26141	2.042328	8.117167
Bhurungamari	0.001	0.027567	0.25276381	2.35437945	0.027136468	0.25276381	3.938460317	4.10470385	3.77895	3.938460317	1.032155	2.712078	0.392815	1.032155
Charrajibpur	0.00075	0.026167	0.220954286	1.90438343	0.025636012	0.220954286	3.738380952	3.87832478	3.603487	3.738380952	0.97025	2.309248	0.407659	0.97025
Chilmari	0.002375	0.009975	0.283190476	1.79468905	0.04468565	0.283190476	1.425753968	1.58498308	1.282521	1.425753968	0.469345	3.363793	0.065487	0.469345
Kurigram S.	0.0082	0.05692	1.106209524	9.01668759	0.135714973	1.106209524	8.134031746	8.83240917	7.490875	8.134031746	2.423333	13.17402	0.445767	2.423333
Nageshwari	0.016	0.027667	1.681906667	6.44845804	0.438680072	1.681906667	3.957507937	4.66688453	3.355958	3.957507937	1.750012	17.16533	0.178414	1.750012
Phulbari	0.00875	0.021167	0.954287619	4.41632247	0.20620434	0.954287619	3.026634921	3.47954067	2.632681	3.026634921	1.172631	10.62638	0.129401	1.172631

Upozilas	Concentration of samples		Cardiovascular effects				Renal effects				Hematological effects			
	As	Cd	HI	SS	SA	Additive	HI	SS	SA	Additive	HI	SS	SA	AddItive
Rajarhat	0.0075	0.01925	0.824285714	3.94635553	0.172170737	0.824285714	2.752380952	3.15142245	2.403867	2.752380952	1.044643	9.282122	0.117568	1.044643
Raomari	0.001583	0.022933	0.281807619	2.80222044	0.028340217	0.281807619	3.276645397	3.4689344	3.095015	3.276645397	0.894417	3.214791	0.248844	0.894417
Ulipur	0.010714	0.013929	1.099975238	3.62701419	0.333592718	1.099975238	1.993258413	2.41051566	1.648228	1.993258413	1.007655	10.0747	0.100784	1.007655
Aditmari	0.006	0.05178	0.867314286	7.69784036	0.097720144	0.867314286	7.399047619	7.96638247	6.872116	7.399047619	2.135	10.24057	0.445114	2.135
Hatibandha	0.003583	0.029667	0.51076381	4.46699239	0.058401637	0.51076381	4.239280317	4.57139085	3.931298	4.239280317	1.230155	6.042551	0.250437	1.230155
Kaliganj	0.0011	0.0103	0.163619048	1.49166295	0.017947213	0.163619048	1.471777778	1.5799583	1.371004	1.471777778	0.420238	1.923665	0.091804	0.420238
Lalhonirhat S.	0.002429	0.079757	0.687087619	6.05571816	0.077957624	0.687087619	11.39462825	11.8345664	10.97104	11.39462825	2.964131	7.230904	1.215072	2.964131
Patgram	0.000625	0.023925	0.196238095	1.6299401	0.023626261	0.196238095	3.418055556	3.54010853	3.300211	3.418055556	0.884226	2.028904	0.385359	0.884226
Dimla	0.0005	0.0138	0.12647619	1.17768007	0.013582829	0.12647619	1.971587302	2.05475777	1.891783	1.971587302	0.516667	1.356875	0.196735	0.516667
Domar	0.001125	0.038325	0.326142857	2.83631401	0.037502605	0.326142857	5.475357143	5.68282931	5.275459	5.475357143	1.422321	3.417954	0.591874	1.422321
Jaldhaka	0.000714	0.036914	0.278937143	2.01480208	0.038617158	0.278937143	5.273655238	5.43529879	5.116819	5.273655238	1.352357	2.780992	0.657632	1.352357
Kishoreganj	0.000667	0.035167	0.264478095	1.89139285	0.03698262	0.264478095	5.024068889	5.17653735	4.876091	5.024068889	1.287726	2.630439	0.630404	1.287726
Nilphahari S.	0.0019	0.0133	0.256952381	2.10200152	0.031410313	0.256952381	1.900603175	2.0630748	1.750927	1.900603175	0.565476	3.059331	0.104521	0.565476
Saidpur	0.000917	0.009333	0.140664762	1.31380411	0.015060522	0.140664762	1.333576825	1.42746126	1.245867	1.333576825	0.376988	1.645775	0.086354	0.376988
Badarganj	0.0005	0.061027	0.396344762	1.7714805	0.088676771	0.396344762	8.718301587	8.89130763	8.548662	8.718301587	2.203345	3.546997	1.368688	2.203345
Gangachhara	0.0005	0.0136	0.125333333	1.17168107	0.013406758	0.125333333	1.943015873	2.02559404	1.863804	1.943015873	0.509524	1.346728	0.192774	0.509524
Kaunia	0.008	0.0099	0.81847619	2.63217885	0.254505226	0.81847619	1.416825397	1.72153812	1.166047	1.416825397	0.734524	7.333492	0.07357	0.734524
Mithapukur	0.006875	0.016	0.746190476	3.37782342	0.164839945	0.746190476	2.287896825	2.63741902	1.984695	2.287896825	0.89881	8.243271	0.098002	0.89881
Pirgachha	0.003214	0.013271	0.381929524	2.39777605	0.060835607	0.381929524	1.89687746	2.11062874	1.704774	1.89687746	0.627012	4.532826	0.086733	0.627012
Pirganj	0.0005	0.014	0.127619048	1.18355987	0.013760708	0.127619048	2.00015873	2.08391722	1.919767	2.00015873	0.52381	1.367008	0.200713	0.52381
Rangpur S.	0.0048	0.10766	1.072342857	10.4571055	0.109965344	1.072342857	15.38152381	16.1029302	14.69244	15.38152381	4.073571	11.75565	1.411576	4.073571
Taraganj	0.003722	0.039344	0.579299048	5.46431145	0.061414396	0.579299048	5.621753016	6.00985474	5.258714	5.621753016	1.582381	6.761791	0.370306	1.582381
Ajmiriganj	0.0606	0.0181	5.874857143	10.7651688	3.20607572	5.874857143	2.604952381	3.86401075	1.756149	2.604952381	3.532143	20.96008	0.595228	3.532143
Bahubal	0.00275	0.007925	0.307190476	1.57200522	0.060029055	0.307190476	1.133015873	1.28745254	0.997105	1.133015873	0.413988	3.524245	0.048631	0.413988
Baniachong	0.072778	0.0122	7.000952381	11.0595842	4.431751983	7.000952381	1.76596127	2.9801763	1.046455	1.76596127	3.901333	16.64049	0.91466	3.901333
Chunarughat	0.021714	0.029714	2.237794286	7.57562603	0.661030949	2.237794286	4.251750476	5.11720749	3.532665	4.251750476	2.095214	20.94807	0.209562	2.095214
Habiganj S.	0.026136	0.010745	2.550542857	5.16637895	1.259154415	2.550542857	1.543297143	2.16122796	1.102043	1.543297143	1.628321	11.49679	0.230624	1.628321
Lakhai	0.00225	0.0053	0.244571429	1.11476877	0.053657032	0.244571429	0.757857143	0.87288888	0.657985	0.757857143	0.296429	2.708686	0.03244	0.296429
Madhabpur	0.0095	0.02134	1.026704762	4.55494911	0.231423588	1.026704762	3.051587302	3.52670463	2.640478	3.051587302	1.214524	11.25471	0.131062	1.214524
Nabiganj	0.005	0.0028	0.492190476	1.11383722	0.2174927	0.492190476	0.401587302	0.53613005	0.300808	0.401587302	0.338095	2.765791	0.041329	0.338095
Barlekha	0.010857	0.006471	1.070977143	2.48276018	0.461982616	1.070977143	0.927875238	1.22788498	0.701167	0.927875238	0.748107	6.281481	0.089098	0.748107
Kamalganj	0.006556	0.006889	0.663746667	1.9697184	0.223666305	0.663746667	0.986224127	1.21830362	0.798354	0.986224127	0.558226	5.492413	0.056736	0.558226
Kulaura	0.014727	0.0116	1.468857143	3.82073248	0.564693109	1.468857143	1.661818095	2.12087841	1.302121	1.661818095	1.115571	10.32375	0.120547	1.115571
Maulvibazar S.	0.036417	0.005383	3.499045714	5.37828586	2.276435507	3.499045714	0.780560952	1.36144204	0.447522	0.780560952	1.926393	7.659591	0.484489	1.926393
Rajnagar	0.0005	0.00955	0.102190476	1.01646741	0.010273712	0.102190476	1.364444444	1.43392413	1.298331	1.364444444	0.364881	1.137874	0.117006	0.364881
Sreemangal	0.019167	0.0124	1.896285714	4.54170751	0.791750569	1.896285714	1.777513333	2.32610032	1.358305	1.777513333	1.355571	11.75252	0.156356	1.355571
Bishwamvarpur	0.006333	0.015133	0.689617143	3.16912767	0.150063946	0.689617143	2.163867619	2.48980337	1.8806	2.163867619	0.842036	7.660216	0.092559	0.842036
Chhatak	0.025429	0.0089	2.472666667	4.75367649	1.286179331	2.472666667	1.27950127	1.84246991	0.888548	1.27950127	1.528762	9.907761	0.235887	1.528762
Derai	0.0645	0.0028	6.158857143	7.78585886	4.871848049	6.158857143	0.42047619	1.13295244	0.156053	0.42047619	3.171429	7.09175	1.418262	3.171429
Dharampasha	0.199	0.027967	19.11219238	29.0689619	12.56583907	19.11219238	4.058460317	7.17695699	2.294998	4.058460317	10.47501	40.50958	2.70864	10.47501
Dowarabazar	0.075833	0.010133	7.280093333	10.9595313	4.835951254	7.280093333	1.471645397	2.63938832	0.820546	1.471645397	3.972988	14.94812	1.055961	3.972988
Jagannathpur	0.035667	0.011056	3.460034286	6.40994482	1.867697398	3.460034286	1.590751429	2.34280626	1.080111	1.590751429	2.093286	12.68405	0.345461	2.093286
Jamalganj	0.071333	0.01275	6.86647619	11.0065994	4.28365688	6.86647619	1.844073968	3.06227688	1.110484	1.844073968	3.852167	17.03781	0.870956	3.852167

Upozilas	Concentration of samples		Cardiovascular effects				Renal effects				Hematological effects			
	As	Cd	HI	SS	SA	Additive	HI	SS	SA	Additive	HI	SS	SA	AddItive
Sullah	0.03325	0.010583	3.227140952	6.02592203	1.728273064	3.227140952	1.522412698	2.23094372	1.038906	1.522412698	1.961298	12.06147	0.318924	1.961298
Sunamganj S.	0.067267	0.00814	6.452895238	9.52674875	4.37083606	6.452895238	1.184211746	2.18559156	0.641637	1.184211746	3.493905	12.46517	0.979319	3.493905
Tahirpur	0.0083	0.00994	0.84727619	2.68041364	0.267823195	0.84727619	1.422634921	1.7341503	1.167079	1.422634921	0.750238	7.477558	0.075273	0.750238
Balaganj	0.038083	0.00445	3.652380952	5.35640754	2.490454006	3.652380952	0.647804127	1.20810835	0.347361	0.647804127	1.972405	6.908152	0.563158	1.972405
Beanibazar	0.0072	0.01048	0.7456	2.60662282	0.213271884	0.7456	1.499428571	1.79453992	1.252848	1.499428571	0.717143	7.155581	0.071873	0.717143
Bishwanath	0.008	0.003	0.779047619	1.5309554	0.39642905	0.779047619	0.431111111	0.61325671	0.303065	0.431111111	0.488095	3.283499	0.072556	0.488095
Companiganj	0.008227	0.006727	0.82196381	2.17333874	0.310869397	0.82196381	0.963611746	1.2242873	0.758439	0.963611746	0.632012	5.909694	0.06759	0.632012
Fenchuganj	0.021857	0.005171	2.111167619	3.6263782	1.229057883	2.111167619	0.745653016	1.16029343	0.479188	0.745653016	1.225488	6.365281	0.235939	1.225488
Golabganj	0.005063	0.0093	0.535333333	2.12165252	0.135074794	0.535333333	1.33017873	1.56095438	1.133522	1.33017873	0.573238	5.567253	0.059024	0.573238
Gowainghat	0.03975	0.006275	3.821571429	5.95745756	2.451449806	3.821571429	0.909047619	1.55806618	0.53038	0.909047619	2.116964	8.73045	0.513323	2.116964
Jaintiapur	0.0805	0.002433	7.680569524	9.34130832	6.315084159	7.680569524	0.373126984	1.19406294	0.116597	0.373126984	3.920226	7.722408	1.990075	3.920226
Kanaighat	0.00125	0.007025	0.159190476	1.17606752	0.021547749	0.159190476	1.003968254	1.10020664	0.916148	1.003968254	0.310417	1.902423	0.05065	0.310417
Sylhet S.	0.000808	0.004962	0.105306667	0.81208348	0.013655608	0.105306667	0.709113651	0.77401145	0.649657	0.709113651	0.21569	1.257494	0.036996	0.21569
Zakiganj	0.003167	0.0064	0.338190476	1.41342253	0.080919043	0.338190476	0.915291111	1.06612572	0.785796	0.915291111	0.379381	3.612798	0.039839	0.379381