ASSESSMENT OF As, Pb AND Cd IN SOILS AND VEGETABLES COLLECTED FROM 5 DIFFERENT LOCATIONS OF CHANDPUR DISTRICT

By

MD. AMINUL ISLAM

REGISTRATION NO. 07-02559

A Thesis
submitted to the Faculty of Agriculture,
Sher-e-Bangla Agricultural University, Dhaka,
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

IN

AGRICULTURAL CHEMISTRY

SEMESTER: JANUARY-JUNE, 2014

Approved By

(Prof. Md. Azizur Rahman Mazumder)	**(Prof. Dr. A. Faiz Md. Jamal Uddin)**
Supervisor	**Co-supervisor**

(Prof. Dr. Md. Abdur Razzaque)
Chairman
Examination Committee

DEDICATED TO

MY

BELOVED PARENTS

DEPARTMENT OF AGRICULTURAL CHEMISTRY
Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207
PABX: 9110351 & 9144270-79

CERTIFICATE

This is to certify that the thesis entitled " ASSESSMENT OF As, Pb AND Cd IN SOILS AND VEGETABLES COLLECTED FROM 5 DIFFERENT LOCATIONS OF CHANDPUR DISTRICT" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE (M.S.) in AGRICULTURAL CHEMISTRY, embodies the results of a piece of bona fide research work carried out by MD. AMINUL ISLAM, Registration. No. **07-02559** *under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.*

I further certify that such help or source of information as has been availed of during the course of this investigation has duly been acknowledged.

Dated:

Dhaka, Bangladesh

(Prof. Md. Azizur Rahman Mazumder)

Supervisor

ACKNOWLEDGEMENTS

All praises are due to the Almighty Allah, the great, the gracious, merciful and supreme ruler of the universe to complete the research work and thesis successfully for the degree of Master of Science (MS) in Agricultural Chemistry.

The author expresses the deepest sense of gratitude, sincere appreciation and heartfelt indebtedness to his reverend research supervisor ***Professor Md. Azizur Rahman Mazumder****, Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka for his scholastic guidance & valuable advice in carrying out the research work and preparation of this manuscript.*

The author deems it a proud privilege to acknowledge his gratefulness, boundless gratitude and best regards to his respectable co-supervisor ***Professor Dr. A. Faiz Md. Jamal Uddin****, Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka for his valuable advice, innovative suggestion, constant inspiration and factual comments in upgrading the research work and this documents.*

The author would like to express his deepest respect and boundless gratitude to all the respected teachers of the Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka, for their valuable teaching, sympathetic co-operation, and inspirations throughout the course of this study and research work.

The author has acknowledged Faculty of Agriculture, Rajshahi University; Department of Botany, Jahangirnagar University, Savar, Dhaka for their co-operation of arsenic, lead and cadmium determination in soil and vegetable samples.

The author wishes to extend his special thanks to Dr. A. M. Mazed Chowdhury, Professor, Department of Accounting, Rajshahi University, Md. Nazmul Haque, Md. Refatul Islam, Md. Zillur Rahman for their help during experimentation. Special thanks to all other friends for their support and encouragement to complete this study.

The author is deeply indebted to his father and grateful to his respectful mother, brother, sister and other relative's for their moral support, encouragement and love with cordial understanding. Finally the author appreciates the assistance rendered by the staffs of the Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, who have helped him during the period of study.

The Author

ASSESSMENT OF As, Pb AND Cd IN SOILS AND VEGETABLES COLLECTED FROM 5 DIFFERENT LOCATIONS OF CHANDPUR DISTRICT

ABSTRACT

An experiment was designed to assess the concentration of Arsenic (As), Lead (Pb) and Cadmium (Cd) in soils and 12 different vegetable species (Cabbage, Radish, Tomato, Sponge gourd, Spinach, Brinjal, Red amaranth, Data shak, Potato, Onion, Garlic, Bottle gourd) collected from five different locations (Karaia, Charbhairabi, Gazra, Tamta and Faridganj unions) of Chandpur district. Forty soil and sixty vegetable samples were collected during Rabi season. Concentrations of As, Pb and Cd in soils were 8.80, 16.24 and 0.53 $\mu g\ g^{-1}$, respectively. As, Pb and Cd concentrations of soils were within the set value for maximum acceptable concentration (20, 100 and 5 $\mu g\ g^{-1}$, respectively) for satisfactory crop production. Concentrations of heavy metals were higher in leafy vegetables compared to fruits and root and tuber type vegetables. The mean concentrations of As, Pb and Cd in vegetables ranged between 0.31-0.81, 0.08-0.59, 0.12-0.34 $\mu g\ g^{-1}$, respectively. Highest concentration of Pb (0.59 $\mu g\ g^{-1}$) was found in both cabbage and radish while the highest concentrations of As (0.81 $\mu g\ g^{-1}$) was recorded with cabbage. Highest concentration of Cd (0.34 $\mu g\ g^{-1}$) was observed in both sponge gourd and red amaranth. However, the highest concentration of As in vegetables under the study was within the safe limit (2.6 $\mu g\ g^{-1}$) whereas Pb and Cd were found above the safe limit (0.3 and 0.2 $\mu g\ g^{-1}$, respectively) for human consumption.

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Chapter 1

Introduction

CHAPTER I

INTRODUCTION

Heavy metals are natural trace components of the soil and environment, but their levels have increased due to industrial, agricultural and mining activities. Heavy metals have a great concern for contamination of soil and water because they are persistent and may affect vegetables, plant and human health. Heavy metals once accumulated as contaminants can neither be destroyed nor can be altered by chemical or physical means, and are circulated in the ecosystems. Heavy metals present in the atmosphere are ultimately accumulated in the soil through precipitation and fall out (Buchauer, 1973). Heavy metals are elements having a density greater than 5.0 in their elemental form and comprise some 38 elements (Andriano, 1986). Some heavy metals are essential in trace amounts, namely Co, Cu, Fe, Mn, Mo and Zn for plants and in addition, Cr, Ni and Sn for animals; As, Cd, Pb and Hg have not been shown to be essential for either plants or animals. The concentrations of heavy metals in soils do not normally exceed 1000 mg kg^{-1} (0.1%), in fact most have average concentrations of less than 100 mg kg^{-1} (Candias *et al.,* 1999).

The heavy metals are widely distributed in environment, in soil, in plants and animals in their tissue. Industrial discharge, fertilizers, manures, pesticides, fossil fuels, municipality wastes, animal wastes, contaminated water etc might be the major sources of heavy metal contamination in soil and water (Alloway, 1998; Smith *et al.,* 2003). Soil is the ultimate sink for all elements and the elements heavy metals may accumulate in soil with a short span of time (Kabata-Pendias, 2001). Bowen (1979) estimated that the residence time of Cd in the soil might be in the range of 75-380 years and that of more strongly sorbed elements like As, Cd and Pb 1000-3000 years. The source of heavy metal in plant is the environment in which they grow and their growth medium (soil) from which heavy metals are taken up by roots or foliage of plants (Okonkwo *et al.,* 2005). Plants grown in polluted environment can accumulate heavy metals at high concentration causing serious risk to human health when consumed. Moreover, heavy metals are toxic because they tend to bioaccumulate in plants and animals, bioconcentrate in the food chain and attack specific organs in the body (Chatterjee and Chatterjee, 2000).

The word Arsenic itself now a day's sounds as a serious threat and cure to the human race because of its capability of causing terrible health hazards to human being (Chaudhuri, 2004 and Rahaman *et. al.,* 2013). Arsenic accumulation by plants and its translocation to the edible or commercial parts were observed to vary with crops and even among the cultivars of the same crop (Kundu *et al.,* 2012).Arsenic contamination of ground water is a severe problem in Bangladesh. At present some portions of 59 districts of the country are affected by arsenic contamination (Joarder *et al.,* 2002). In Bangladesh, arsenic in tube-wells was first confirmedIn 1993 in the Nawabganj district (Allan *et al.,* 2001). Arsenic is associated with many types of various minerals deposits especially sulphide minerals.

Rapid urbanization, industrialization and motorization in many parts of tropical Asia have considerably increased the risks of heavy metal pollution. Weathering of rocks converts arsenic sulphides to arsenic trioxide, which enters the arsenic cycle as dust or by dissolution in rain, rivers or ground water. Heavy metal contamination in irrigation water has a detrimental effect on food quality and a devastating long term effect on soil and a constant threat to agricultural sustainability and hazardous to human and animal health.

Vegetables constitute an important part of the human diet since there contain carbohydrates, proteins, as well as vitamins, minerals and heavy metals. Heavy metals are one of a range of important types of contaminants that can be found on the surface and in the tissue of fresh vegetables (Bigdeli and Seilsepour, 2008). A number of elements, such as lead (Pb), arsenic (As) and cadmium (Cd) can be harmful to plants and humans even at quite low concentrations (Bowen, 1979). Plant species have a variety of capacities in removing and accumulating heavy metals. So there are reports indicating that some plant species may accumulate specific heavy metals (Markert, 1993). The uptake of metals from the soil depends on different factors, such as their soluble content in it, soil pH, plant species, fertilizers, and soil type (Lubben and Sauerberck, 1991). Vegetables, especially leafy vegetables, accumulate higher amounts of heavy metals (Sharma and Kansal, 1986). Roots and leaves of herbaceous plants retain higher concentration of heavy metal than stems and fruits (Yargholi and Azimi, 2008). Of all the heavy metals, Cd has the highest tendency to get into crops, especially leafy vegetables such as spinach, red amaranth, cabbage etc. Leaves are the dominant organs in Cd accumulation but arsenic is accumulated more in root (Tlustos *et al.,* 1998).

Due to lack of statistics and information on lead pollution in the Bangladesh environment, it is difficult to estimate the human intake of lead at this stage. It is reported that the major source of lead intake for adults is food where the absorption of lead takes at the gastrointestinal tract and it is about 5 to

10% (WHO, 1999). The upper limit of lead is single or mixed foods should be held at 10 ppm in the dry substance and that of 100-470 ppm is taken as the toxic level (Kolke, 1984)

These heavy metals create hazards on vegetables to change the mode of metabolic activity of vegetables, decrease the permeability of membrane, selective uptake of nutrients, Cd, Ni and other heavy metals produce metal-phosphate on vegetable body act as toxic substance to vegetables. The accumulation of Pb on the root surface produces insoluble compounds outside the plant system. The high lead content decrease the chlorophyll content of the leaf; hamper the absorption and transportation of the nutrient uptake of the vegetables. The soil waters of Chandpur district are badly affected by As and also the heavy metal status (Jahiruddin *et al.*, 2003; Islam *et al.*, 2004).

The research in this area is very limited in Bangladesh. Therefore, the present study was under taken to determine the status of As, Pb and Cd in soils and vegetables in five vegetable growing areas of Chandpur with the following objectives.

1. To study the As, Pb and Cd contamination in soils and different vegetables collected from different locations of Chandpur district.
2. To study the variation in the levels of As, Pb and Cd in soils and different vegetables of different locations.

Chapter 2
Review of literature

CHAPTER II

REVIEW OF LITERATURE

Numerous experiments have been conducted throughout the world on soil and vegetables but information regarding arsenic (As), lead (Pb) and cadmium (Cd) contamination in soil and vegetables and their effects on growth, yield and quality parameters are still inadequate. Brief reviews of available literature pertinent to the present study have been reviewed in this chapter.

2.1 Heavy metal concentration in soil

Bhattacharya *et al.* (2010) reported that the As-contaminated soil (5.70-9.71 mg kg^{-1}) and irrigation water (0.318-0.643 mg L^{-1}) considerably influenced in the accumulation of As in rice, pulses, and vegetables. As concentrations of irrigation water samples were many folds higher than the FAO permissible limit (0.10 mg L^{-1}). The highest and lowest mean As concentrations (mg kg^{-1}) were found in potato (0.654) and in turmeric (0.003), respectively. Higher mean arsenic concentrations (mg $kg^{-1)}$ were observed in Boro rice grain (0.451), arum (0.407), amaranth (0.372), radish (0.344), Aman rice grain (0.334), lady's finger (0.301), cauliflower (0.293), and brinjal (0.279). Apart from a few potato samples, As concentrations in the studied crop samples, including rice grain samples were found not to exceed the food hygiene concentration limit (1.0 mg kg^{-1}).

Khan *et al.* (2010) measured As and cadmium (Cd) in soils and foods from Matlab, a rural area in Bangladesh that is extensively affected by As. Raw and cooked food samples were collected from village homes (households, n=13) and analyzed to quantify concentrations of As and Cd using atomic absorption spectrophotometry. Compared to raw vegetables (e.g. arum), concentration of As increased significantly ($p=0.024$) when cooked with As-contaminated water.

Surdyk *et al.* (2010) studied in a three years experiment on the accumulation of heavy metals in soil and potato plants (*Solanum tuberosum* L.) irrigated with treated low quality surface water. The low quality surface water used for irrigation experiments contained a significant proportion of urban sewage and was spiked with selected heavy metals (Cd, Cr, Cu, Pb) and As before treatment for years 2 and 3. They found that after the third harvest, no impact of the irrigation water on potato quality could be detected except for total sugar and sugar in total solids. The principal conclusion of this investigation is that, when appropriately treated, low quality feed waters with high heavy metal contents can be used for irrigation over several years without significant degradation of soil and produces.

Arain *et al.* (2009) developed a database of As in soil, lake water, ground water, sediment, vegetables, grain crops and fish to evaluate the potential human health risks posed by higher level of As, in south east part of Sindh, Pakistan during 2005-2007. The concentration of As in lake sediment and agricultural soil samples ranged between 11.3-55.8 and 8.7-46.2 mg kg^{-1}. It was observed that the leafy vegetables (spinach, coriander and peppermint) contain higher As levels (0.90-1.20 mg kg^{-1}) as compared to ground vegetables (0.048-0.25) and grain crops (0.248-0.367 mg kg^{-1}) on dried weight basis.

Karim *et al.* (2008) conducted an experiment to investigate the As poisoning in soils and vegetables in five upazillas under Feni district of Bangladesh. Samples were assessed and screened for As, Pb, Cd, Br, U, Th, Cr, Sc, Fe, Zn and Co in soils and As, Pb, Cd, Br, Na, K, Cr, Sc, Fe, Zn and Co in vegetables (i.e. eddoe, taro, green papaya, plantain, potato, callaloo, bottle ground and carambola). They reported that the mean levels of As in Parsuram, Feni Sadar and Pulgazi upazillas are higher than the world typical value of 2 mg kg^{-1}. For the case of vegetables, the mean concentration of As is found only in Eddoe (5.33 mg kg^{-1}) and Taro (1.46 mg kg^{-1}) collected from Sonagazi and Feni Sadar upazilla; which are higher than the values in Samta (0.1 mg kg-1 for eddoe and 0.44 mg kg^{-1} for taro) under Jessore district of Bangladesh. The mean estimated daily dietary intake of As from vegetables are found to be 0.105 mg, which are higher than the recommended values of some countries.

Lim *et al.* (2008) set up an experiment to estimate the bioaccessible fraction of the metals in soil and crop plant in Songcheon Au-Ag mine, Korea. After appropriate preparation, all samples were analyzed for As, Cd, Cu, Pb and Zn by ICP-AES and ICP-MS. Especially, maximum levels of As in farmland soil was up to 626 mg kg^{-1}. The highest levels in crop plant were 33 mg As kg^{-1} and 3.8 mg Pb kg^{-1} (in green onion root), 0.87 mg Cd kg^{-1} and 226 mg Zn kg-1 (in lettuce root), 16.3 mg Cu kg^{-1} (in sesame leaves). Vegetables grown on the contaminated soil were rich in As and heavy metals.

Islam *et al.* (2004) studied the As status of five districts of Gangetic floodplains and found that As levels ranged from 2.09-11.37 μg g^{-1} .

Among five districts, the soils of Pabna and Gopalganj districts had relatively lower levels of As compared to Rajbari, Faridpur and Chapai Nawabganj districts. The highest soil As concentration of 11.37 μg g^{-1} was found in soil Rajbari followd by 10.44 μg g^{-1} in soil from Faridpur.

Ahmed *et al.* (2003) collected 21 soil samples from Bhaluka region of Mymensingh. They reported that the detected heavy metal ranges in soil were As 3.90-25.50 ppm, Cr 80.0-117, Cu 1.2-49, Mo 2.00-2.2, Nb 9.00-20.00, Ni 44.0-76.0 ppm, Pb 12.0-34.0 ppm, Sr 31.0-120.0 ppm, Th 12.0-26.0 ppm, U 1.60- 5.8 ppm, V 134.0-273.0 ppm, Y 33.0-54.0 ppm, Zn 35.0-129.0 ppm.

Bibi *et al.* (2003) reported that the detected heavy metal ranges in soil of different depth were 3.60-26.20 ppm As, 89.0-117.0 ppm Cr, 8.0-48.0 ppm Cu, 19.0-24.0 ppm Pb, 127.0-177.0 ppm Sr, 41.0-143.0 ppm Zn.

Diaz-Valverde *et al.* (2003) collected soil samples from namely which were sun shine soil, predominant vegetation, nearby roads, urban centres and mines in Huelva, Spain. They found that the average lead and cadmium contents in soil were 2.90 and 0.19 mg kg^{-1} respectively. There was no significant variation in heavy metal contents between samples.

Elik (2003) analyzed the street dust samples of Sivas city, Yurkey and reported that the mean concentration of lead, zinc, copper and cadmium in soil were 197, 206, 68, 84 and 2.60 μg g^{-1}, respectively.

Warren *et al.* (2003) conducted an experiment in agricultural and industrial land in England. They reported that the most contaminated clay loam soil contains 74.8 mg As kg^{-1} soil and a sandy loam soil contains 65.0 mg As

kg^{-1} soil. The highest bio-availability was found on the soil which had been contaminated by industrial deposition and high sand content.

Jahiruddin *et al.* (2003) reported that the soils of Gangetic alluvium contain more arsenic than that of Brahmaputra alluvium and the former soils had more than20 μg As g^{-1} whereas the later soils had As level below 20 μg g^{-1} which was below maximum acceptable limit for agricultural soils. They also found that the mean concentration (mg kg^{-1}) in calcareous soil were Pb (22.80), Cd (0.25), Sb (0.74), Mo (0.31), Mn (457), Cu (29.20) and Zn (78.50), whereas in non-calcareous soil were Pb (24.1), Cd (0.15), Sb (0.31), Mo (0.31), Mn (444), Cu (22.4) and Zn (66.4). The concentration of trace element in calcareous soil was considerably higher than that of non-calcareous soils. The total amount of trace elements in both calcareous and non calcareous soil followed the order: Mn > Zn > Pb > Cu > As > Mo > Sb > Cd.

Mantylahti and Laakso (2002) conducted an experiment in South Savo Province in Finland. They found that the median concentrations of As, Cd, Cr, Cu, Hg, Ni, Pb and Zn in the mineral soils were 2.90, 0.084, 17.0, 13.0, 0.06, 5.40, 7.70 and 36.5 mg kg^{-1}, respectively. The corresponding values in the organic soils were 2-80 mg As kg^{-1}, 0.265 mg Cd kg^{-1}, 15.0 mg Cr kg^{-1}, 29.0 mg Cu kg^{-1}, 0.20 mg Hg kg^{-1}, 5.9 mg Ni kg^{-1}, 11.0 mg Pb kg^{-1} and 25.5 mg Zn kg^{-1}.

Roychowdhury *et al.* (2002) carried out an experiment on arsenic affected area of Murshidabad in West Bengal, India. They reported that the mean concentrations of As, Pb, Cd, Cr, Fe, Cu, Ni, Zn, Mn, Se, V, Sb and Hg in fallow land soils were 5.31, 10.40, 0.37, 33.10, 674, 18.30, 18.80, 44.30, 342.0, 0.53, 44.60, 0.29 and 0.54 mg kg^{-1} respectively

Oliveira and Mattiazzo (2001) conducted a study during 1996-98 to evaluate the possibilities of heavy metal accumulation in an acid soil after low successive sewage sludge applications. After two sewage sludge applicationes during the whole study period, a decrease in As, Cd, Cr, Ni and Zn levels in the topsoil was observed.

Wang-Qingren *et al.* (2001) investigated on heavy metal contamination on soils in China and found that the level of Cd, Hg and Pb in soils was greater than the governmental standards. The mean cadmium ranged from 0.45 to 1.04 mg kg^{-1} and was as high 145 mg kg^{-1}.

Nan-Zhong Ren *et al.* (2000) conducted an experiment on heavy metal concentration in grey soils of Baiyin region, Gansu province, China. Concentrations of Cd, Cu, Pb, Zn and Ni were measured in cultivated grey calcareous soils collected from two basins of the Baiyin urban areas, China. The value showed fluctuating and enriched Cd, Pb, Cu and Zn concentrations in cultivated soils, and suggesting recent inputs from anthropogenic sources.

Candias *et al.* (1999) conducted an investigation on contamination of soil by sewage sludge and other fertilizers. The found that the heavy metal load to Swiss soils has decreased significantly in recent years. Nevertheless, the input still is considerably higher than crop uptake. Fertilizers contribute 50% to the load of most metals, except for Pb, Cd and Zn with 90% and 80% respectively. Sewage sludge contributes 42% of lead, 26% of Cu and 24% of Cd load but only 9% of P input in fertilizers.

Sultana Ahmed (1999) conducted isotope-aided studies on the effects of radiation processed sewage sludge application on crop yields and bioavailability of heavy metal content of BAU soil. BAU soil contains0.25, 14.0, 21.0 and 19.0 mg kg^{-1} aqua regia extracted heavy metal for Cd, Pb, Cu and Zn, respectively.

Jack *et al.* (1998) stated that arsenic is one of the most abundant elements on earth and there are thousands of arsenic contaminated cattle dip sites near northeastern New South Wales. The samples contained relatively high level of As through anthropogenic contamination. Nine soil samples were obtained from a copper chrome arsenate contaminated site and arsenic concentration ranged from 52-138 mg kg^{-1}.

Moslehuddin *et al.* (1998) carried out a survey to the heavy metal pollution of roadside soils of Bangladesh. Accumulation of Pb, Cd, Cr and Zn in roadside soils along Dhaka-Mymesingh highway, possible due to the intensive traffic of vehicles. On the other hand, spoaradic high Pb accumulation was noticed in soils along Dhaka-Aricha, Dhaka-Chittagong and Dhaka- Mymensingh highways, which was ascribed to the industrial discharge.

Julustos *et al.* (1998) conducted a three year pot experiment in three different soils: sandy fluvisols (containing 4.4 mg As kg^{-1} and 0.36 mg Cd kg^{-1}) loamy greyzems soil (containing 16.70 mg As kg^{-1} and 17.56 mg Cd kg^{-1}) and sand loam luvisols (containing 49.50 mg As kg^{-1} and 0.60 mg Cd kg^{-1}) where carrots, spinach, radishes, oat and bean were grown. They found that the accumulation of As in soil in the order luvisols > fluvisols > greyzems.

Simon *et al.* (1998) conducted a pot experiment with different concentration of arsenic and nickel on radish cv. Rampouch. Tolerance limits were about 150-300 mg As kg^{-1} soil and 100 mg Cd kg^{-1} soil for radish growth. Soil microorganism's activity was also determined after crop harvest. Potential microbial respiration was inhibited at higher As and Cd concentrations.

Asami (1998) reported that sludged, irrigated or fertilizer farmland surface paddy soil contains 2.2 to 7.5 mg kg^{-1} Cd in Japan.

Bell *et al.* (1998) conducted a study on soil in Maryland which were amended in 1972 with dewatered, digested sludge containing 13 mg Cd, 280 mg Pb and 45 mg Ni kg^{-1} at 56, 112 or 224 t/ha. Total soil Pb and Cd content increased >3 fold and Extractable Cd in soils were increased >10 fold.

Ullah (1998) reported that arsenic concentration in Bangladesh soils ranged from 4-8 μg g^{-1}. However, in areas where irrigation was performed with arsenic contaminated ground water, soil As level can reach up to 83 μg g^{-1}.

Klose and Braun (1997) studied the arsenic content of soil and uptake of As by fodder crop, spring barley, potatoes, maize, winter rape, pasture grass and clover. The soil arsenic content of all the soils tested was over 50.0 mg kg^{-1} soil. In maize, rape, barley and potatoes, arsenic content ranged from 0.04 to 1.31 mg kg^{-1} dry matter when grown on soil containing 60-362 mg As kg^{-1} soils.

Willams *et al.* (1996) reported that sludged, irrigated or farmland surface soil contains 2.60 to 8.30 ppm Cd in the United States.

Gimeno-Garcia *et al.* (1996) investigated the incidence of heavy metals due to the application of inorganic fertilizers to rice field. They found that soil surface horizon contains 1.83, 45.96 mg kg^{-1} for Cd and Pb respectively.

Nuruzzaman (1995) had examined the arsenic status of industrial pollution soils around Dhaka city and reported a higher concentration of arsenic (>20 $\mu g\ g^{-1}$) in soils particularly near Tannery industry.

Barman and Lal (1994) conducted an experiment in industrially polluted field in Kalipur, West Bengal. They reported that the cadmium and lead concentrations of soil samples were 6.11±1.65 and 180.43±75.61 $\mu g\ g^{-1}$ soils, respectively.

Holmgren *et al.* (1993) conducted an experiment in polluted region of Slovenia. They reported that the cadmium concentration of leaves and carrot roots was high. The concentration of Pb in washed samples was lower compared to unwashed leaves indicating that cadmium was deposited on leaves by industrial emissions.

Holmgren *et al.* (1993) conducted an experiment on cadmium, lead in agricultural soils of the United States of America. They found that the value of surface soils for Pb, Zn and Cu in the major agricultural production areas of the USA are 10.60 mg kg^{-1}, 42.90 mg kg^{-1}, 18 mg kg^{-1}, respectively, within the range from <1 to 135 mg kg^{-1}, <3 to 264 mg kg^{-1}, 0.06 to 495 mg kg^{-1}, respectively.

Machelett *et al.* (1990) conducted trials on acid sandy soil at Berlin-Malchow. Potatoes-winter rye-(*Lolium multiflorum*) rotation was given 9 annual applications of totaling 26 or 52 ton sewage sludge DM or 296 ton dry sludge DM ha^{-1}. The dry bed sludge (50-70% DM) markedly increased soil Cd, Pb contents after 9 years and Cd contents exceed the permitted limit.

Holmgren *et al.* (1986) reported that the mean value for Cd in USA podzols and sandy soils, loamy and clay soils and brown soils were 0.21, 0.27 and 0.27 ppm respectively within the range of 0.08 to 0.47 ppm, 0.13 to 0.55 ppm, 0.05 to 0.71 ppm respectively.

Wiersma *et al.* (1986) found that the level of Cd, Pb, Hg and As in soils of Netharlands were 0.40, 23.0, 0.07 and 11.0 mg kg^{-1} of dry soil respectively.

Shacklette and Boemgen (1984) reported that the mean values for Pb in cited soils of USA are 27, 19 and 22 mg kg^{-1} respectively, within the range from <10-70, 10-30 and 10-70 mg kg^{-1} respectively.

2.2 Heavy metal concentration in manures and fertilizers

Orihara *et al.* (2002) investigated the content of heavy metals in the animal manure and compost produced in Kanagawa, Japan. A total of 112 cattle manure, composts, 32 pig manure composts and 83 poultry manure composts were used in the study. There were more micronutrients such as Zn, Cu and Mn in pig manure compost than cattle and poultry manure compost. Generally, there was little environmental pollution from heavy metals such as As, Cd, Hg, and Pb. In some compost, Zn, Cu, Mn and Pb were present in high concentration, and in particularly cattle manure compost exceeded maximum recommended standard for sludge fertilizer.

Sultana (2000) investigated on effect of intensive fertilization on heavy metal concentration in fertilizers. She found that 59.97 mg kg^{-1} Cd, 50.90

mg kg^{-1} Pb, 31.58 mg kg^{-1} Zn in TSP. In MP it was 2.52 mg kg^{-1} Cd and 37.80 mg kg^{-1} Pb.

Sultana Ahmed (1999) investigated the heavy metal concentration in sewage sludge collected from Pagla, Dhaka. She found that the concentrations of aqua regia extracted Cd, Pb and Zn in sewage sludge were 6.0, 157 and 698 mg kg^{-1}, respectively.

Alloway *et al.* (1988) found that the range of Cd and Pb concentrations in phosphate fertilizers were 0.10-170, 7.0-225 mg kg^{-1}, respectively.

Henkens (1983) reported that TSP (45% P_2O_5) contains 61-100 mg Cd kg^{-1} in Holland.

David and Willian (1973) reported that the Cd content in super phosphate (45% P_2O_5) was 84-106 mg kg^{-1} in Australia.

2.3 Heavy metal concentration in Groundwater

Rahman *et al.* (2013) assessed the daily consumption by adults of As in drinking water and home-grown vegetables in a severely As-contaminated area of Bangladesh. The median concentrations of As in vegetables were 90 μg kg^{-1}. Daily intakes of As from vegetables and drinking water for adults were 839 μg. Vegetables alone contribute 0.05 μg of As and 0.008 mg of body weight daily.

Jameel *et al.* (2012) conducted an experiment to evaluate the translocation of As by different vegetables grown in agricultural soil irrigated for long period with tube well water as test vegetable samples and compared those vegetables of same species grown in agricultural soil irrigated with fresh canal water marked as control vegetable samples. Moreover, the total and ethylenediamine-tetra acetic acid (EDTA) extractable contents of As in soil irrigated by tube well and canal water were determined and correlate with total concentrations of As in edible parts of vegetables. High level of total and EDTA extractable As were found in tested vegetable samples as compared to controlled vegetable samples. This investigation highlights the increased danger of growing vegetables in the agricultural land continuously irrigated by As contaminated water.

Abdullah *et al.* (2010) measured As concentrations in water, soil and arum (vegetables) samples using the Neutron Activation Analysis method and a correlation between As concentrations in the samples was investigated. As concentration of all the water samples ranged from 0.09 to 0.87 mg L^{-1}. The concentrations in soil and aurum samples were found to be in the range of 2.22- 35.21 and 0.07-0.73 mg kg-1, respectively. A positive correlation between As concentrations in soil and water samples was observed. Aurum sample was found to be contaminated by As to a harmful level if the corresponding water sample was also highly contaminated.

Islam *et al.* (2004) conducted an experiment to study the problems of contamination caused by As and other toxic metals in ground water, surface water and soils in the Bengal basin of Bangladesh. They reported that the concentration of As in ground water were very high compared with surface water and soil.

Chakraborti *et al.* (2003) conducted an experiment in West Bengal, India. The analyses of the arsenic content of 206 tube wells (95% of the total) showed 56.8% to exceed arsenic concentrations of 50 g/L with 19.9% > 300 g/L. the concentration predicting overt arsenical skin lesions.

Rahman *et al.* (2003) conducted a detailed study spanning 7 years in North 24-Parganas, one of the nine arsenic affected districts to understand the magnitude of the arsenic calamity in West Bengal and found that 29.2% of the tube-wells have arsenic above 50 $\mu g\ L^{-1}$. the maximum permissible limit of World Health Organization (WHO) and 52.8% have arsenic above 10 $\mu g\ L^{-1}$, WHO recommended value of arsenic in drinking water. From the generated data, it is estimated that about 2.0 million and 1.0 million people are drinking arsenic contaminated water above 10 $\mu g L^{-1}$ and 50 $\mu g\ L^{-1}$ level, respectively in North 24- Parganas alone. Due to use of arsenic contaminated groundwater for agricultural irrigation, rice and vegetable are getting arsenic contaminated.

Shrestha *et al.* (2003) reported that arsenic contamination of groundwater has been recognized as a public health problem in Nepal. So far, 15,000 tube wells has been tested where 23% samples exceeded World Health Organization guideline value of 10 $\mu g\ L^{-1}$ and 5% exceeded "Nepal Arsenic Guideline" of 50 $\mu g\ L^{-1}$. They estimated that the around 0.5 million people in Terai are living at risk of arsenic poisoning (>50 $\mu g\ L^{-1}$). Some recent studies have reported the prevalence of dermatosis related to arsenicosis from 1.3 to 5.1% and the accumulation of arsenic in biological samples like hair and nail much higher than the acceptable level.

Khatun (2002) collected a total of 45 shallow tubewell water samples from different villages of 10 unions of Faridpur Upazilla. She recorded the highest concentration of 216.50 ppb at Bilmamudpur village and the lowest. 13.22 ppb at Char-Madhobdia village and the highest and the mean arsenic oncentrations were about 4 and 2 times higher than the maximum permissible limit of drinking water (50 ppb), respectively.

Molla (2002) conducted an experiment in As contaminated four districts of Chapai-Nawabganj, Rajbari, Faridpur and Gopalganj and one partially As contamination free site of Mymensingh. Arsenic and other elements like Pb, Cd, Ca. Mg, S and Na were analyzed. He found that the As status of irrigation water of the selected As affected areas ranged between 0.10 to 2.0 mg As L^{-1} and soil As status ranged between 12.0 to 78.37 mg As kg^{-1} soil.

Farjood *et al.* (2001) conducted an experiment in Shiraz area in the South of Iran. They found that the inorganic and organic pollutants have been detected including As^{2+}, Cd^{2+}, Cr^{2+}, Fe^{2+}, Hg^{+} and Pb^{2+}. They showed that the concentrations of Cd^{2+}, Cr^{2+}, Fe^{2+}, Mn^{2+} and Pb^{2+} exceeded permissible values for crop production. In other areas, the concentrations were found to be within safety margins.

Khan *et al.* (2000) conducted an experiment to know the environmental impacts of groundwater abstraction in Barind area. They observed that out of 30 water samples collected from Bagmara Upazilla. Only three samples had As levels of 0.05, 0.19 and 0.35 mg L^{-1}, respectively. They also showed that among the samples of Mahadebpur Upazilla three samples responded to As test and the concentrations were 0. l, 0.5 and 0.5 mg L^{-1}, respectively.

Nizam *et al.* (2000) stated that out of 130 surface and groundwater samples collected from Madhupur tract, the content of arsenic (As) fluctuated within the limit of trace to 0.05 mg L^{-1}.

The groundwater in Bangladesh is heavily contaminated with arsenic IDPHE- BGS), (2000) and 40% of the mostly studies tube wells exceeded the Bangladesh Standard Limit (0.05 mg L^{-1}) whereas the permissible level of arsenic in drinking water is only 0.01 mg L^{-1} as per WHO recommendation (WHO, 1999).

Ali (1999) found that in Northern and Eastern Piedmont plains. As content of surface and groundwater samples was detected in trace amount (<0.05 mg L^{-1} As) and these waters might not be toxic for irrigation and drinking usages.

Ahmed *et al.* (1998) stated that arsenic concentration of groundwater has been found in Rajarampur village in the Nawabganj district of Bangladesh. Survey indicated that 1 1% of tube-well water had arsenic in the range of 0.01 to 0.05 mg L^{-1} and 29%, above maximum permissible limit of 0.05mg L^{-1}. None the water samples from tube-wells of < 60 ft depth showed arsenic levels above > 0.05 mg L^{-1}. Out of 13,452 samples 2562 samples contained more than 0.05 mg L^{-1} As.

Ahmed (1998) reported that a total of 13,452 water samples from tubewells were tested by field kits covering almost all over the country. Of these, 2,562 water samples had As content more than 0.05 mg L^{-1}.

Csanady *et al.* (1998) stated that, before 1984 the As content of piped water in Karcag, a town on the great plain of Hungary was between 0.096 and 0.13 mg L^{-1}, i.e. well over the hygienic limit value of 50 µg L^{-1} . Due to various interventions the arsenic content started to decrease from 1984 but a steady concentration. i.e. 50 µg L^{-1} could be reached in 1990.

Dhar *et al.* (1998) stated that ground water arsenic level exceeding the recommended value of WHO (0.01 mg L^{-1}) has been found in 52 districts out of total 64 districts in Bangladesh. They also stated that arsenic level was higher than maximum permissible limit (0.05 mg L^{-1}) in 41 districts out of 60 districts. They further stated that arsenic was found above 0.05 mg L^{-1} in 27 villages of Ramganj thana of Laxmipur district.

Mandal *et al.* (1998) showed that in eight districts of West Bengal, arsenic in ground water has been found above the maximum permissible limits, 0.05 mg L^{-1}. At present 61 blocks and 863 villages/wards of these districts by the side of the river Ganga are affected by As. The mean arsenic concentration in shallow water is 0.07 I mg L^{-1} in this area.

Sen (1997) reported that As pollution was not detected in all water samples collected from Tongi aquifer because the content of As was below 0.05 mg L^{-1}.

Shamsuzzman (1997) found the concentration of As in all water samples collected from Mithapukur Upazilla under the district of Rangpur was in trace quantities (<0.05 mg As L^{-1}) and these waters might not be toxic for irrigation and drinking purposes.

Klose *et al.* (1997) found that arsenic toxicity was not detected in some irrigated areas of Nawabganj where the concentration of As ion was below the recommended limits (< 0.05 mg L^{-1}).

Amin and Islam (1997) tested 1,987 water samples from 37 districts of Bangladesh and 475 samples were found to have arsenic > 0.05 mg L^{-1} and 243 samples between 0.01 and 0.05 mg L^{-1} and the rest samples had As level below 0.05 mg L^{-1}.

Dipankar Das *et al.* (1996) stated that As in groundwater above the WHO maximum permissible limit 0.05 mg L^{-1} was found in 6 districts of West Bengal.

Cabrera *et al.* (1995) reported that the range of Pb concentration in potable water, irrigation water and wastewater were 9.6-22.4, 6.30-103.7 and 10.0-63.5 μg L^{-1}, respectively.

Rahman (1993) reported that Cd, Mn, Zn and Cu contents of collected irrigation water of Shahzadpur sadar upazilla of Sirajgonj district from surface and ground surfaces ranged from 0.1-0.42, 0.03-0.064, 0.01-0.03 and 0.1-0.03 mg L^{-1}, respectively.

India, at present 37 administrative blocks by the side of the River Ganga and adjoining areas were affected by arsenic contamination with groundwater.

Quddus (1996) reported that the concentrations of the Pb, Mn, Cd and As in surface and ground water of Meherpur sadar thana ranged 16.3-20.4, 26.3-30.4, .8-1.4 and 7.7-11.4 mg L^{-1} respectively.

According to U.S. Environmental protection Agency (1985) the recommended concentration of As for drinking water is 0.01 mg L^{-1}, while the tolerance limit is 0.05 mg L^{-1}.

2.4 Heavy metal concentration in vegetables

Bergqvist *et al.* (2014) conducted an experiment to evaluate the accumulation and speciation of As in carrot, lettuce and spinach cultivated in soils with various As concentrations. They showed that the As accumulation was higher in plants cultivated in soil with higher As extractability.

Paul *et al.* (2014) investigated the effects of arsenic on radish in the pot (green house experiment), result revealed that length, fresh weight and dry weight of plant (edible part and leaf) was significantly (P<0.05) affected at higher concentration of As (≥40 mg kg-1) treatment. Chlorophyll a and chlorophyll b was significantly affected at >40 mg kg^{-1} As treated plant compared with control. Total soluble solids (TSS) and proline content in plant showed increasing trend at increasing concentration of As. About 70 µg of As g^{-1} of dry weight of edible part accumulate after 60 DAS at ≥ 40 to 80 mg kg^{-1}, it was more than leaf.

Bhatti *et al.* (2013) used a pot trial to determine the As uptake of four vegetable species (carrot, radish, spinach and tomato) with As irrigation levels ranging from 50 to 1000 µg L^{-1}. Only the 1000 µg As L^{-1} treatment showed a significant increase of As concentration in the vegetables over all other treatments ($P < 0.05$). The distribution of As in vegetable tissues was species dependent; As was mainly found in the roots of tomato and spinach, but accumulated in the leaves and skin of root crops. There was a higher concentration of As in the vegetables grown under flood irrigation relative to non-flood irrigation. The trend of As bioaccumulation was spinach > tomato > radish > carrot.

Norton *et al.* (2013) conducted a field study of locally grown fruits and vegetables from historically mined regions of southwest England (Cornwall and Devon). They found that the concentration of total As in potatoes, swedes, and carrots was lower in peeled produce compared to unpeeled produce. For baked potatoes, the concentration of total As in the skin was higher compared to the total As concentration of the potato flesh.

Halder (2013) investigated the risk of As exposure from staple diet to the communities in rural Bengal, even when they have been supplied with As safe drinking water. Among the vegetables generally consumed in rural villages, the accumulation of As was highest in the leafy type of vegetables (0.21 mg kg^{-1}), compared to non-leafy (0.07 mg kg^{-1}) and root vegetables (0.10 mg kg^{-1}). Arsenic (As) predominantly accumulates in rice (>90%) and vegetables (almost 100%) in inorganic species.

Rahaman *et al.* (2013) found the highest As concentration in potato (0.456 mg kg-1), followed by rice grain (0.429 mg kg^{-1}). The total mean As content (milligrams kg^{-1} dry weight) in cereals ranged from 0.121 to 0.429 mg kg^{-1}, in pulses and oilseeds ranged from 0.076 to 0.168 mg kg^{-1}, in tuber crops ranged from 0.243 to 0.456 mg kg^{-1}, in spices ranged from 0.031 to 0.175 mg kg^{-1}, in fruits ranged from 0.021 to 0.145 mg kg^{-1} and in vegetables ranged from 0.032 to 0.411 mg kg^{-1}, respectively.

Santra *et al.* (2013) studied As accumulation in different vegetables, they found that tuberous vegetables accumulated higher amount of As than leafy vegetables and leafy vegetables followed by fruity vegetable. The highest As accumulation was observed in potato, brinjal, arum, amaranth, radish, lady's finger, cauliflower whereas lower level of As accumulation was observed in beans, green chilli, tomato, bitter guard, lemon, turmeric.

Biswas *et al.* (2012) examined total As concentrations in 32 types of vegetables and 7 types of pulses. Range of total As concentration in edible parts of vegetables collected from grown fields was 0.114-0.910 mg kg^{-1}. Highest arsenic values were in spinach 0.910 mg kg^{-1}. Vegetable samples were grouped into leafy, non-leafy-fruity, root-tubers. Eighteen common types of vegetables and pulses were collected through market basket survey, total As were approximately 100 mg lower than those observed for the vegetables collected from the fields.

Islam *et al.* (2012) studied As accumulation pattern in eight types of vegetables commonly found in Bangladesh. They found that As accumulation decreased in the order: arum > arum leaf > amaranth > brinjal > radish > Indian spinach > carrot > okra. A single harvesting of 10 irrigations with water (3.0 L/irrigation) having arsenic concentrations of $\geq$0.45 mg L^{-1} to 0.071 m^2 area (equivalent to 1.89 kg As ha^{-1}) exceeded the maximum permissible limit in vegetables (1 mg kg^{-1}, wet weight).

Temmerman *et al.* (2012) carried out an experiment where root crops, carrot and celeriac, were exposed to atmospheric deposition in a polluted versus reference area. An effect was observed on the As, Cd and Pb concentrations of the leaves and the storage organs. As such the experiments allowed deriving regression equations, useful for modeling the atmospheric impact of trace elements on the edible parts of root crops.

Wright *et al.* (2012) determined the concentrations of nine residual metals in some Jamaican foods by using inductively coupled plasma mass spectrometry technique. They found that sweet potato had the highest concentrations of As (0.70 mg kg^{-1}), lead (0.31 mg kg^{-1}) and mercury (0.35 mg kg^{-1}). These results suggest that the elements were available in soluble forms in the soil for absorption by food crops.

Imtiaz *et al.* (2010) collected a total of 120 vegetable samples from five different markets of three different villages of Pabna district of Bangladesh and were tested for As concentration. They reported that the mean concentration of As in leafy vegetables (0.52 $\mu g\ g^{-1}$) was significantly higher compared to those found in fruity (0.422 $\mu g\ g^{-1}$) and root and tuber vegetables (0.486 $\mu g\ g^{-1}$).

Laizu (2007) collected a total 400 vegetable sample of 20 varieties of three categories from a local market of Dhaka city, Bangladesh. In case of As accumulation the fruiting vegetables, root and tuber vegetables (arum, arum loti, carrot, radish and potato) and leafy vegetables showed significant variation. In root and tuber vegetables, significant relationship was present in arum.

Alam *et al.* (2003) reported that the mean concentration of Pb in cabbage, cauliflower, tomato, potato, radish, lady's ringer, brinjal and bottle gourd were 0.53, 1.13, 3.0, 0.38, 0.09, 0.23, 0.08 and 0.23 $\mu g\ g^{-1}$,respectively. They also reported that the mean concentrations of Pb in cabbage, cauliflower, tomato, potato, radish, lady's linger, brinjal and bottle gourd were 0.53, 1.13, 3.0, 0.38, 0.29, 023, 0.08 and 0.23, $\mu g\ g^{-1}$, respectively.

Farid *et al.* (2003) conducted an experiment in both arsenic free and arsenic contaminated irrigation plots were analyzed for arsenic. Arsenic concentration (ppm) of different vegetables grown with arsenic containing irrigation water found in the descending order of amaranth (0.572) > china shak (0.539) > red amaranth (0.321) > katua data (0.284) > indian spinach (0.189) > chilli (0.112) > potato(0.103) > bitter gourd (0.049) > cabbage (0.072) > brinjal (0.049) > okra (0.04) > tomato (0.03) > cauliflower (0.011) and that for arsenic tree irrigation water were much lower and in the order of: china shak (0.278) > red arnaranth (0.163) > amaranth (0.139) > katua data (0.114) > chilli (0.103) > indian spinach (0.1) > potato (0.063) >

cabbage (0.055) > okra (0.031) > tomato (0.011) > cauliflower (0.001). Relationship between arsenic in irrigation water and the descending order of tomato (R^2= 0.986) > potato (R^2= 0.889) > red amaranth (R^2= 0.887) > katua data (R^2= 0.682).

Alam *et al.* (2003) conducted an experiment in Samta village in Jessore district of Bangladesh to see the arsenic level of various vegetables. They reported that the highest As concentrations of snake gourd, ghotkol, taro, green papaya, elephant foot, and bottle gourd leaf were 0.489, 0.440, 0.446, 0.389, 0.338, and 0.306 $\mu g\ g^{-1}$, respectively. Some vegetables such as bottle gourd leaf, ghotkol, taro and elephant foot had much higher concentrations of lead.

Tlustos *et al.* (2002) carried out a pot experiment and observed that highest accumulation of arsenic was found in spinach roots, mainly in secondary roots. Radish, carrot and green beans accumulated higher amount of As in roots than in above ground portion.

Cobb *et al.* (2000) conducted an experiment in mine wastes and in waste amended soils and found that tomato and beans contained As, Cd and Pb mainly in the roots and little was translocated to fruits. Lettuce leaves and radish roots accumulated significantly more than bean and tomato fruits.
Tlustos *et al.* (2002) have grown radish, carrots, spinach and green bean on unpolluted fluvisols, luvisols with elevated content of arsenic and Chernozem with high content of Cd. They reported that the highest content of As was accumulated in spinach grown in Luvisols. The highest Cd content was always found in vegetables grown on contaminated Chernozem

soil. Among the vegetables, the highest accumulation of As and Cd was found in leaves and roots of spinach.

Roychowdhury *et al.* (2002) conducted an experiment in arsenic affected area of West Bengal, India. They reported that the shallow, large diameter tube-wells installed for agricultural irrigation contain an appreciable amount of arsenic (mean 0.58 mg L^{-1}). They also found that the individual food composites and group food contained the highest arsenic levels (µg g^{-1}) were potato skin (0.293 and 0.104), leaf of vegetables (0.212 and 0.294), arum leaf (0.33 and 0.34), papaya (0.196 and 0.373), rice (0.226 and 0.245), wheat (0.007 and 0.362), cumin (0.478 and 0.209), turmeric powder (0.297 and 0.280), cereals and bakery goods (0.136 and 0.294). Other vegetables (0.092 and 0.123), spices (0.092 and 0.207), for the Jalangi and Domki blocks, respectively.

Bunzl *et al.* (2001) reported that the plant uptake of metals from slag-contaminated soils and studied the soil to plant transfer of arsenic, copper, lead, thallium, and zinc by the bean (*Phatseolus vulgaris* L.), knolkhol (*Brassica olearcea var. gongylodes* L.), lettuce (*Lactuca sativa*). carrot (*Daucas carrota* L.), from a control soil (Entisol) and from a contaminated soil (1:1 soil-slag mixture). As, Pb, Cu and Zn for all vegetables were significantly smaller than the corresponding plant-soil concentration ratios for the uncontaminated soil. The ability of a plant to accumulate a given metal as observed for a control soil might not exist for a soil- slag mixture and vice versa.

Mitev and Peycheva (1999) carried out an experiment to know the accumulation rate of arsenic in leaves of green beans and tomatoes from the soil having 0.0 to 50.0 mg kg^{-1} soil. They found that the concentration of arsenic in green bean were higher than tomatoes.

Carbonell-Barrachina *et al.* (1999) found inner root and outer skin concentration of more than 1 mg As kg^{-1} (above permissible limit) in turnip (*Brassica napus* L.).

Helgensen *et al.* (1998) reported that the soil to carrot uptake rate (bio availability) of arsenic was 0.47 ± 0.06% of the As content of soils having As concentrations of 6.5-338 mg kg^{-1}.

Moslehuddin *et al.* (1998) carried out 4 pot and 2 field experiments to evaluate the vegetables uptake of heavy metals from the application of zinc oxysulphate containing 20% Zn, 4.17 % Cd as Zn sources in red amaranth, sorghum, tomato and cabbage. Zinc was applied at the rate of 0,2,4 and 6 kg ha^{-1} in all eases. They reported that the edible portion take up more of Zn and lesser uptake of Cd and Pb. The highest uptake of Cd was found as 0.02, 0.016, 0.028 and 0.019 that of Pb were 0.40, 0.25, 2.80 and 2.10 mg kg^{-1} in case of red amaranth, sorghum, tomato and cabbage, respectively.

Li *et al.* (1998) conducted an experiment in greenhouse on cabbage to determine the accumulation of heavy metal from metal enriched sewage sludge compost. They found that the accumulation of Cu. Cd, Zn, Ni and Pb were higher where the higher rates of compost application.

Thomas *et al.* (1997) reported that the cadmium and lead content in some vegetables (potato, tomato, lettuce and cabbage) foodstuffs were in the range of 0.01-0.22 and 0.01-3.85 μg g^{-1}, respectively.

Barman and Lal (1996) conducted an experiment an industrially polluted field in Kalipur , West Bengal. They reported that the averages levels (and ranges) of metal bioaccumulation, irrespective of vegetables species, were 259.20 (40.0-530.0); 58.20 (9.0-93.0); 3.2 (1.0-0-8.0); 90.0 (27-245) $\mu g\ g^{-1}$ in dry weight for Zn, Cu, Cd and Pb, respectively.

O'Neill (1995) reported that the accumulation of arsenic in the edible parts of most plants was generally low. Organic arsenicals and As (III) were the most phototoxic for grass species in relation to plant growth. Arsenic uptake and translocation was species-specific and the phyto-availability of As concentration followed the trend of As (V) < As (III). Arsenic concentration in root and shoot was significantly increased with increasing As application rate regardless of the As chemical forms (Carbonell *et al.* 1999).

Carbonell-Barrachina *et al.* (1995) carried out a pot experiment by supplying different concentrations of As (0-10 mg L^{-1}) through irrigation water and found that the concentration of arsenic in tomato remained within 0.5 mg As kg^{-1}.

Venter (1993) conducted an experiment in five locations of Germany. They found that the lettuce and kohlrabi had higher contents of heavy metals (Pb, Cd. Zn. Cu, Cr, and Ni) than the spinach. Limits for toxic substances exceeded in some samples of lettuce and kohlrabi.

Low and Lee (1992) analyzed arsenic content of the edible parts of vegetables (onions, lettuces, tomatoes, spinach and various *Brassica sp.*) for arsenic concentration. The highest arsenic concentration (2.0 $\mu g\ g^{-1}$) was found in bean sprouts (*Phaseolus radiates*) and lowest (0.20 $\mu g\ g^{-1}$) in *Pachyrhizus erosus*.

Wiersma *et al.* (1986) collected and analyzed the cereals, fruits, fodder crops and vegetables from major growing areas in the Netherlands together with their corresponding soils. The Cd and Pd levels of cereals were high with respect to the proposed maximum acceptable concentrations. In lettuce and spinach relatively high Cd levels occurred, and fruits such as tomatoes, cucumbers and apples Cd level were low. The Pb level in curly kale was high. The soils had median values for As, Cd, Pb, Hg of 11.0, 0.4, 23.0 and 0.07 mg kg^{-1}, respectively.

Hibben *et al.* (1984) reported that a mean Pb concentration of 15.20 µg g^{-1}. in some vegetables of Spain and 4.61 µg g^{-1}, 3.80 µg g^{-1} and 1.24 µg g^{-1} in some vegetables of USA, Egypt and Netherlands, respectively.

Smiled *et al.* (1982) carried out field experiments to determine the yield and As accumulation by radish, lettuce, carrot, potato and wheat on soils having As concentration between 35 and 108 mg As kg^{-1} on dredged soil of the river Rhine and Meuse, UK. The highest level of arsenic accumulation in radish (Concentration ranging from U.8 to 21 mg As kg^{-1}). The order of decreasing arsenic accumulation was radish > lettuce > carrot > potato > spring wheat grain.

Chapter 3

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

The present study was conducted during the Rabi season of 2013-14 to determine the status of heavy metals in soils and vegetables of five intensively growing areas of Chandpur. The details of materials and methods for the study are presented in this chapter.

3.1 Location

Chandpur is one districts of Chittagong division lying between 23.2139^0 North latitudes and between 90.6361^0 East longitudes. The total area of the district is 1704.06 km^2 (657.94 sq. miles).

3.2 Climatic condition

Chandpur's climate is classified as tropical. In winter, there is much less rainfall than in summer. The temperature here averages 25.9°C. Precipitation here averages 2151 mm. Chandpur is generally marked with a typical monsoon climate with high temperature, considerable humidity and less rainfall. Precipitation is the lowest in January, with an average of 7 mm. Most precipitation falls in July, with an average of 445 mm. At an average temperature of 29.2°C, May is the hottest month of the year. In January, the average temperature is 19.3°C. It is the lowest average temperature of the whole year. Between the driest and wettest months, the difference in precipitation is 438 mm. The average temperatures vary during the year by 9.9°C. The average daily relative humidity for May is around 79%. According to the report of Meteorological Department, the hot season commences early in March and continues till the middle of June.

The highest mean temperature of about 32.9°C during the months of April-June. The minimum mean temperature of about 11°C is during January. Eighty percent of total rainfall occurs during the months of monsoon.

3.3 Soil

The region is under the AEZ 16 of "Middle Meghna River Floodplain". The region occupies unstable alluvial land within and adjoining Ganges and Meghna Rivers. It has irregular relief of broad and narrow ridge and depression. The area has complex mixture of calcareous sandy, silty and clayey alluvium. The general soil types predominantly include Calcareous Alluvium and Calcareous Brown Flood plain soils. Soils are low and medium low in organic matter and alkaline in reaction. General fertility level is medium with high CEC.

3.4 Site

The vegetables samples were collected from five intensively vegetable growing areas by the side of the road of comunicating Chandpur on medium low, low or very low lands. The selected vegetable growing areas were Karaia, Charbhairabi, Gazra, Tamta and Faridganj (Five unions of Chandpur district)

3.5 Collection of soil and vegetables sample

Soil samples were collected at a depth of 0-15 cm from eight fields of each location. The vegetable samples were collected from respective fields. Vegetables were collected at the stage of harvest by farmers and some vegetables were collected from the nearest local market. The growth stage for vegetable sample was more or less same. The surface of vegetables was washed with water to remove dusts adhering on the surface. The vegetable and soil samples were put into the individual polythene bag with definite marking and tagging and brought to lab and the vegetable samples were cut into small pieces and air-dried. Then the samples were brought to the Department of Botany, Jahangir Nagar University, Savar, Dhaka. In the laboratory, the dried vegetables were then oven dried at 65 °C for 48 hour. The samples were then ground using grinding mill and stored in plastic containers in the desiccator. Plant roots and other extraneous materials were removed from the collected soil samples, air-dried, ground and passed through 2-mesh sieve. The samples were kept in plastic containers.

3.6 Types of vegetables

The following 12 different types of vegetable were collected from five areas:

Table 1: List of the vegetables collected

SI No	Bengali Name	English Name	Scientific Name	Family Name
Leafy vegetable				
1	পালংশাক	Spinach	*Spinacia oleraceae*	Chenopodiaceae
2	লালশাক	Red amaranth	*Amaranthus tricolor*	Amanarthaceae
3	ডাটাশাক	Data Shak	*Amaranthus oleraseus*	Amanarthaceae
4	বাধাকপি	Cabbage	*Brassica oleracea var. capitata*	Cruciferae
Fruits				
5	টমেটো	Tomato	*Lycopersicon esculentum*	Solanaceae
6	বেগুন	Brinjal	*solanum melongena*	Solanaceae
7	ধুন্দল	Sponge gourd	*Luffa cylendrica*	Cucurbitaceae
8	লাউ	Bottle gourd	*Lagenaria vulgaris*	Cucurbitaceae
Roots and tubers				
9	আলু	Potato	*Solanum melongena*	Solanaceae
10	মুলা	Radish	*Raphanus sativus*	Cruciferae
11	পিয়াজ	Onion	*Allium cepa*	Alliaceae
12	রসুন	Garlic	*Allium sativum*	Alliaceae

3.7 Soil Analysis

Soil samples were analyzed for both physical and chemical characteristics. The soil samples were analyzed following the standard methods as follows:

3.7.1 Textural class

Mechanical analysis of soil was done by hydrometer method (Bouyoucos, 1962) and the textural class was determined by fitting the values for % sand, %silt and %clay to the Marshall's triangular co-ordinate following USDA system.

3.7.2 Soil pH

Soil pH was measured with the help of a glass electrode pH meter, the soil water ratio being maintained at 1:2.5 (Jackson, 1962).

3.7.3 Organic matter

Organic carbon in soil sample was determined volumetrically by wet oxidation method of Walkley and Black (1935). The organic matter content was calculated by multiplying the percent organic carbon by 1.73 (van Bemmelen factor).

3.7.4 Digestion of soil samples

The soil sample weighing 1.0 g was transferred into a dry clean digestion vessel. Five ml nitric acid (HNO_3) was added to the vessel and allowed to stand it for overnight with covering the vessel to vapor recovery device. The following day, the digestion vessel was placed on a heating block and was heated at a temperature slowly raised to 120^0 C for two hours. After cooling, 2 ml of hydrogen peroxide (H_2O_2) was added and kept for few minutes. Again, the vessel was heated at 120°C. Heating was momentarily stopped when the dense white fumes occurred and clean solution appeared. After which the volume was reduced to 3-4 ml. The digest was cooled, diluted to 50 ml with deionized water and filtered through Whatman No. 42 filter paper into plastic bottle.

3.7.5 Determination of total As, Pb and Cd

Total As content in soil was determined from the digest by flow ingestion hydride generator atomic absorption spectrophotometer with UNICAM Model No. 969 with a hydride generator assembly using matrix method standards. Total Pb and Cd were determined by using the AAS at 193.70, 217.00, 224.8, 213.90, 279.60 and 248.4 nm, respectively (Welsh *et al.* 1990).

3.8 Vegetables Analysis

3.8.1 Digestion of vegetables samples

A sub-sample weighing 0.5 g was transferred into a dry clean digestion vessel. Five ml of HNO_3 was added and the sample was allowed to stand for overnight under fume hood. The following day, the vessels were placed on a heating block and heated at a temperature slowly raised to 120 ^{O}C for two hours. After cooling, 2 ml of hydrogen peroxide (H_2O_2) was added and kept for few minutes. Again, the vessel was heated at 120°C. Heating was continued until clear solution appeared. After which the volume was reduced to 3-4 ml. The digest was cooled, diluted to 50 ml with deionized water and filtered through Whatman No. 42 filter paper into plastic bottle.

3.8.2 Determination of As, Pb and Cd

The elements As Pb and Cd the digest were determined by the same method as described in the soil analysis section (3.7.5).

3.8.3 Statistical Analysis

Range, mean and standard deviation of the contents of heavy metals of soils and vegetables were calculated. Correlation statistics was done to examine the interrelationship among the heavy metals with soil pH, organic matter and texture.

Chapter 4
Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

In this chapter, the results on the status of As, Pb and Cd in soils and vegetables collected from five intensively vegetable growing areas of Chandpur are presented and discussed.

4. l. Soil characteristics

The soils of the five sites of Chandpur were Loamy, Grey loam and Grey dark loam in texture. All the soils of the Karaia, Tamta and Faridganj were loamy in texture. In Charbhairabi site, only one soil was dark grey loam and the rest were loamy in texture. In Gazra site, one soil was grey loam, another was dark grey loam and the rest were loamy in texture (Table 2).

Results presented in Table 2 showed that all the soils were alkaline in reactions. The soil pH values ranged from 7.4 to 8.1. The high pH of the soils was due to presence of calcite and dolomite minerals in soils. The variation in soil pH in different soils is mainly due to degree of decalcification and losses of carbonate minerals from the topsoil to the subsoil (Brammer, 1996).

Organic matter status of the soils varied widely, ranging between 0.7 and 2.4% with a mean value of 1.7% (Table 2). The variation in soil organic matter may be due to variation in organic matter addition through FYM, poultry manure and green manuring practices. Besides, the intensity of the land use and use of fertilizers might have played an important role in organic matter status of soils. In general the soils of Bangladesh are low in organic matter (BARC 1997).

4.2. Status of Heavy Metals in Soil

4.2.1. Status of Arsenic (As)

There was a wide variation in the levels of As in soils of the five locations (Table 3). Arsenic status of the soils ranged from 4.3 to15.2 μg g^{-1} with a mean of value of 8.80 μg g^{-1} (Table 3). The soil As status varied widely among soils of a particular site. The range of As concentration in Karaia, Charbhairabi, Gazra, Tamta and Faridganj sites were from 7.7-11.6, 5.8-10.3, 7.0-9.6, 7.6-15.2 and 4.3-14.1 μg g^{-1},respectively. The As status of the soils was negatively correlated with sand ($r = -0.149^{ns}$) (Fig. 1) and silt ($r = -0.182^{ns}$) (Fig. 2) and positively correlated with clay content ($r = 0.497^{**}$) (Fig. 3). The As status of soil was also positively correlated with soil pH ($r = 0.217^{ns}$) (Fig. 4) but negatively with organic matter ($r = -0.161^{ns}$) (Fig. 5). None of the soils of the study sites had arsenic level more than 20μg g^{-1}, the maximum acceptable limit for agricultural soils (Kabata-Pendias and Pendis 2001). Islam *et al.* (2004) studied the As status of five districts of Meghna River Floodplain that As levels ranged front 2.09-11.37 μg g^{-1} which is inline of the present study.

Table 2. Soil pH and soil separates, textural class status of soils of Chandpur

Sampling site	Sample No	Sand (%)	Silt (%)	Clay (%)	Textural class	Soil pH	Organic matter (%)
Karaia	K_1	29.0	44.0	27.0	Loamy	7.9	2.2
	K_2	33.0	40.0	27.0	Loamy	8.1	2.2
	K_3	34.0	37.0	29.0	Loamy	7.9	1.8
	K_4	32.2	34.0	33.8	Loamy	7.9	2.3
	K_5	40.2	30.0	29.8	Loamy	7.6	1.0
	K_6	37.2	35.0	27.8	Loamy	7.9	2.4
	K_7	36.0	33.0	31.0	Loamy	8.0	2.2
	K_8	32.0	39.0	29.0	Loamy	7.9	1.9
Charbhairabi	C_1	27.2	35.0	37.8	Loamy	7.5	1.2
	C_2	36.2	38.0	25.8	Loamy	7.8	0.7
	C_3	43.0	32.0	25.0	Loamy	7.8	1.7
	C_4	31.0	34.0	35.0	Loamy	8.0	2.1
	C_5	38.2	30.0	31.8	Loamy	7.4	1.5
	C_6	37.0	36.0	27.0	Dark grey loam	7.4	2.2
	C_7	38.2	32.0	29.8	Loamy	8.0	1.7
	C_8	40.0	37.0	23.0	Loamy	8.1	2.2
Gazra	G_1	33.0	34.0	33.0	Dark grey loam	7.9	1.4
	G_2	29.6	36.0	34.4	Loamy	8.1	0.8
	G_3	24.3	39.0	36.7	Loamy	8.0	1.7
	G_4	31.2	39.0	29.8	Loamy	7.8	1.5
	G_5	44.6	30.0	25.4	Loamy	8.0	1.4
	G_6	38.2	35.0	26.8	Grey loam	7.9	1.3
	G_7	36.9	32.0	31.1	Loamy	7.4	1.8
	G_8	36.0	37.0	27.0	Loamy	8.1	2.0
Tamta	T_1	47.0	28.0	25.0	Loamy	7.7	1.4
	T_2	35.1	33.0	31.9	Loamy	7.8	1.3
	T_3	32.3	36.0	31.7	Loamy	7.8	1.2
	T_4	37.1	31.0	31.9	Loamy	8.0	1.2
	T_5	34.3	30.0	35.7	Loamy	7.9	1.7
	T_6	29.2	36.0	34.8	Loamy	7.9	1.2
	T_7	46.0	29.0	25.0	Loamy	8.0	1.8
	T_8	42.0	34.0	24.0	Loamy	7.9	1.0
Faridganj	F_1	44.2	34.0	21.8	Loamy	8.1	1.5
	F_2	44.2	28.0	27.8	Loamy	7.8	2.4
	F_3	40.2	32.0	27.8	Loamy	7.6	2.1
	F_4	37.2	35.0	27.8	Loamy	7.5	1.9
	F_5	40.2	30.0	29.8	Loamy	7.9	1.3
	F_6	28.2	32.0	39.8	Loamy	7.9	2.4
	F_7	44.2	30.0	25.8	Loamy	7.8	2.3
	F_8	50.2	20.0	29.8	Loamy	8.1	1.7

Table 3. Total concentration of As, Pb & Cd of the soils of Chandpur

Sampling site	Sample No	As ($\mu g\ g^{-1}$)	Pb ($\mu g\ g^{-1}$)	Cd ($\mu g\ g^{-1}$)
Karaia	K_1	7.9	15.3	0.6
	K_2	9.6	13.6	0.5
	K_3	9.8	14.3	0.8
	K_4	11.6	17.3	0.8
	K_5	7.7	14.6	0.7
	K_6	8.9	16.3	0.8
	K_7	8.6	17.3	0.9
	K_8	7.9	20.7	0.8
Charbhairabi	C_1	7.7	20.7	0.8
	C_2	8.4	16.4	0.6
	C_3	10.3	14.6	0.6
	C_4	10.0	15.8	0.8
	C_5	5.8	19.3	0.7
	C_6	7.0	16.3	0.9
	C_7	6.3	16.8	0.6
	C_8	6.7	12.2	0.4
Gazra	G_1	9.6	16.0	0.6
	G_2	9.2	18.3	0.6
	G_3	9.2	16.1	0.7
	G_4	8.6	16.7	0.7
	G_5	6.4	17.4	0.6
	G_6	7.3	11.4	0.2
	G_7	8.2	14.4	0.6
	G_8	7.0	17.1	0.8
Tamta	T_1	14.7	14.8	0.2
	T_2	9.1	15.7	0.1
	T_3	7.6	16.2	0.1
	T_4	10.3	14.1	0.2
	T_5	13.3	17.1	0.1
	T_6	15.2	17.7	0.1
	T_7	9.6	18.3	0.3
	T_8	7.9	17.3	0.2
Faridganj	F_1	4.9	12.3	0.3
	F_2	4.3	17.5	0.3
	F_3	5.3	18.0	0.9
	F_4	5.8	14.5	0.4
	F_5	14.1	15.3	0.4
	F_6	11.9	16.0	0.4
	F_7	6.3	18.7	0.4
	F_8	12.1	17.3	0.5
Range		4.3-15.2	11.4-20.7	0.1- 0.9
Mean		8.80	16.24	0.53
Standard deviation		2.68	2.18	0.26
Max Permissible limit		20	100	5

Ref: Maximum permissible limit in agricultural soils (Kabata-Pendias and Pendias, 2001)

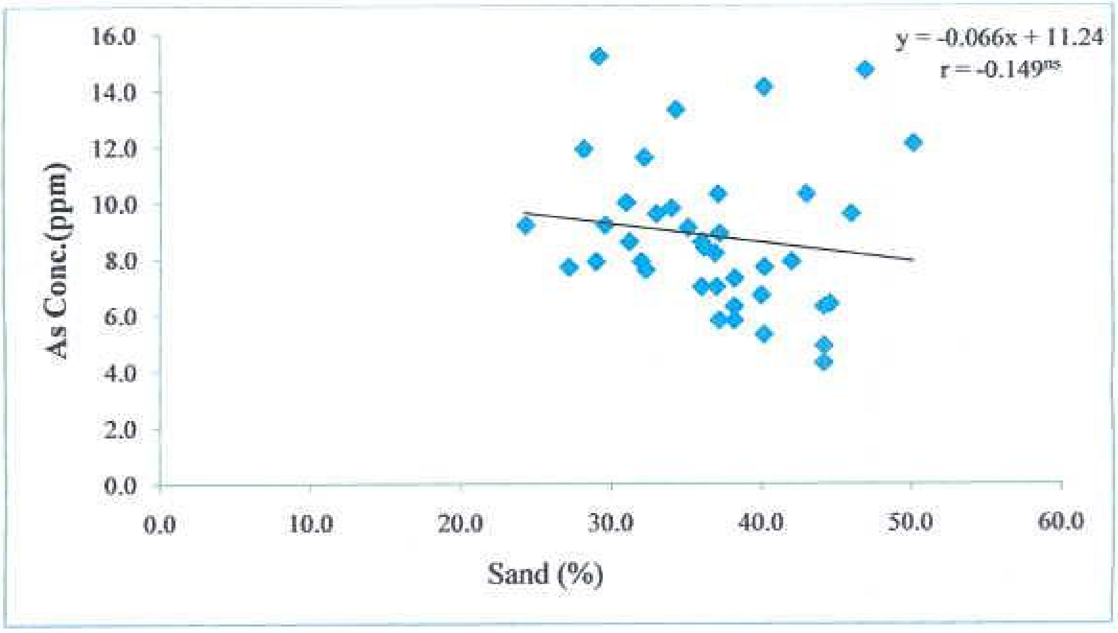

Fig. 1: Relationship of As contents with soil particles (Sand %)

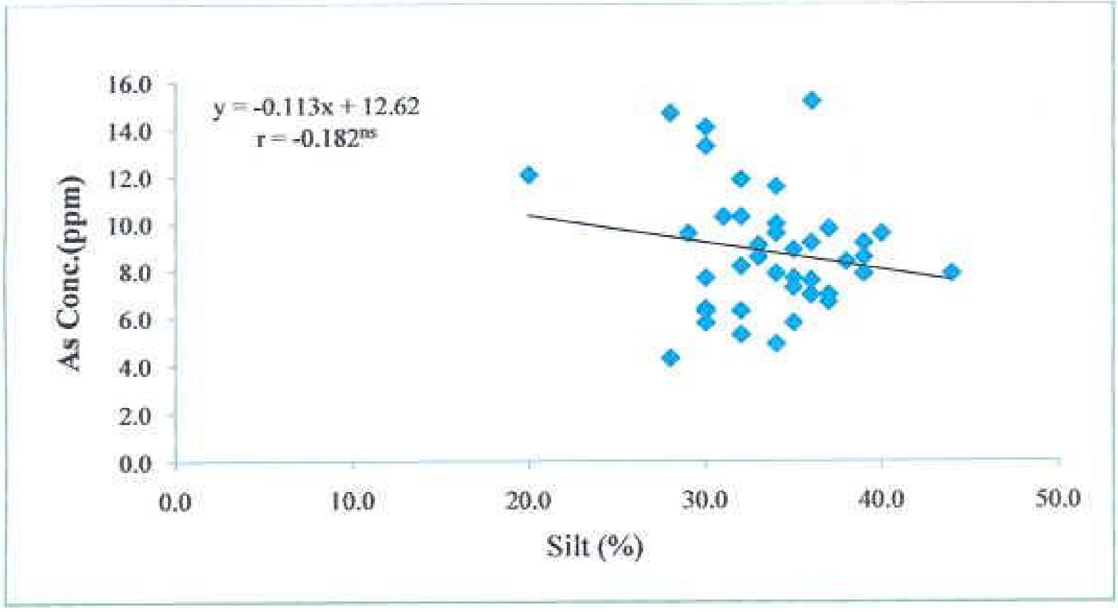

Fig. 2: Relationship of As contents with soil particles (Silt %)

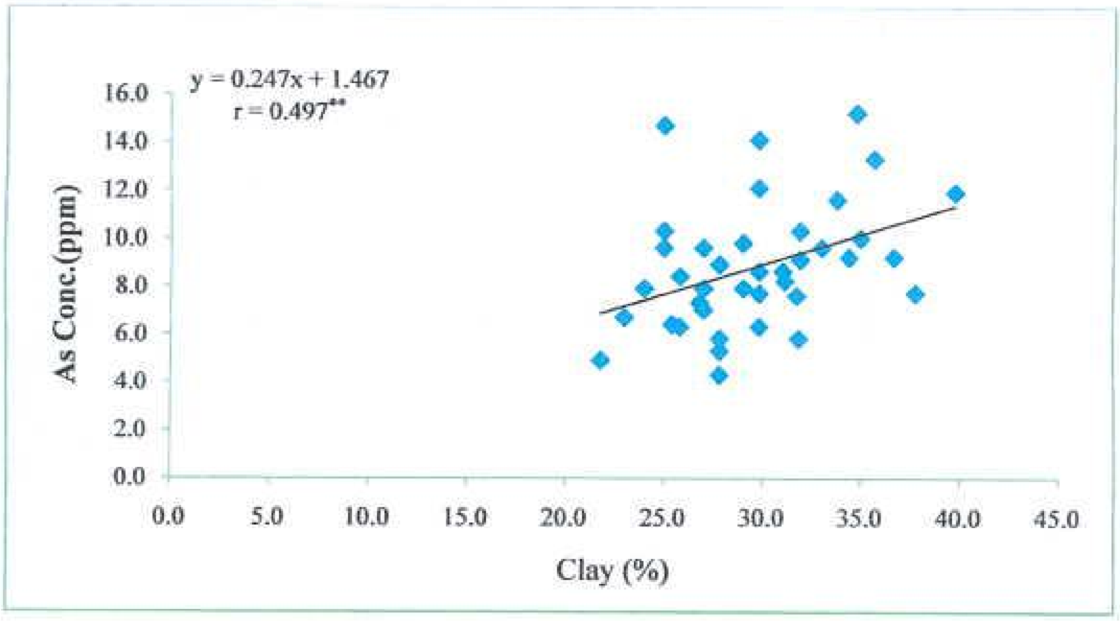

Fig. 3: Relationship of As contents with soil particles (Clay %)

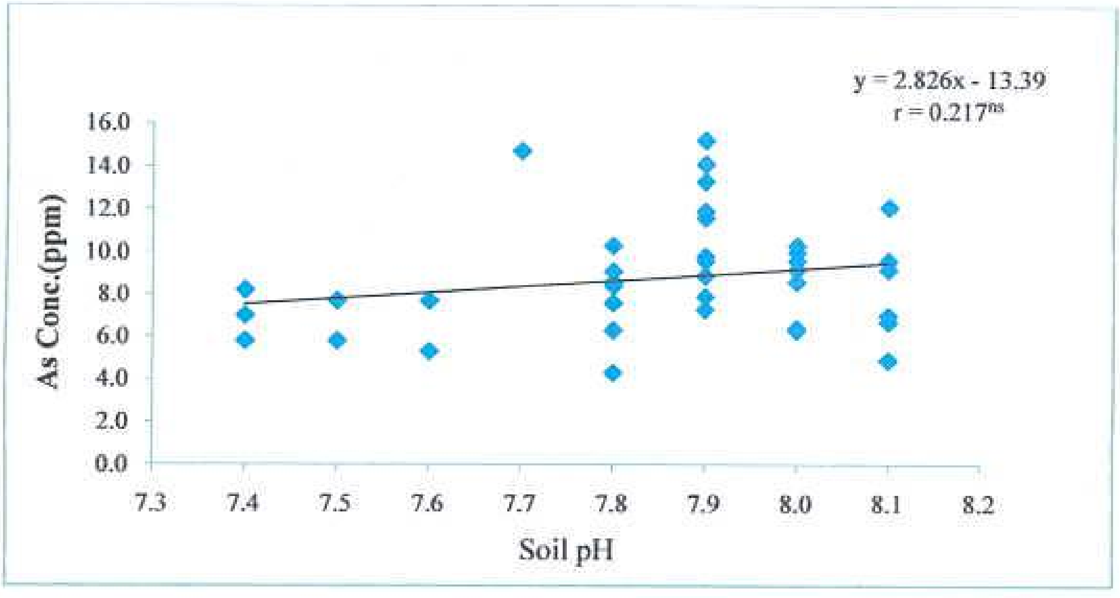

Fig. 4: Relationship of As concentrations with soil pH

Jahiruddin *et al.* (2003) studied the As levels of twenty calcareous and 20 non-calcareous soils of Bangladesh. They reported that the mean As levels of calcareous soils was 17 μg g^{-1} while for non-calcareous soils was 7.65 μg g^{-1}. Based on a review on As concentration in soils, American soils

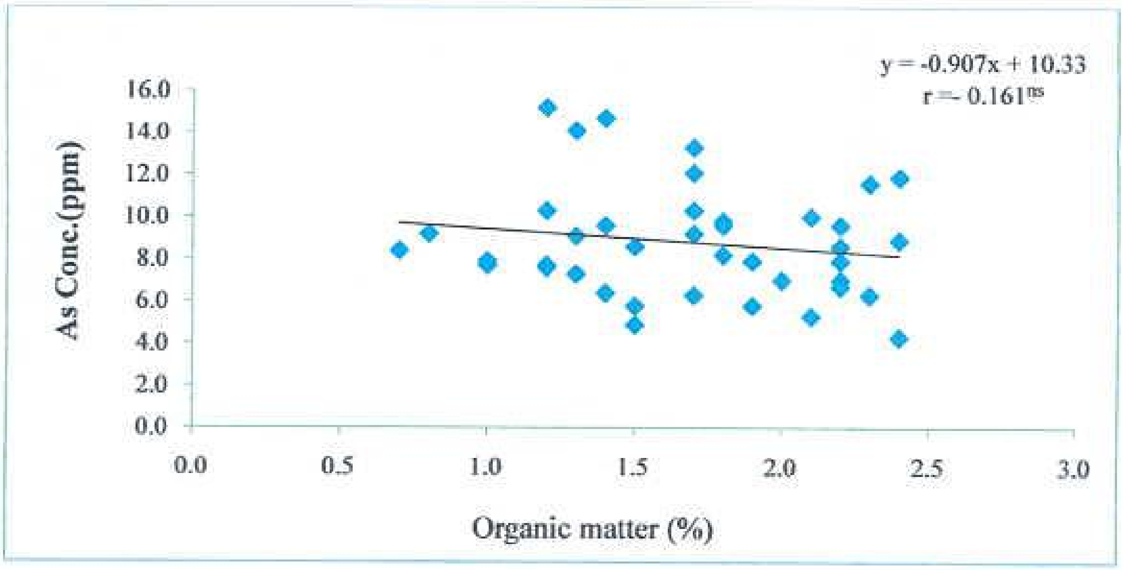

Fig. 5: Relationship of As concentrations with soil organic matter

seldom contained more than 10 μg g^{-1} As, while in the Canadian soils the level generally did not exceed 15 μg g^{-1} and in Australian soils 0.6-3.9 μgg^{-1} (Smith *et al.* 1998).

4.2.2. Status of Lead (Pb)

Results presented in Table 3 showed that the status of Pb in soils varied among the locations as well as within the fields of a particular location. The status of lead in soil ranged between 11.4-20.7 μg g^{-1}, having an average value of 16.24 μg g^{-1}. The range of Pb in soils of Karaia, Charbhairabi, Gazra, Tamta and Faridganj were 13.6-20.7, 12.2-20.7, 11.4-18.3, 14.1-18.3, 12.3- 18.7, μg g^{-1}, respectively. The Pb status in soils was negatively correlated with sand ($r = -0.141^{ns}$) (Fig. 6) and silt($r = -0.134^{ns}$) (Fig. 7) contents but positively correlated with clay content($r = 0.338^{*}$)

(Fig. 8). The Pb concentration in the soils was weakly correlated with soil pH (r = -0.127^{ns}) (Fig. 9) and organic matter (r = - 0.114^{ns}) (Fig. 10). The

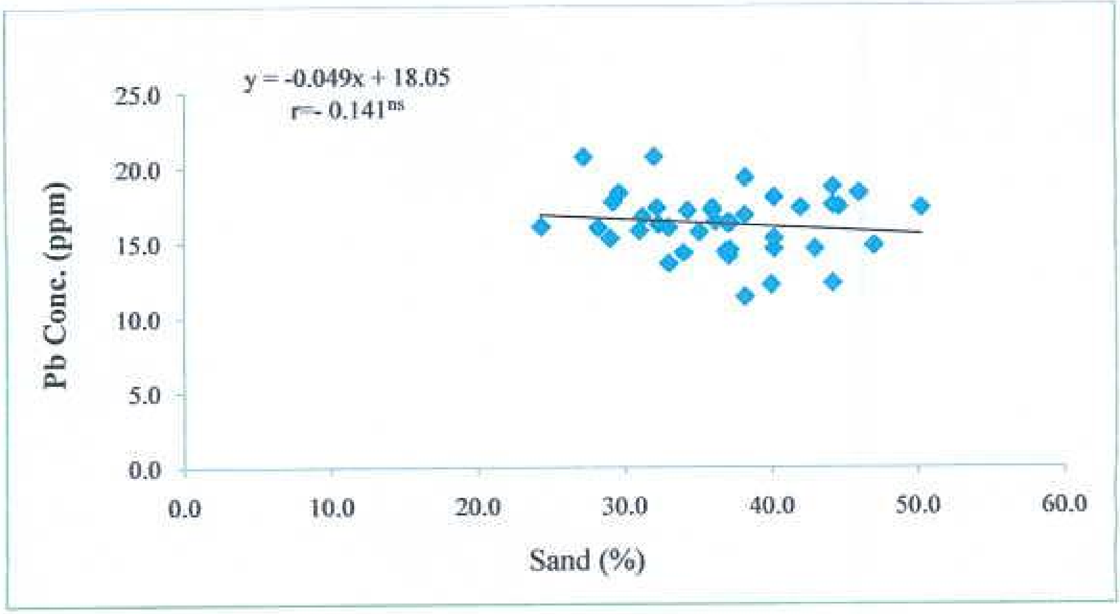

Fig. 6: Relationship of Pb contents with soil particles (Sand %)

observed status of lead in soil was lower than maximum acceptable concentration of 50 μg g^{-1} for crop production (Kabata- Pendias and Pendias, 2001). Others also reported similar results in soils of Bangladesh (Bibi *et al.,* 2003, Jahiruddin *et al*., 2003). Bibi *et al.* (2003) reported that Pb concentration of soils of different depths of Bangladesh ranged 19-24 μg g^{-1}. Jahiruddin *et al.* (2003) reported that the range of Pb content of 20 calcareous soils ranged from 17.8-26.8 μg g^{-1} with a mean value of 22.8 μg g^{-1}.

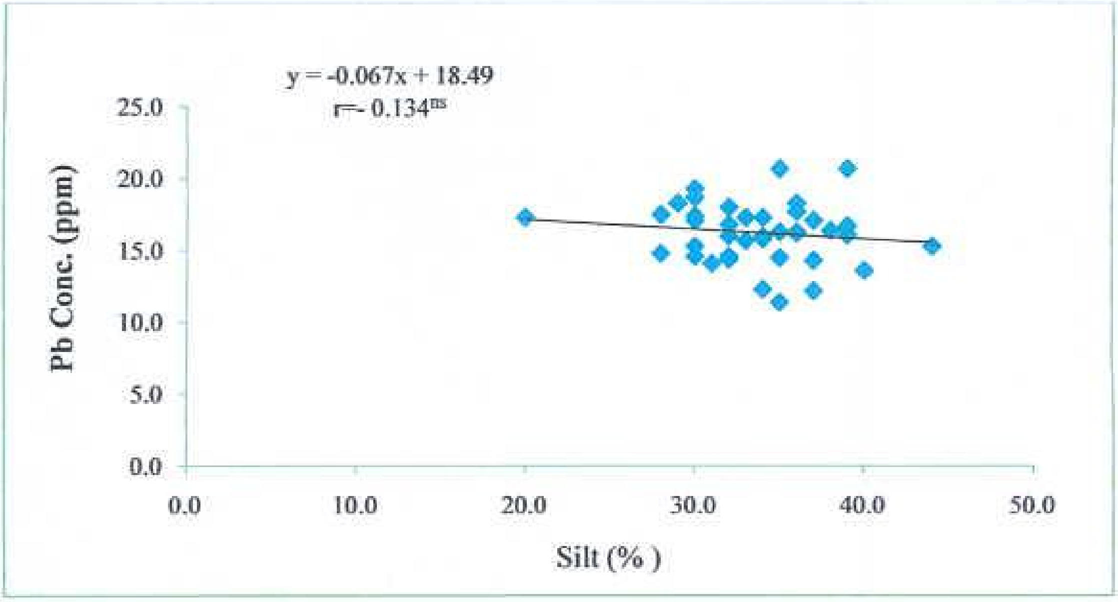

Fig. 7: Relationship of Pb contents with soil particles (Silt %)

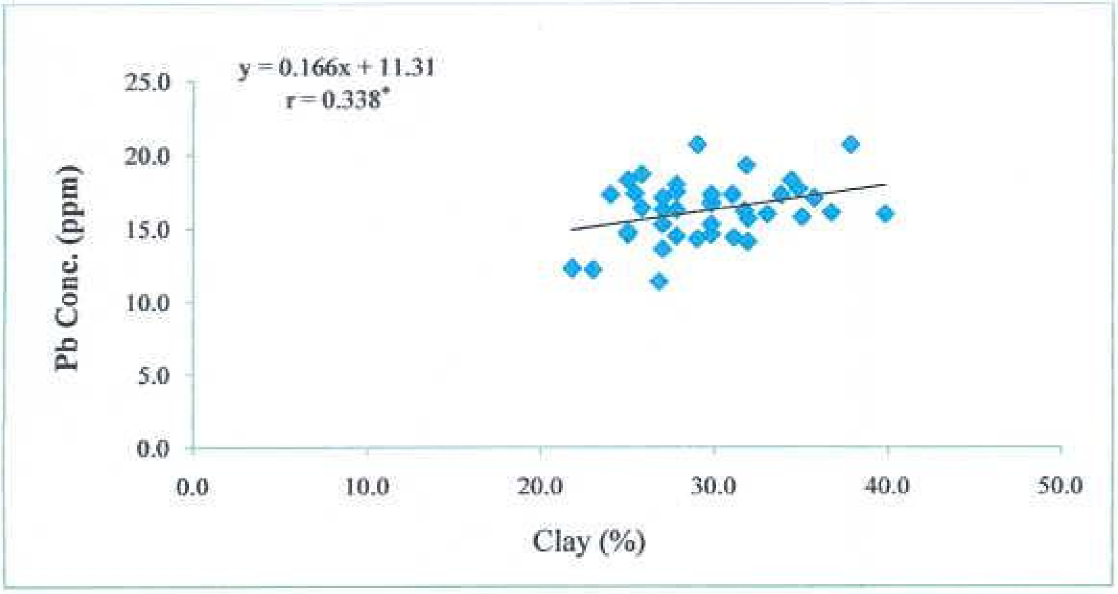

Fig. 8: Relationship of Pb contents with soil particles (Clay %)

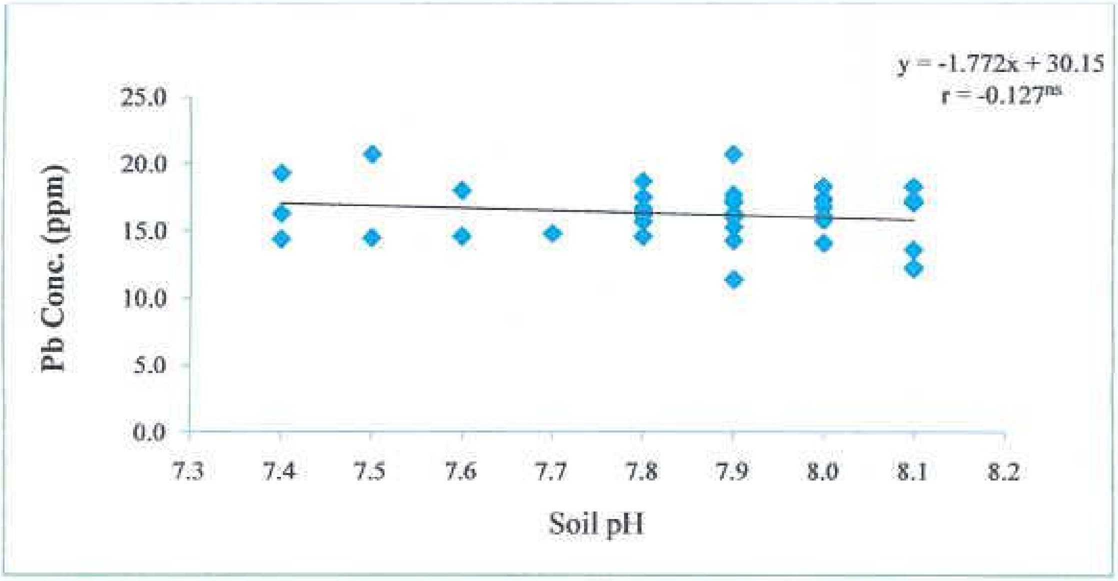

Fig. 9: Relationship of Pb concentrations with soil pH

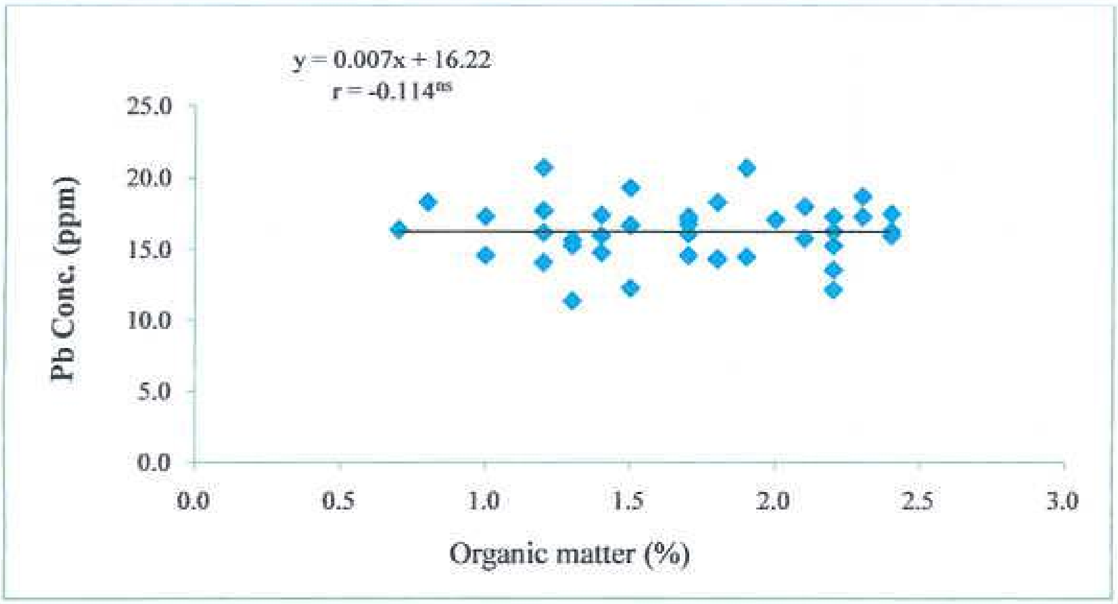

Fig. 10: Relationship of Pb concentrations with soil organic matter

4.2.3. Status of Cadmium (Cd)

There was wide variation in Cd status of soils among the five command areas of Chandpur (Table 3). The level of Cd in soils ranged 0.1-0.9 µg g^{-1} having an average value of 0.53 µg g^{-1}. The range of Cd in soils of Karaia, Charbhairabi, Gazra, Tamta and Faridganj sites were 0.5-0.9, 0.4-0.9, 0.2-0.8, 0.1-0.8, 0.3-0.9 µg g^{-1}, respectively.

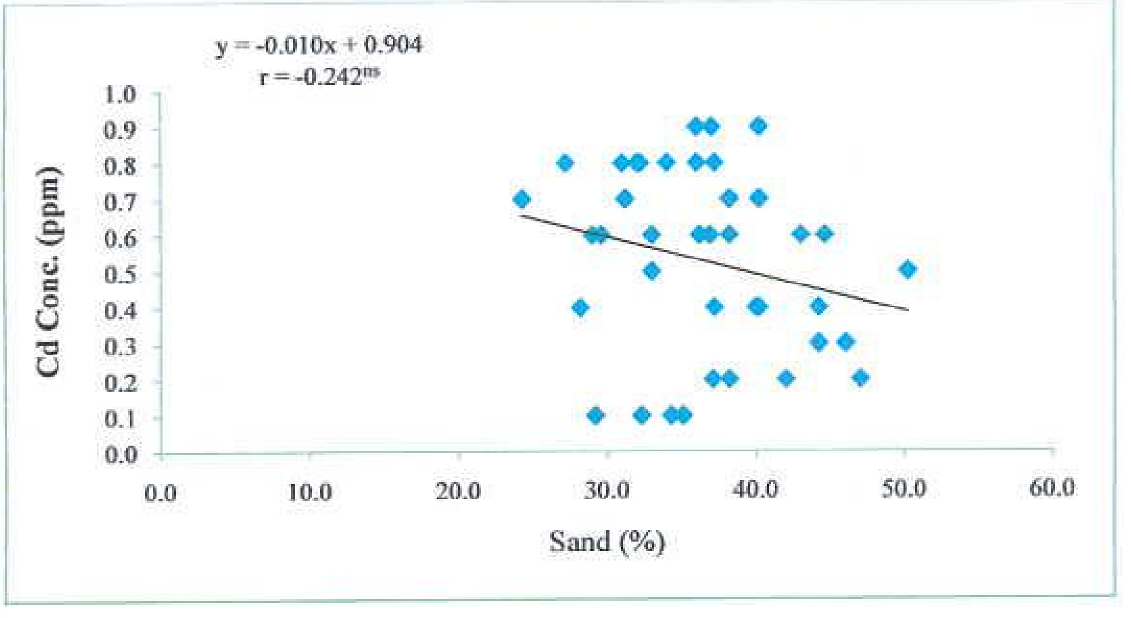

Fig. 11: Relationship between Cd contents with soil particles (Sand %)

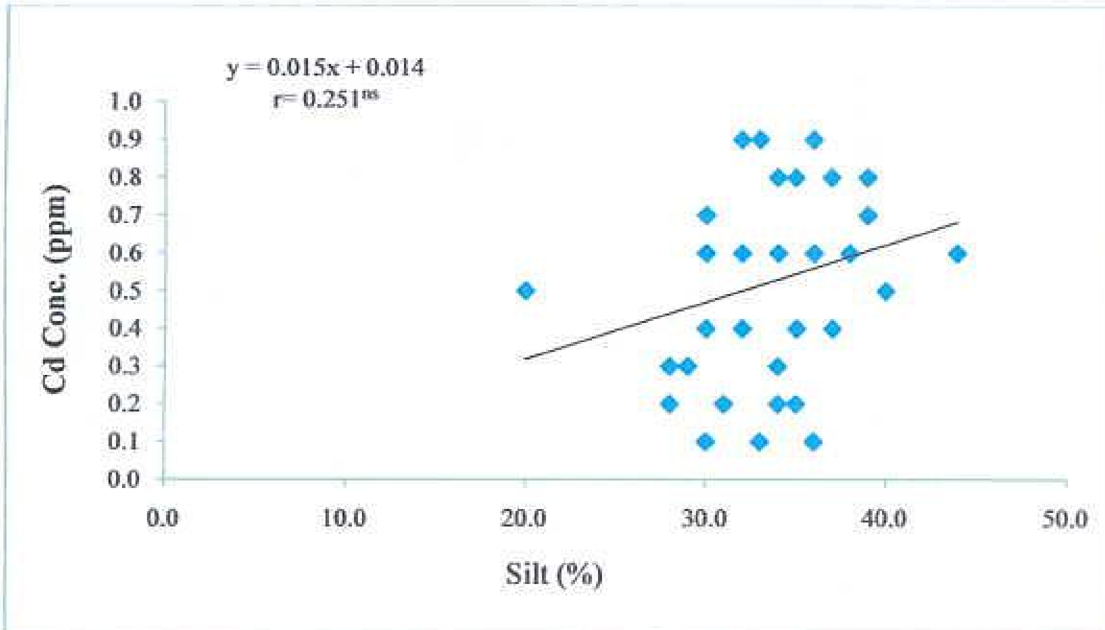

Fig. 12: Relationship between Cd contents with soil particles (Silt %)

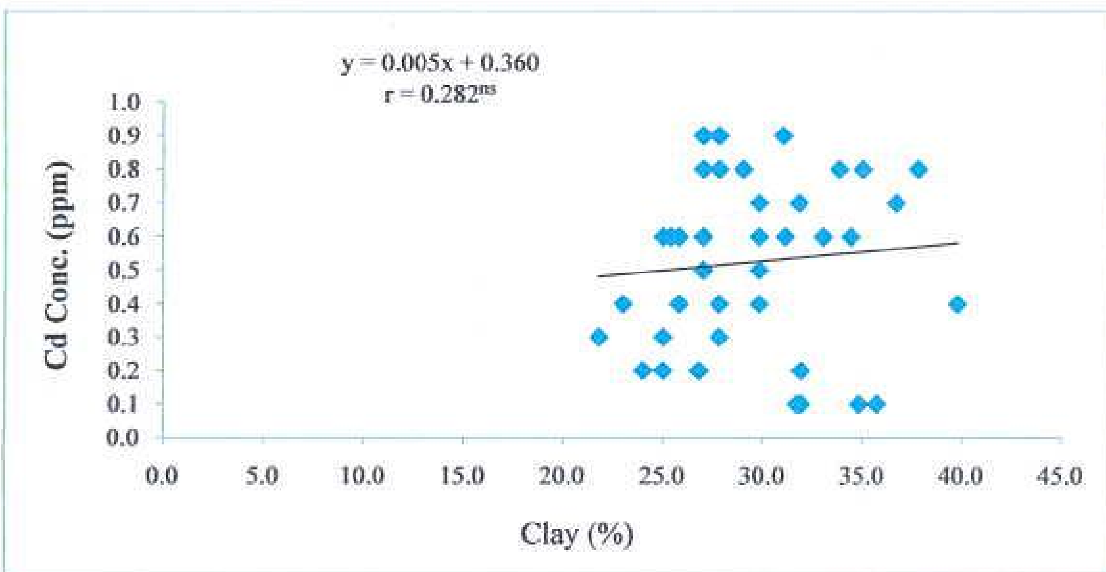

Fig. 13: Relationship between Cd contents with soil particles (Clay %)

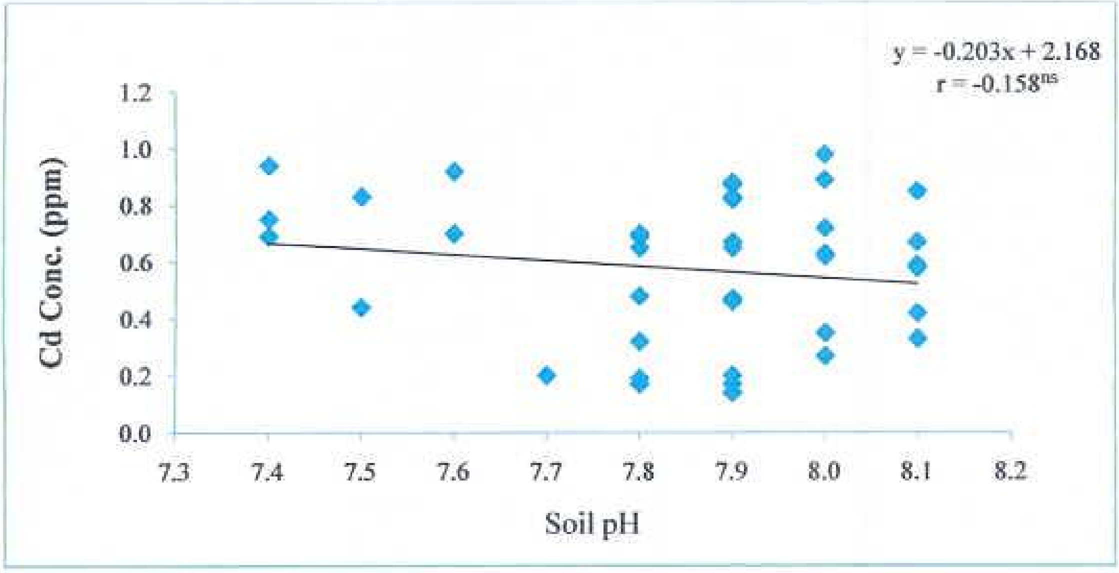

Fig. 14: Relationship of Cd concentrations with soil pH

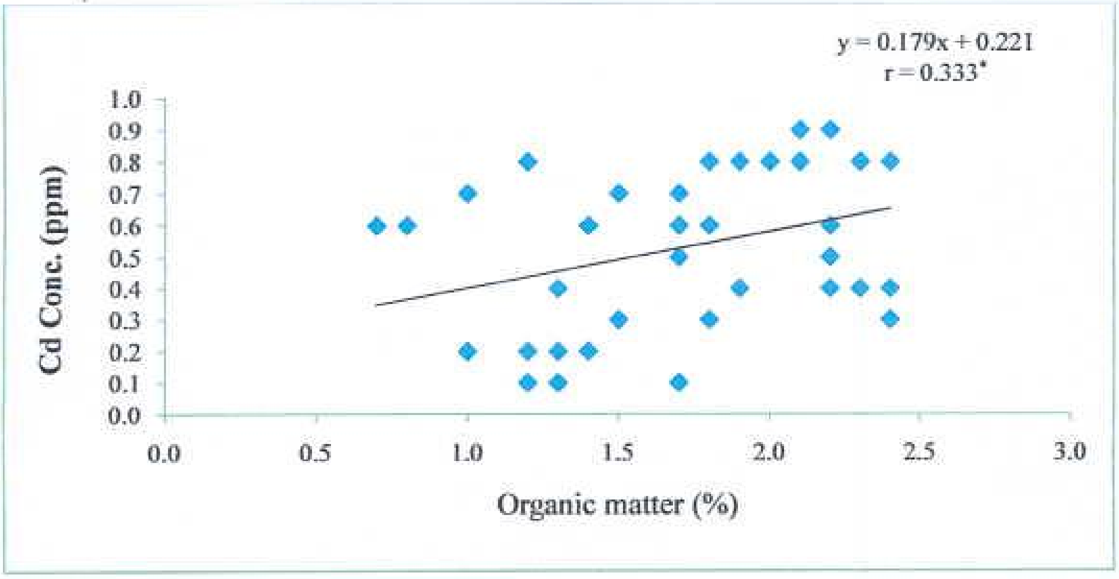

Fig. 15: Relationship of Cd concentrations with soil organic matter

Cadmium status of soils was negatively correlated with sand ($r = -0.242^{ns}$) (Fig. 11) but positively with silt ($r = 0.251^{ns}$) (Fig. 12) and clay (r =

0.282^{ns}) (Fig. 13). Cadmium status in soils was also negatively correlated with soil pH ($r = - 0.158^{ns}$) (Fig. 14) but positively with organic matter ($r = 0.333^{*}$) content (Fig. 15). The observed level of Cd in soil was less than the maximum acceptance concentration (MAC) of 5 $\mu g\ g^{-1}$ for food crop production (NSWEPA, 1994). Roychowdhury *et al.* (2002) carried out an experiment on arsenic affected area of Murshidabad in West Bengal, India. They reported that the mean concentration of Cd was 0.37 $\mu g\ g^{-1}$ in the fallow land soils. Mantylahti and Laakso (2002) reported that the median concentration of Cd in mineral and organic soils were 0.034 and 0.265 $\mu g\ g^{-1}$, respectively. Barman and Lal (1994) found that the Cd concentration of the industrially polluted soils were 6.11±1 .65 $\mu g\ g^{-1}$ of West Bengal, India.

4.3 Heavy Metal Levels in Vegetables

4.3.1. Arsenic Concentration (As)

There was wide variation in As concentrations of different types of vegetables collected from five sites of Chandpur (Table 4). The mean As concentrations of the vegetables ranged from 0.31 $\mu g\ g^{-1}$ in both bottle gourd and garlic to 0.81 $\mu g\ g^{-1}$ in cabbage. There was also wide variation in As concentration even in a particular vegetable collected from different fields of a particular site. For example, the As concentrations of data shak was in the range 0.21 to 0.97 $\mu g\ g^{-1}$ with a mean value of 0.51 $\mu g\ g^{-1}$. The mean As concentrations of leafy vegetables ranged from 0.51 $\mu g\ g^{-1}$ in data shak to 0.81 $\mu g\ g^{-1}$ in cabbage. Among the fruity vegetables, the mean As concentration ranged from 0.31 $\mu g\ g^{-1}$ in bottle gourd to 0.75 $\mu g\ g^{-1}$ in tomato while in case of root and tuber crops it ranged from 0.31 $\mu g\ g^{-1}$ in garlic to 0.75 $\mu g\ g^{-1}$ in radish. The vegetables can be arranged in descending order of As concentrations ($\mu g\ g^{-1}$) as: Cabbage (0·81) > radish (0.75) > tomato (0.75) > sponge gourd (0.71) > spinach (0.67) > brinjal (0.61) > red amaranth (0.53) > data shak (0.51) > potato (0.49) > onion (0.45) > garlic (0.31) > bottle gourd (0.31).

Table 4. Arsenic concentration (dry weight basis) in different vegetables collected from Chandpur district

SL. No	Name of Vegetable	As Concentration (µg g^{-1})			
		Range		Mean	Std. Dev
		Min	Max		
Leafy vegetable					
1.	Spinach	0.65	0.85	0.67	0.052
2.	Red amaranth	0.33	0.78	0.53	0.128
3.	Data Shak	0.21	0.97	0.51	0.117
4.	Cabbage	0.63	0.90	0.81	0.143
Fruits					
5.	Tomato	0.58	0.80	0.75	0.108
6.	Brinjal	0.33	0.72	0.61	0.184
7.	Sponge gourd	0.46	0.78	0.71	0.156
8.	Bottle gourd	0.27	0.41	0.31	0.076
Roots and tubers					
9.	Potato	0.56	0.60	0.49	0.135
10.	Radish	0.65	0.78	0.75	0.089
11.	Onion	0.31	0.56	0.45	0.070
12.	Garlic	0.27	0.43	0.31	0.070

Klose *et al.* (1997) observed that in experiment with maize, rape, barley and potatoes, arsenic content ranged from 0.04 to 1.31 µg g^{-1} dry matter when grown on soil containing 60- 362 µg As g^{-1} soil. Farid *et al.* (2003) analyzed the vegetable samples grown by irrigating with arsenic contaminated irrigation water in Bangladesh. Arsenic concentration (µg g^{-1}) of different vegetables grown with arsenic containing irrigation water found in the descending order of amaranth (0.572) > china Shak (0.539) > red amaranth (0.321) > katua data (0.234) > indian spinach (0.189) > chilli

(0.112) > potato (0.103) > bitter gourd (0.049) > cabbage (0.072) > brinjal (0.049) > okra (0.04) > tomato (0.03) > cauliflower (0.011). Alam *et al.* (2003) collected vegetables from Samta village in Jessore district of Bangladesh and reported that the highest As concentrations of snake gourd, ghotkol, taro, green papaya, elephant foot and bottle gourd leaf were 0.489, 0.440, 0.446, 0.389, 0.338 and 0.306 μg g^{-1}, respectively.

4.3.2 Lead Concentration (Pb)

A wide variation in Pb concentration was noticed in vegetables from five intensively growing areas of Chandpur (Table 5). The mean Pb concentrations of the vegetables ranged from 0.08 μg g^{-1} in sponge gourd to 0.59 μg g^{-1} in both cabbage and radish. The mean Pb concentrations of leafy vegetables ranged from 0.25 μg g^{-1} in spinach to 0.59 μg g^{-1} in cabbage. Among the fruity vegetables, the mean Pb concentration ranged from 0.08μg g^{-1} in sponge gourd to 0.50 μg g^{-1} in bottle gourd while in case of root and tuber crops; it ranged from 0.30 μg g^{-1} in potato to 0.59 μg g^{-1} in radish. The vegetables can be arranged in descending order of descending Pb concentrations (μg g^{-1}) as: Cabbage (0.59) > radish (0.59) > bottle gourd (0.50) > tomato (0.48) > onion (0.46) > brinjal (0.42) > garlic (0.36) > potato (0.30) > red amaranth (0.27) > data shak(0.26) > spinach (0.25) > sponge gourd (0.08).

Table 5. Lead concentration (dry weight basis) in different vegetables collected from Chandpur district

SL. No	Name of Vegetable	Pb concentration ($\mu g\ g^{-1}$)			
		Range		Mean	Std. Dev
		Min	Max		
Leafy vegetable					
1.	Spinach	0.19	0.32	0.25	0.080
2.	Red amaranth	0.18	0.44	0.27	0.056
3.	Data Shak	0.19	0.33	0.26	0.094
4.	Cabbage	0.41	0.68	0.59	0.120
Fruits					
5.	Tomato	0.35	0.60	0.48	0.117
6.	Brinjal	0.20	0.65	0.42	0.060
7.	Sponge gourd	0.04	0.12	0.08	0.041
8.	Bottle gourd	0.34	0.61	0.50	0.180
Roots and tubers					
9.	Potato	0.18	0.40	0.30	0.110
10.	Radish	0.45	0.64	0.59	0.140
11.	Onion	0.21	0.62	0.46	0.026
12.	Garlic	0.20	0.56	0.36	0.058

The mean highest Pb concentration of 0.59 $\mu g\ g^{-1}$ is far below the mean Pb concentration in some vegetables 4.61, 3.8 and 1.24 μgg^{-1} in USA, Egypt and Netherlands, respectively (Hibben *et al.,* 1984 and Douwe Wiersma *et al.,* 1986) as well as below the maximum permissble level of 2 $\mu g\ g^{-1}$ Pb for vegetables (Lead in Food Regulations, 1961). Thomas *et al.* (1997) reported that the concentrations of Pb in potato, tomato, lettuce and cabbage were in the range of 0.01-3.85 $\mu g\ g^{-1}$. Moslehuddin *et al.* (1998)

carried out 4 pot and 2 field experiments and reported that the highest concentrations of Pb were 0.40, 0.25, 2.80 and 2.10 $\mu g\ g^{-1}$ in red amaranth, sorghum, tomato and cabbage, respectively. Alam and Chakrabarty (2003) reported that the mean concentration of Pb in cabbage, cauliflower, tomato, potato, radish, lady`s linger, brinjal and bottle gourd were 0.53, 1.13, 3.0, 0.38, 0.09, 0.23, 0.08 and 0.23 $\mu g\ g^{-1}$, respectively.

4.3.3. Cadmium Concentration (Cd)

There was wide variation in Cd concentrations of different types of vegetables from five sampling sites of Chandpur (Table 6).

Table 6. Cadmium concentration (dry weight basis) in different vegetables collected from Chandpur district

SL. No	Name of Vegetable	Cd Concentration ($\mu g\ g^{-1}$)			
		Range		Mean	Std. Dev
		Min	Max		
Leafy vegetable					
1.	Spinach	0.19	0.35	0.26	0.058
2.	Red amaranth	0.16	0.45	0.34	0.065
3.	Data Shak	0.18	0.32	0.26	0.060
4.	Cabbage	0.15	0.27	0.25	0.060
Fruits					
5.	Tomato	0.22	0.30	0.26	0.070
6.	Brinjal	0.16	0.30	0.23	0.078
7.	Sponge gourd	0.22	0.45	0.34	0.031
8.	Bottle gourd	0.14	0.44	0.21	0.042
Roots and tubers					
9.	Potato	0.22	0.33	0.26	0.059
10.	Radish	0.11	0.14	0.12	0.013
11.	Onion	0.17	0.41	0.23	0.120
12.	Garlic	0.14	0.47	0.31	0.070

The mean cadmium concentrations of the vegetables ranged from 0.12 μg g^{-1} in radish to 0.34 μg g^{-1} in both sponge gourd and red amaranth. There was also wide variation in Cd concentration in a particular vegetable collected from different fields. For example, the Cd concentrations in garlic ranged from 0.14 to 0.47 μg g^{-1} with a mean of 0.31 μg g^{-1}. The mean Cd concentrations in leafy vegetables ranged from 0.25 μg g^{-1} in Cabbage to 0.34 μg g^{-1} in red amaranth while in case of fruity vegetables, Cd Concentration ranged from 0.21 μg g^{-1} in bottle gourd to 0.34 μg g^{-1} in sponge gourd. In root and tuber crops, it ranged from 0.12 μg g^{-1} in radish 0.31 μg g^{-1} in garlic. The vegetables can be arranged in descending order of Cd concentrations (μg g^{-1}) as: Sponge gourd (0.34) > red amaranth (0.34) > garlic (0.31) > tomato (0.26) > potato (0.26) > data shak (0.26) > spinach (0.26) > cabbage (0.25) > brinjal (0.23) > onion (0.23) > botlte gourd (0.21) > radish (0.12). Literature survey indicates that Cd level in the present vegetables is not alarming, compared to that of Spain (2.68 μg g^{-1} (Cala-Rivero, 1985), Netherlands (0.36 μg g^{-1}) (Douwe Wiersma *et al.*, 1986) and USA (0.95 μg g^{-1}) (Hibben *et al.*, 1984). Hadi *et al.* (1995) reported that the Cd concentrations in cabbage, palang shak, red shak, potato, tomato, brinjal, pumpkin, cauliflower, bean, lady's finger, radish, sweet gourd and arum root were 0.35, 1.17, 1.16, 0.35, 0.41, 0.30, 0.34, 0.28, 0.26, 0.37, 0.44, 0.39 and 0.11 μg g^{-1}, respectively.

Wiersma et al. (1986) collected the vegetables from major growing areas of Netherland and analyzed, together with their corresponding soils. In lettuce and spinach relatively high Cd levels occurred, and fruits such as tomatoes, cucumbers and apples Cd levels were low. Julustos *et al.* (1998) conducted a three years pot experiment having different levels of Cd in soils where carrot, spinach, radish, oat and bean were grown. They found that among the vegetables the highest concentration of Cd was found in spinach. Alam and Chakrabarty (2003) reported that the mean concentration of Cd in cabbage, cauliflower, tomato, potato, radish, lady's finger, brinjal and bottle gourd were 0.39, 0.31, 0.56, 0.46, 0.41, 0.38, 0.26 and 0,15 $\mu g\ g^{-1}$, respectively.

Chapter 5

Summary and conclusion

CHAPTER V

SUMMARY ADN CONCLUSION

A study was undertaken to determine the status of heavy metals in soils and vegetables growing at different locations of Chandpur district. Forty soil and 60 vegetable samples were collected during the Rabi season of 2013-14 from Karaia, Charbhairabi, Gazra, Tamta and Faridganj unions of Chandpur district. The vegetable samples were washed with As free water to remove the dust particles adhering on the surface. The collected soil and vegetable samples were brought first to the laboratory of the department of Agricultural Chemistry, Sher-e-Bangla Agricultural University for primary preparations. The samples were cut into small pieces, air-dried and finally oven dried. The dried samples were ground through grinding mill. After some primary preparations half of these samples were brought to the Department of Botany, Jahangir Nagar University, Savar, Dhaka and half to the laboratory of the Faculty of Agriculture, Rajshahi University, Rajshahi for chemical analysis. As, Pb and Cd concentrations in soils and vegetables were determined and also analyzed for texture, pH and organic matter.

The textural classes of the soils were loam, grey loam and dark grey loam. Out of the forty soils, 37 soils were loam in texture, one was grey loam and the rest two were dark grey loam. The range of soil pH varied from 7.4 to 8.1. Organic matter status of the soils varied widely, ranging between 0.7 to 2.4% with a mean value of 1.5%. There was wide variation in the levels of As, Pb and Cd in soils of the five locations. Arsenic status of the soil samples ranged from 4.3 to15.2 $\mu g\ g^{-1}$ with a mean of value of 8.80 $\mu g\ g^{-1}$.

The As status of the soils was negatively correlated with sand but positively correlated with clay content but this correlation was not statistically significant. None of the soils of the study sites had arsenic level more than 20 $\mu g\ g^{-1}$, the maximum acceptable limit for agricultural soils. The concentration of Pb in soil ranged from 11.4 to 20.7 $\mu g\ g^{-1}$ having an average value of 16.24 $\mu g\ g^{-1}$. The Pb concentration in soils was positively correlated with clay content. The observed level of Pb in soil was lower than critical level of 100 $\mu g\ g^{-1}$, the maximum permissible concentration for crop production. The concentration of Cd in soils ranged from 0.1 to 0.9 $\mu g\ g^{-1}$, having an average value of 0.53 $\mu g\ g^{-1}$. The Cd status of the soils was negatively correlated with sand but positively correlated with silt and clay but this correlation was not statistically significant. The observed level of Cd in soil was less than the maximum acceptable concentration in soil of 5 $\mu g\ g^{-1}$.

There was wide variation in As, Pb and Cd concentrations of different types of vegetables collected from five sampling sites of Chandpur. The mean As concentrations of the vegetables ranged from 0.31 $\mu g\ g^{-1}$ in both bottle gourd and garlic to 0.81 $\mu g\ g^{-1}$ in cabbage. There was also wide variation in As concentration even in a particular vegetable collected from different fields of the sampling sites. The vegetables can be arranged in the descending order of As concentrations as: Cabbage > radish > tomato > sponge gourd > spinach > brinjal > red amaranth > data shak > potato > onion > garlic > bottle gourd. However, the As concentrations in all vegetables were less than 1.0 $\mu g\ g^{-1}$, the maximum permissible limit for human consumption.

The mean Pb concentrations of the vegetables ranged from 0.08 μg g^{-1} in sponge gourd to 0.59 μg g^{-1} in both cabbage and radish. There was also wide variation in Pb concentration in leafy and fruity Vegetables. The vegetables can be arranged in the descending order of Pb concentrations as: Spinach > cabbage > radish > bottle gourd > onion > brinjal > tomato > data shak > garlic > potato > red amaranth > sponge gourd.

The mean Cd concentrations of the vegetables ranged from 0.12 μg g^{-1} in radish to 0.34 μg g^{-1} in sponge gourd and amaranth .The Cd concentrations in all vegetables were below the maximum permissible limit. The vegetables can be arranged in the descending order of Cd concentrations as: Sponge gourd > red amaranth > bottle gourd > garlic > tomato > potato > data shak > spinach > cabbage > brinjal > onion > radish.

It appears from the results of the present study that the levels of the all the heavy metals in soils were below the maximum acceptable concentration for cultivation of crops. However, the use of As contaminated irrigation water, use of heavy metal containing fertilizers and poultry manure may increase their levels in soil. The levels of heavy metals in the vegetables were within the safe limit. However, more random data in various locations at regular intervals to confirm the findings of the present study and more research work should be done in other districts to reach a specific recommendation.

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Plates

Plate 1: Collection of vegetable samples (brinjal) from Tamta local market

Plate 2: Collection of vegetable samples (data shak) from Faridganj local market

Plate 3: Vegetable samples collected from Gazra in Chandpur district

Plate 4: Vegetable samples collected from Chorbhoirabi in Chandpur district

Brinjals collected from Karaia

Brinjals collected from Chorbhoirabi

Brinjals collected from Tamta

Brinjals collected from Gazra

Brinjals collected from Faridganj

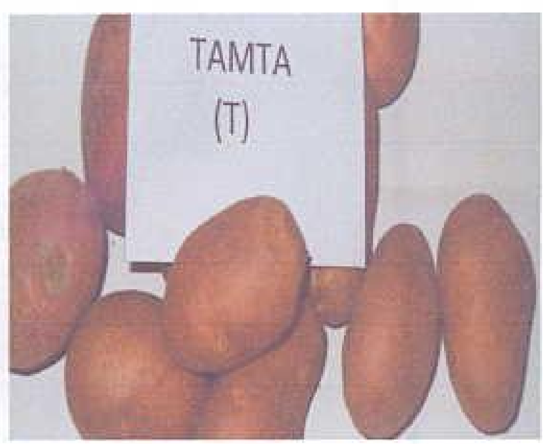
Plate 5: Various brinjal samples collected from the five locations of Chandpur district

Tomato

Data shak

Potato, Onion and Garlic

Bottle gourd



Potato

Plate 6: Various vegetable samples collected from the different locations of Chandpur district

Soil samples (Karaia)

Soil samples (Chorbhoirabi)

Soil samples (Tamta)

Soil samples (Gazra)

Soil samples (Faridganj)

Plate 7: Soil samples (Dry powder) kept in plastic containers

Plate 8: Vegetable samples (Dry powder) kept in plastic containers