HEAVY METALS AND THEIR CONTAMINATION STATUS IN SOILS AND VEGETABLES AT GAZIPUR IN BANGLADESH

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CERTIFICATE

This is to certify that the thesis entitled **“HEAVY METALS AND THEIR CONTAMINATION STATUS IN SOILS AND VEGETABLES AT GAZIPUR IN BANGLADESH”** submitted to the Department of Agroforestry and Environmental Science, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE(MS) IN AGROFORESTRY AND ENVIRONMENTAL SCIENCE**, embodies the result of a piece of *bona fide* research work carried out by **REZWANA KHAN**, Registration No. **10-04145** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that any help or source of information, received during the course of this investigation has been duly acknowledged.

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TO

MY BELOVED PARENTS

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ABSTRACT

Heavy metal pollution is now a days; one of the most serious environmental issues on a world scale and also in Bangladesh. A study was carried out to determine the status of heavy metals in non-polluted and polluted soils and vegetables from intensively growing areas of Gazipur district. Sixty soil samples and sixty vegetable samples were collected from Gazipur district. Total amount of heavy metals like Pb, Cd, Ni,Co,Cr, and Mn in soils and vegetables were determined. The soils were also analyzed for texture, pH and organic matter. Data were analyzed by SPSS software. It was found that the levels of heavy metals in soils varied from location to location. The mean concentrations of Pb, Cd, Ni, Co, Cr, and Mn in non-polluted soils were5.16, 0.89, 15.14, 12.84, 21.95, 12.59μg g^{-1}, respectively and in polluted soils7.33, 2.41, 27.36, 22.64, 31.32, 17.83 μg g^{-1}, respectively. The heavy metal concentrations in non-polluted soils were within the limit allowed for maximum acceptable concentration (MAC) for satisfactory crop production. Heavy metals in polluted soils were also below the limit considered as contaminated soil. Most of the heavy metals in both non-polluted and polluted soils were negatively correlated with silt and positively correlated with sand. There was no significant correlation between heavy metal content and soil pH or organic matter in both non-polluted and polluted soils with very few exceptions. Most of the heavy metals determined do not have any significant correlation with each other expect Cr that showed significant correlation in both non-polluted and polluted soils with Pb, Ni, Co, Mn and Cd. The concentrations of Pb, Cd, Ni, Co, Cr and Mn in different vegetables also varied widely. Concentrations of heavy metals were higher in leafy vegetables compared to fruit vegetables, root and tuber vegetables .The highest concentrations of Cd (1.21μg g^{-1}), Ni (8.19μg g^{-1}) were found in spinach while the highest concentrations of Pb (1.37μg g^{-1}) in Amaranth, Cr (17.61μg g^{-1}) in Cauliflower and Co (3.27μg g^{-1}) recorded in Red amaranth and Mn(17.10 μg g^{-1}) in Cabbage recorded for polluted vegetable samples. For both soils and vegetables, among all the heavy metals; the Cr concentration was highest. The status was almost uncontaminated to slightly contaminate for both soils and vegetables. However, existing concentrations of heavy metals in vegetables under study areas were almost within the safe limit for human consumption.

LIST OF CONTENTS

LIST OF CONTENTS(Contd.)

LIST OF CONTENTS (Contd.)

LIST OF CONTENTS(Contd.)

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

BARI = Bangladesh Agricultural Research Institute

Pb = Lead

Cd = Cadmium

Ni = Nickel

Co = Cobalt

Cr = Chromium

Mn = Manganese

et.al, = etallii(others)

mg kg^{-1} = mili gram per kilogram

HNO_3 = Nitric acid

H_2O_2 = Hydrogen per oxide

DS = Drain soil

RSS = Road side soil

BSS = Bus stand soil

% = Percentage

IPM	=	Integrated Pest Management
MAC	=	Maximum Acceptable Concentration
DAE	=	Department of Agricultural Extension

CHAPTER I

INTRODUCTION

Heavy metal pollution of soil and vegetables is one of the most severe and devastating ecological problems on a world scale and also in Bangladesh. Heavy metals have a great potential for contamination of soil and water because they are persistent enough and may affect vegetables, plants and thereby human health. Rapid urbanization, larger scale industrialization and unprotected population growth in the last few decades are responsible for lowering environmental quality 2and thus cause various pollution which are now mostly hazardous for future generation. Heavy metal pollution is the most serious issues due to their toxicity and ability to accumulate in the biota. The food chain contamination is one of the the major pathway of heavy metal exposure for humans (Khan *et al*., 2008). The consumption of vegetables is one of the most important pathways for heavy metals that harm human health (Sipter *et al.*, 2008). Industrial or municipal waste water irrigation is a common example in three fourth of the cities in Asia, Africa, and Latin America (Gupta *et al.*, 2008). Investigations on the accumulation of heavy metals from vegetables grown around the industrial sites have revealed high levels of Ni, Pb and Cd in vegetables (Ahmad and Goni, 2010). The term “heavy metals” refers to any metallic compound that has a relatively high density and is toxic or poisonous even at a low concentration (Lenntech, 2004). Heavy metals are the compounds that have specific gravity greater than 5. The “heavy metals” is generally a collective term, which applies to the group of metals and metalloids with atomic absorption density greater than 4 g cm^{-3} or 5 times or more, greater than water (Huton and Symon, 1986 ; Hawkes, 1997). The term heavy metals are also known as trace compounds, micronutrients, microelements, minor elements and trace organic or inorganic. There are 38 heavy metals, of them 13 are used or 2discharged by the industries. These 13 metals are cadmium (Cd), chromium (Cr), cobalt (Co), copper (Co), iron (Fe), mercury (Hg), molybdenum (Mo), nickel (Ni), lead (Pb), arsenic (As), tin (Sn) and zinc (Zn). Among these heavy metals; some are essential in trace amounts, namely Cobalt (Co), Copper (Cu), Iron (Fe), Manganese (Mn), Molybdenum (Mo) and Zinc (Zn) for plants and in addition, Cromium (Cr), Nickel (Ni) and Tin (Sn) for animals whereas Arsenic (As), Cadmium (Cd), Mercury (Hg) and Lead (Pb) have not been shown to be essential for either plants or animals. They can be regarded as toxic metals because they have adverse effects on plants, animals and humans. Heavy metals that have detrimental effects are mostly found at specific adsorption sites in the soil where they are retained very strongly either on the organic or inorganic colloids.

The heavy metals are widely distributed at trace levels in environment, in soil and vegetation and living organisms feel the need for micro-elements of these metals. Industrial discharge, fertilizers, manure, pesticides, fossil fuels, municipal wastes, sewage-sludge, mining wastes, animal wastes, contaminated water etc. might be some of the major sources of heavy metal contamination in soil and water (Alloyway *et al*, 1988). When a heavy metal element enters into the environment, it follows some bio-geochemical cycles, being transported by air, water and gravity, until they reach a geo-chemical sink. Soil is the final sink or goal for all the trace elements, and the elements i.e. heavy metals may accumulate in soil with a very short span of time (Kabata and Pendias, 1992). Bowen (1979) expected that the residence time of Cd in the soil might be in the range of 75 - 380 years and more strongly sorbed elements like As, Cu, Ni, Pb and Zn ranged from 1500 - 3000 years.

The use of chemical fertilizers and manures are now widely spread for the supplementation of nutrients to the human beings. Some phosphatic fertilizers and pesticides are also adding various heavy metals like Cd, Pb and Zn as impurities varying amounts (Hankens, 1983; Alloway *et al*, 1988), which continued after fertilizer application may significantly increase their percentage in the soil. The excess amount of heavy metals in soil creates toxicity to vegetables and thus ultimately pollutes the soil.

Vegetables absorb Pb and Cd from the soil as well from exterior deposits on parts of vegetables exposed to polluted air (Buchauer, 1973; Zurera *et al*,, 1987). Some plant species (spinach) can collect exceptionally high amounts of Cd (Jaakkola *et al*, 1979; Schroeder *et al.*, 1967). The upper limit of Pb is single or mixed foods should be held at 10 ppm in the dry substance and that of 100 - 470 ppm is regarded as the lethal level (Kolke, 1974). Cd, Ni and other heavy metals produce metal- phosphate on vegetable body and act as toxic substance to vegetables. The addition of Pb on the root surface produces insoluble compounds outside the plant system.

The cultivation of vegetables in different areas of Bangladesh has increased rapidly over the few years due to more return from unit area compared to cereal crops. The output is more than the input in vegetable production. The farmers use a lot of fertilizers and also different kinds of manures like poultry manure, oilcake, compost etc. for cultivation of vegetables. Besides, the use of pesticides and manures is much higher in vegetables compared to cereal crops. Therefore, these practices may increase the heavy metal status of soils and vegetables and may also transfer these metals to the vegetables and causes acute health problems.

Emissions from heavy road traffic on the roads contain lead (Pb), cadmium (Cd), zinc (Zn), and nickel (Ni), which are present in fuel as anti-knock agents and this leads to heavy contamination of air and soils on which vegetables are planted (Ikeda *et al*., 2000). Accumulation of heavy metal in agricultural land through traffic emission may result in soil and air contamination and elevated heavy metal uptake by crops, and thus affect food quality and human safety (Ho and Tai, 1988; Garcia and Millan, 1998).

It is obvious that heavy metals at contamination level can cause devastating effect on crop production and also human health. The present study was therefore undertaken with the following objectives:

Objectives:

- To determine the contamination status of heavy metals in non-polluted and polluted soil,
- To determine the contamination status of heavy metals in vegetables and
- To find out the correlation among the heavy metals.

CHAPTER II

REVIEW OF LITERATURE

An attempt has been made in this chapter to review the pertinent research information relating to heavy metal contamination in soil and vegetables.

2.1 Heavy metal concentration in soils

Mottalib *et al.,* (2016) conducted an experiment. He found that; out of eight metals examined in tannery effluent contaminated soil in Dhaka leather industrial area, concentration of heavy metals (mg kg-1) were found ranged from 994 to 1120 for Cr, 34.35 to 39.66 for Cu, 46.70 to 55.16 for Pb, 24.10 to 26.73 for Ni, 0.32 to 0.54 for Cd, 1.49 to 2.21 for As, 0.44 to 1.10 for Sb and 20812 to 21216 for Fe.

Rakib *et al*., (2014) carried out an experiment to assess the heavy metals in Dhaka Metropolitan city. He found that, The highest content of Pb, Zn, Cr and Cu were found in Hazaribagh and the lowest concentration of Pb, Zn, Cr and Cu was observed in Savar Bazar area in the greater Dhaka City. In addition, the minimum concentration of Pb, Zn, Cr and Cu was found to be 30.02 ppm, 49.91 ppm, 61.24 ppm and 12.21 ppm, respectively. Consecutively, the maximum concentration of Pb, Zn, Cr and Cu was identified 198.16 ppm, 283.21 ppm, 303.89 ppm and 179.80 ppm, respectively . However, the average concentration of Pb, Zn, Cr and Cu was observed 67.60 ppm, 144.20 ppm, 124.70 ppm and 98.90 ppm respectively.

Naser *et al*., (2012) investigated that, The heavy metal contents at the same distance from the road was found in the following order: Ni>Pb>Cd. Examining the Pb, Cd, and Ni content of roadside soil, it can be concluded that the concentration decreases with increasing distance from the motorway, except Cd.

Rahman *et al.,* (2012) carried out a survey for the assessment of heavy metal contamination. He found that average concentration of Fe, As, Mn, Cu, Zn, Cr, Pb, Hg, Ni and Cd in the study area during the dry season was 30,404, 4,073.1, 339, 60, 209, 49.66, 27.6, 486.6, 48.1 and 0.0072 mg/kg, respectively. While average concentration of Fe, As, Mn, Cu, Zn, Cr, Pb, Hg, Ni and Cd in the wet season was 17,103,2,326.2, 305, 90, 194, 34.2, 23.83, 133.2, 5.5 and 1.04 mg/kg, respectively.

Das *et al.*, (2011) examined that Zn concentration in tannary effluents was lower than in textile effluents while in adjacent river water is varied both seasonally and spacially.

Shakery *et al*., (2010) found that, the results of soils texture and the concentrations of selected heavy metals, along with Sc, Fe and Al in the three sampled depths show that soil texture spreads out from a clay end-member to a silty - sandy end member with an average ratio of clay over silt and sand being 1.07 and 3.19, respectively. The highest and lowest average organic carbon (OC) content in A and B are (0.1%) and (0.063%), respectively. Soil pH varies between 7.79 and 8.7.

Islam *et al*., (2004) studied that the As status of five districts of Gangetic floodplains. Among the five districts, the soils of Pabna and Gopalganj districts had relatively lower levels of As compared to Rajbari, Faridpur and Chapai Nawabgonj districts.

Hoque (2003) carried out an experiment for the determination of the status of As and other heavy metals and vegetables of five intensively growing areas of Chapai Nawabganj, he investigated that the mean concentration of Pb, Cd, Fe and Mn in soils were 16.2, 0.26, 4030 and 62.72 µg g-1, respectively.

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

Diaz–Valverde *et al.,* (2003) collected soil samples which were sun shine soil, predominant vegetation, nearby roads, urban centers and 6 mines in Huelva, Spain. They found that average Pb and cd contents in soil were 2.90 and 0.19 mgkg^{-1}, respectively. There was no such significant variation in heavy metal contents between samples.

Chowdhury (2003) detected that Fe, Mn, Zn, Cu and Pb from soils of various land use practice from BAU farms, Bhaluka (forest land), Boira farmer's field of Mymensingh district, Board Bazar industrial site of Gazipur. He found that total concentrations of Fe, Mn and Pb in surface soils ranged between 2066.80 – 3951.75, 150.5 – 365.71 and 21.48 – 34.00 mg kg^{-1}, respectively.

Bibi *et al.,* (2003) found that the detected heavy metal ranges in soil of different depth were 3.60- 26.20 ppm As, 89.0 - 117 ppm Cr, 8.0 - 48.0 ppm Cu, 19 -24 ppm Pb, 127 - 177 ppm Sr, 41 - 143 ppm Zn and 109 - 212 ppm Zr.

Ahmed *et al.,* (2003) collected 19 soil samples from Bhaluka region of Mymensingh. They investicated that the detected heavy metal ranges in soil were As 3.90-25.50 ppm, Cr 80 - 117, Cu 1.20 - 49, Mo 2.00-2.2, Nb 9 - 20, Ni 44 -76 ppm, Pb 12.0-34.0 ppm, Sr 31.0-120.0 ppm, Th 12.0-26 ppm, U 1.60-5.8 ppm, V 134.0-273.0 ppm, Y 33 - 54 ppm, Zn 35 -129 ppm and Zr 130.0-370.0 ppm.

Roychowdhury *et al.,* (2002) conducted an experiment on As 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 the fallow land soils were 5.31, 10.40, 0.37, 33.10, 674, 18.30, 18.80, 44.30, 342 , 0.53, 44.60, 0.29, and 0.54, mg kg^{-1}, respectively.

Jahiruddin *et al.,* (2000) investigated that the soils of Gangetic alluvium contain more As than that of Brahmaputra alluvium and the former soils had more than 20 mg kg-

1As, whereas the later soils had As level below 20 mg kg- 1which 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 soils were Pb (24. 1), Cd (0.15), Sb (0.31), Mo (0.31), Mn (444), Cu (22.4) and Zn (66.4).

Sattar and Blume (2000) carried out an experiment on total and available trace metals like Cr, Mn, Co, Zn, Pb, Cu, As, Mo, Ag, Cu, Sn, Sb, Ti, Hg and Ni contents were determined from the representative general soil types of Bangladesh at 0 – 15 depth. A variable available trace metals contents were recorded from the twenty soils and they are Pb (3.6 – 90 mg kg^{-1}), Cd (0.69 – 1.00 mg kg^{-1}), Cr (42 - 74 mg kg^{-1}) and Mn (26 – 716 mg kg^{-1}).

Sultana (2000) investigated isotope-aided studies on the effects of radiation processed sewage sludge application on crop yields and bio availability of heavy metal content of BAU soil. BAU soil contains 0.25, 14.0, 21.0 and 19.0 mg kg^{-1} aqua regia extracted heavy metal for Cd, Pb, Cu and Zn, respectively.

Sattar and Blume (1999) reported that the total Pb concentrations of road dusts at city areas varied from 57.70 - 212 mg kg^{-1}, but from rural areas 6.20 – 17.10 $mgkg^{-1}$, low Pb was observed from rural area.

Sattar (1998) is the pioneer for the determination of maximum number of heavy metals in the soil environment in Bangladesh like Pb, Al, Ti, Cr, Fe, Co, Ni, Cu, Zn, Cd, Sn, Sb, Ba, Hg, Mo, Ag, Th etc. Recently it was reviewed 30 heavy metals related article of Sattar (Ajker Bangladesh, 5 June, 2012).

Marshall (1998) conducted a survey to the heavy metal pollution of roadside soils in Bangladesh. Accumulation of Pb, Ni, Cr, Cu and Zn in roadside soils along Dhaka-Mymensingh highway, possibly due to the heavy traffic of vehicles. On the other hand, sporadic high Zn accumulation was noticed in soils along Dhaka- Aricha, Dhaka-Chittagong and Dhaka-Mymensingh highways, which was ascribed to the industrial discharge.

Barman and Lal (1994) carried out an experiment in industrially polluted field in Kalipur, West Bengal. They reported that the Zn, Cu, Cd and Pb concentration of the soil samples were 309.74 ± 146.47; 41.50 ± 14.52; 6.11 ± 1.65 and 180.43 ± 75.61 μg g^{-1} soils, respectively.

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

Holmgren *et al.,* (1986) found that the mean value for Cd in 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.

Shacklette *et al.*, (1984) investigated that the mean values for Pb in cited soils of USA are 17, 19 and 22 mg kg-1, within the range from 10-70, 10-30 and 10-70 mg kg^{-1}, respectively.

Domingo and Kyuma (1983) reported that the mean trace elements status of Cu, Zn, B, Mo, Co, Cr and Ni of paddy soils of Bangladesh were 27.0, 68.0, 68.0, 3.3, 58.0, 133.0, and 22mg kg^{-1} respectively. All the elements tested in this study were below the contamination limit (Appendix I).

2.2 Heavy metal concentration in vegetables

Mottalib *et al*., (2016) studied an experiment and found that the PCF values of the investigated heavy metals in current study for the root of spinach was found Cr 0.06, Cu 0.60 – 0.79, Pb 0.13 – 0.43, Ni 0.15 – 0.27, Cd 0.74 –0.94, As 0.13 –0.34, Sb 0.65 – 0.82 and Fe 0.15 – 0.17. Metal uptake by the root of spinach was in the following order: Cd >Sb > Cu > Pb > As > Ni > Fe > Cr.

Tasrina *et al*., (2015) carried out an experiment and resulted that the Hg in the sampling station was below the detection limit (<0.03 mg/ kg) and the concentration of Ni, Cu, Cd, Pb, Cr, Co were below the permissible limits recommended by Indian Standard Awashthi and European Union.

Ayenew *et. al*., (2014) conducted an experiment in Ethiopia on khat sample and found that the level of Cu in Khat samples varies from 5.44 mg/Kg to 9.05 mg/Kg. The smallest and biggest amounts were found in samples obtained from Addis Ababa and Bahir Dar near the airport respectively.

Napattaorn (2014) found that the highest metal concentrations were found in Soybean. Metal accumulation factors in plants were calculated as 1.2, 0.003, 0.14, 0.080 and 0.001 ppm for Cu, Pb, Zn, Cd and Fe, respectively.

Olafisoye *et al*., (2013) conducted an experiment in South Africa and found that Heavy metals concentrations in vegetables were lower in the wet season when compared to the dry season. Pb showed the highest level of heavy metals concentrations in the roots of the plant.

Naser *et al*., (2012) carried out an investigation and found that the concentrations of lead (Pb) and nickel (Ni) in soil and vegetables (bottle gourd and pumpkin) decreased with distance from the road, indicating their relation to traffic and automotive emissions.

Naser *et al*., (2011) carried an experiment on leafy vegetables in BARI, Gazipur. He found that the Cd and Cr contents in leafy vegetables in this study were detected higher while Pb and Ni were within the permissible limits as per the WHO standard but all the metals were within the maximum allowable level as per PFA, 1954, India.

Satter (2005) is the pioneer for the determination of maximum number of heavy metals from the different foods and vegetables of Bangladesh like Pb, Al, Ti, Cr, Fe, Co, Ni, Cu, Zn, Cd, Sn, Sb, Ba and Hg.

Hoque (2003) conducted an experiment to determine the status of As and other heavy metals and vegetables of five intensively growing areas of Chapai Nawabganj, he reported that the mean concentration of heavy metal is higher in the the leafy vegetables compared to tuber, roots and fruit vegetables.

Alamgir and Chakrabarty (2000) resulted that the mean concentration of Pb in cabbage, cauliflower, tomato, potato, radish, lady's finger, brinjal and bottlegourd were 0.53, 1.13, 3.0, 0.38, 0.09, 0.23, 0.08 and 0.23µg g^{-1} respectively.

Wiersma *et al.*, (1986) did collection and analysation of the cereals, fruits, fodder crops and vegetables from major growing areas in the Netherlands together with their responding soils. The Cd and Pd levels of cereals were much 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, 0.40, 23 and 0.07 mg kg^{-1}, respectively.

Marshall (1998) conducted 4 pot and 2 field experiments to evaluate the vegetables uptake of heavy metals from the application of Zn oxysulphate containing 20% Zn, 4.17 % Cd as Zn sources in red amaranth, sorghum, tomato and cabbage. Zn was applied at the rate of 0, 2, 4 and 6 kg ha -1 in all cases. He resulted 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 in case of red amaranth, sorghum, tomato and cabbage, respectively.

Zupan *et al.*, (1997) carried out an experiment in heavy metal contaminated soil in Slovenia. They found that the highest concentrations of heavy metals (Cd, Pb and

Zn) were observed in edible green parts of vegetables (spinach, lettuce) and roots (carrot and radish) whereas in leguminous vegetables (pods and seeds) was very low.

Metz and Wilke (1997) carried out a pot trial experiment on the influence of irrigated sewage affected soil and heavy metal uptake by plant. They reported that contents of Cd, Cu, Pb and Zn increased in crop with increasing soil pollution, but Cd and Zn uptake increased relatively more that of Cu and Pb. The Cd in leaves ranged from 0.10 - 8.20 mg kg^{-1}, dry matter, respectively.

Barman and Lal (1994) carried out an experiment at an industrially polluted field in Kalipur, West Bengal. They resulted that the averages levels and ranges of metal bioaccumulation, irrespective of vegetables species, were 259.20 (40 - 530); 58.20 (9-93); 3.2 (1- 8); 90 (27 - 245) μg g^{-1} in dry weight for Zn, Cu, Cd and Pb, respectively.

Thomas *et al.,* (1992) resulted that the Cd and Pb content in some vegetables (potato, tomato, lettuce and cabbage) food stuffs were in the range of 0.01- 0.22 and 0.01-3.85 μg/g, respectively.

Fritaz and Venter (1988) carried out a pot experiment and grown the vegetables of lettuce, spinach, carrot, radish, bush bean and tomato. They resulted that heavy metal (Pb, Cu, Zn, and Ni) concentrations were generally highest in the leaves and lowest the roots and fruits. Among the heavy metal, a high Cu level was found carrots in root.

Williams *et al*., (1987) investigated that the range of Pb level in some vegetables was 0.30 - 45 μg g^{-1}, respectively.

Hibben *et al.,* (1984) resulted 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.

CHAPTER III

MATERIALS AND METHODS

A study was conducted during November, 2016 to January, 2017to determine the status of heavy metals in non-polluted soils (inside of Bangladesh Agricultural Research Institute), polluted soils (Gazipur sadar, Sreepur and Kapasia) and vegetables of non-pollluted soil and mentioned 3 upazillas of Gazipur. The fine points of materials and methods for the study are presented in this chapter.

3.1 Location

Gazipur is one of the districts under Dhaka Division lying between 23° 53’ to 24° 20’ North latitudes and between 90° 09’ to 90° 42’East latitudes. The total area of the district is 1806.36sq.km. The district is bounded on the north by Mymensingh and Kishoreganj Districts, on the east by Narshingdi District, on the south by Naranyanganj and Dhaka Districts and on the west by the Tangail district.

3.2 Climatic conditions

Gazipur is generally marked with monsoon climate with moderate temperature, considerable humidity and moderate rainfall. The rainy season starts from mid May and continues up to the month of mid September. The annual rainfall is 1547mm. The highest mean temperature of about 16-18°C during the month of November-December and minimum mean temperature about 14°C. The maximum mean temperature of about 15-16°C during January and minimum mean temperature about 13.6°C. Maximum relative humidity recorded of about 55% (November to December) and minimum of about 51%. Maximum relative humidity was about 50% (January) and minimum about 48%.

Figure 1: Map showing locale of the study area at Gazipur district

3.3 Soil

Sandy loam and clay loam are the dominant soil types of this region. The area has complex mixture of non calcareous sandy, silty and clayey alluvium. The general soil type includes non calcareous grey floodplain soil, non calcareous brown floodplain soil and non calcareous dark grey floodplain. Soils are quite low in organic matter and slightly acidic in reaction.

3.4 Sampling sites

Thirty (30) soil samples were collected from non-polluted area inside of BARI and thirty from industrial areas; Gazipur Sadar, Sreepur and Kapasia upazillas of Gazipur district. From the mentioned upazillas soils were collected near from bus stands, drains and road side. Thirty vegetable samples were collected from various vegetable fields inside of BARI and also thirty vegetable samples were collected from 3 mentioned upazillas of Gazipur district near from bus stands, drains and also roadside.

3.5 Collection of soil and vegetable samples

Soil samples were collected from the surface layer at a depth of 0-15 cm from fields of each location with a stainless steel Ekman Grab Sampler. The samples that were collected from each location were made into a composite sample. Plant roots and other extraneous materials were cleaned with ambient water from the collected soil samples, air-dried, ground and passed through 2-mesh sieve. The samples that were collected kept in plastic container. Vegetable samples showed in Table 1 were collected at the stage of harvesting. The growth stage for vegetable sample was more or less same. The surface of vegetables were washed with ambient water to remove dusts adhering on the surface. The vegetable and soil samples were put into the individual polythene bag with distinct marking and tagging and brought to the laboratory of Department of Soil Science, BARI, Gazipur. In the laboratory, the vegetable samples that were collected cut into small pieces and then air dried. The air dried vegetables were then oven dried at 65°C for 48 hours. The samples were then grounded using grinding mill and stored in plastic containers for next work.

3.6 Types of vegetables:

For the conducted study the following vegetable samples were collected and they are listed below:

Table1. List of the vegetables collected for the study

Sl no.	English Name	Type	Scientific Name	Family
1.	Red amaranth	Leafy	*Amaranthus tricolor*	Amaranthaceae
2.	Amaranth	Leafy	*Amaranthus* sp.	Amaranthaceae
3.	Spinach	Leafy	*Spinacia oleraceae*	Chenopodiaceae
4.	Cabbage	Leafy	*Brassica oleracea var. capitata*	Cruciferae
5.	Cauliflower	Fruit	*Brassica oleracea var. botrytis sub. Var. cauliflower*	Cruciferae
6.	Tomato	Fruit	*Lycopersicon con esculentum*	Solanaceae
7.	Chilli	Fruit	*Capsicum fruticens*	Solanaceae
8.	Bottlegourd	Fruit	*Momordica sp.*	Cucurbitaceae
9.	Potato	Tuber	*Solanum melongena*	Solanaceae
10.	Onion	Root	*Allium cepa*	Alliaceae

3.7 Soil analysis

Collected soil samples were analyzed for both physical and chemical properties and the soil samples were analyzed using the standard techniques as follows:

3.7.1 Textural class

Mechanical analysis of soil samples was done by hydrometer method (Bouyoucos, 1926) and the textural class was determined by plotting the values for %sand, %silt and % clay to the Marshall's triangular co-ordinate following USDA system (Marshall, 1962).

3.7.2 Soil pH

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

3.7.3 Organic matter

Organic carbon of soil samples were measured 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). (Page *et al.,* 1989)

3.7.4 Digestion of soil samples

The collected soil samples weighing 1.0 g were transferred into a dry clean digestion vessel. Then Nitric acid (HNO_3), 5 ml. was added to the vessel and allowed to stand it overnight with covering the vessel to vapor recovery device. On the following day, the digestion vessel was placed on a heating block and was heated at a temperature slowly raised to 120° C for 2 hours. After cooling, 2 ml of hydrogen per oxide (H_2O_2) was added into it and kept for few minutes. Again, the vessel was heated at 120°C. Heating was momentarily stopped when the dense white fumes occurred, 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. The soil samples were digested at digestion laboratory, Dept. of Soil Science, Bangladesh Agricultural Research Institute, Gazipur.

3.7.5 Determination of total Pb, Cd, Ni, Co, Cr and Mn

Total Pb, Cd, Ni, Cr, Co and Mn were determined at the laboratory of soil science of Bangladesh Rice Research Institute, Gazipur by using the Atomic Absorbtion Spectrophotometer (AAS) at 193.70, 217.00, 224.80, 213.90, 248.40 and 279.60 nm, respectively (Welsh *et al.*, 1990).

3.8 Vegetable analysis

The collected vegetable samples were only analyzed to determine the Pb, Cd, Ni, Cr, Co and Mn content in vegetables.

3.8.1 Digestion of vegetables samples

A sub-sample weighing 0.5 g was transferred into a dry clean digestion vessel. Then Nitric acid of 5 ml. was added to the sample and was allowed for standing overnight under fume hood. On the following day, the vessels were placed on a heating block and heated at a temperature slowly raised to 120° C for two hours. After cooling, 2 ml of hydrogen per oxide was added into it and kept for few minutes. Again, the vessel was heated at 120°C. Heating was momentarily stopped when the dense white fumes occurred, 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. The vegetable samples were then digested at digestion laboratory, Dept. of Soil Science, Bangladesh Agricultural Research Institute, Gazipur.

3.8.2 Determination of Pb, Cd, Ni, Cr, Co and Mn

The elements Pb, Cd, Ni, Co, Cr, and Mn were determined by the same technique as described in section 3.7.5.

3.9 Statistical analysis

Range, mean and standard deviation of the contents of heavy metals of collected soils and vegetables were calculated. Correlation statistics was done to observe the interrelationship among the heavy metals with soil pH, organic matter and texture by using SPSS software. MS Excel was used in drawing the correlation graphs.

Chapter IV
RESULTS AND DISCUSSION

The results of the status of heavy metals in soils and vegetables collected from different areas of Gazipur have been discussed by the following headings in this chapter:

4.1 Physical properties of non-polluted soils

The non-polluted soil collected from inside of BARI were mostly sandy loam, only 3 soil samples represents as silty clay and silt loam (Table 2.)The sand percentage recorded inside of BARI were found uniform and showed in Table 2.

4.2 Chemical properties of non- polluted soils

Most of the soil samples were acidic to neutral in nature represented in Table 2. The range of pH values were from 6.00 to 8.8, having an average value of 7.39. The lowest pH was recorded in the soils of Tomato plot (6.00) and the highest pH value was recorded in the soils of Cabbage plot (8.8). The range of organic carbon were between 0.45% and 1.12%with a mean value of 0.79% showed in Table 2.The lowest amount of organic carbon was recorded from the site of Cabbage plot (0.45) and the highest amount of organic carbon was found from the site of Onion plot (1.12). Almost similar amount of organic carbon was recorded from Potato plot (0.99), Red amaranth plot (0.84) and Amaranth plot (0.62). The variation occurred in soil organic carbon may be due to variation of adding organic matter through FYM (Farm Yard Manure), poultry manure and green manure practices and so on. Moreover, the higher intensity of the land use practices and use of fertilizers and pesticides might have played a vital role in organic matter and pH status of soils. In general the organic matter content in Bangladesh soil is quite low (BARC, 2005).

Table 2.Physical and chemical properties of non-polluted soil

SL. NO.	Sampling plot/field	Physical properties				Chemical properties	
		Sand (%)	Silt (%)	Clay (%)	Textural class	Soil pH	Organic carbon (%)

1.	Red amaranth	54	32	14	Sandy loam	6.8	0.84
2.	Amaranth	50	25	25	Sandy loam	8.4	0.62
3.	Spinach	66	26	08	Sandy loam	7.29	0.53
114.	Cabbage	73	05	22	Sandy loam	8.8	0.45
5.	Cauliflower	60	35	05	Sandy loam	7.42	1.00
6.	Tomato	45	35	20	Sandy loam	6.00	0.75
7.	Chili	40	38	22	Silty clay	7.62	1.02
8.	Bottlegourd	70	17.92	12.08	Sandy loam	7.48	0.55
9.	Potato	34.30	56	9.70	Silt loam	7.40	0.99
10.	Onion	30	50	20	Silt loam	6.67	1.12

4.3 Heavy metal concentration

4.3.1 Lead (Pb) status of non-polluted soils

Pb status of soils, inside of BARI, Gazipur ranged between 4.1- 6.21µg g^{-1}, having an average value of 5.16 µg g^{-1} showed in Table 3. The lowest amount of Pb was recorded from Chilli plot (4.1 µg g^{-1}) and the maximum amount was recorded from Bottlegourd plot (6.21 µg g^{-1}).

All the soil samples contain below or within the limit of Maximum Allowable Concentrations (MAC) for Pb (20 - 300 mg kg-1) in agricultural soils (Appendix I) or within the typical values for uncontaminated soil range (0 - 500 mg kg^{-1}) (Appendix II). The Pb status from non-polluted soils was lower than the maximum acceptable limit of 150 µg g^{-1} for crop production (Kabata and Pendias, 1992). Sultana Ahmed (2000) reported that soil of Bangladesh Agricultural University, Mymensingh contains 14.40 μgg^{-1} of Pb, Ahmed *et al.,* (2003) have collected 21 soil samples from Bhaluka region of Mymensingh. He found that 12 - 34 ppm Pb in the collected soil samples. Bibi *et al.,* (2003) reported that the mean Pb concentration of soils at different depths of Bangladesh ranged between 19 - 24 µg g^{-1}, and Jahiruddin *et al.,* (2002) reported that the mean Pb concentration of 20 calcareous soils ranged from 17.80 - 26.80 µg g^{-1}, averaging 22.80 µg g^{-1}. Hoque (2003) found that the mean concentration of Pb was 16.20 µg g^{-1} in the five intensively growing areas of Chapai Nawabganj district.

The Pb status of the present study falls within the acceptable limit according to the references of these findings. The soils inside of BARI, Gazipur are in developed condition. The application of limestone, phosphotic fertilizers, use of excessive fertilizers and pesticides and use of waste material in agricultural field is quite less. For these above reasons, the Pb status in non-polluted soil in this present study is not shocking yet for further crop production. The health risk is also below the hazard condition.

But the farmers of Bangladesh are still in dark condition about this serious heavy metal contamination, now the situation demands for immediate steps to build awareness among the farmers so that further increase of these heavy metal contaminations can be restricted as early as possible. Public awareness can play a vital role to restrict the activities that are responsible for heavy metal contamination. Application of organic fertilizers and adoption of IPM (Integrated Pest Management) can be a very important alternative to meet the requirements of nutrients and soil testing should make popular idea among farmers so that application of fertilizer can be need based.

4.3.2 Cadmium (Cd) status of non-polluted soils

Cd status of soils, inside of the BARI, Gazipur ranged between 0.697-1.12 μg g^{-1}, having an average value of 0.89 μg g^{-1} (Table 3). The lowest amount of Cd was recorded from Amaranth plot and the maximum amount was recorded from Bottlegourd plot.

Cd status from non-polluted soils was lower than the MAC (Maximum Allowable Concentrations) of 5 μg g^{-1} for crop production (NSWEPA, 1994), all the soil samples contain below or within the limit of MAC for Cd (1 to 5 mg kg^{-1}) in agricultural soils (Appendix I) or within typical values for uncontaminated soil range (0 to 1 mg kg^{-1}) (Appendix II). Sultana Ahmed (2000) reported that, BAU, Mymensingh soil contains 0.25 μg g^{-1} of Cd.

Ahmed *et al.,* (2003) reported 12 to 34 μg g^{-1} status of Cd at Bhaluka region of Mymensingh. Hoque (2003) reported that the mean concentration of Cd was 0.26 μg g^{-1} in Chapai Nawabganj district. Jahiruddin *et al.,* (2000) also found that the mean Cd concentration was 0.15 μg g^{-1}at Brahmaputra alluvium twenty calcareous soils.

The conclusions of the present study are very close to this result; again Cd status in non-polluted soils is not alarming yet as the soil is in developed condition here and also use of hazardous pesticides and manures is quite low. Organic fertilizer application and IPM practice can reduce the further heavy metal contamination.

4.3.3 Nickel (Ni) status of non-polluted soils

Ni status of soils, inside of the BARI, Gazipur ranged between(13.89-16.24) μg g^{-1}, having an average value of 15.14 μg g^{-1} showed in Table 3. The lowest amount of Ni was recorded from Onion plot (13.89 μg g^{-1}) and the maximum amount was recorded from Bottlegourd plot (16.24 μg g^{-1}).

All the soil samples contain below or within the limit of MAC for Ni (20 – 60 mg kg^{-1}) in agricultural soils or within typical values of uncontaminated soil range (0-20 mg kg^{-1}) (Appendix II). Domingo and Kyuma (1983) reported that the status of Ni in paddy fields of Bangladesh was 22 mg kg^{-1}. Ahmed *et al.,* (2003) reported that 44 - 76 ppm range of Ni at Bhaluka region of Mymensingh district.

These findings also associate with the present study, where the investigation of this study indicates Ni status is still under acceptable limit considered to be not a threat for crop production and hazardous for health as well.

4.3.4 Cobalt (Co) status of non-polluted soils

The Co status of soils, inside of BARI, Gazipur ranged between 11.91-14.03 µg g^{-1}, having an average value of 12.84 µg g^{-1} showed in Table 3. The lowest amount of Cr was recorded from Cauliflower plot and the highest amount was recorded from Tomato plot.

Domingo and Kyuma (1983) reported that the status of Co in paddy soils of Bangladesh was 133 mg kg^{-1}. Ahmed *et al.,* (2003) reported 80 - 117 ppm of Co at Bhaluka region of Mymensingh. Bibi *et al.,* (2003) reported the mean Co concentration of soils of different depths of Bangladesh ranged between 8 - 48 µgg^{-1}.

The present study resembles also with the findings cited above. Outcome of this study conclude that Co status is still under a safe limit for crop production.

4.3.5 Cromium (Cr) status of non-polluted soils

Cr status of non- polluted soils inside of the BARI, Gazipur ranged between 20.16-23.61µg g^{-1}, having an average value of 21.95 µg g^{-1} (Table 3). The lowest amount of Cr was recorded from Onion plot (20.16 µg g^{-1}) and the maximum amount was recorded from Bottlegourd plot (23.61 µgg^{-1}) .

All the soil samples contains below or within the limit of MAC for Cr (50 - 200 mg kg^{-1}) in agricultural soils (Appendix I), or within typical values for uncontaminated soil range (0 - 100 mg kg^{-1}) (Appendix II). Domingo and Kyuma (1983) reported that the status of Cr in paddy fields of Bangladesh was 13 $mgkg^{-1}$. Ahmed *et al.*, (2003) found that 80 - 117 ppm of Cr at Bhaluka region of Mymensingh. Bibi *et al.*, (2003) found that the mean Cr concentration of soils at different depths of Bangladesh ranged between 8 - 48 µg g^{-1}.

These findings also correlate with the present study, where the investigation of this study indicates Cr status is still under acceptable limit considered to be not a threat for crop production and hazardous for health as well.

4.3.6 Manganese (Mn) status of non-polluted soil

The Mn concentration ranged between 10.96-14.09 µg g^{-1}, having an average value of 12.59 µg g^{-1} (Table 3). The lowest amount of Mn was recorded from Cauliflower plot (10.96 µg g^{-1}) and the maximum amount was recorded from Bottlegourd plot (14.09 µg g^{-1}).

All the soil samples contains below the limit of MAC for Mn (1500 - 3000 $mgkg^{-1}$) in agricultural soils (Appendix I), or within typical values for uncontaminated soil (0 - 500 mg kg^{-1}) (Appendix II). Almost similar amount of Mn was reecorded from Bhaluka and Mymensingh Sadar (40 µg g^{-1}). Jahiruddin *et al.*, (2002) reported that the mean Mn concentration of 20 soils ranged from 444 - 457µgg^{-1} in Mymensingh. Hoque (2003) reported that the mean concentration of Mn was found 62.72 µg g^{-1} in five intensively growing areas of Chapai Nawabganj district. Sattar and Blume (2000) reported that Mn status of 20 general soil types of Bangladesh were 26 – 716 mg kg^{-1}.

The status of Mn found in non-polluted soils in this present study falls within the safe limit and also correlate with the findings. Thus it can be said that; developed soil condition may limits the heavy metal status and also help in reduction of their contamination.

4.4 Correlation coefficient of heavy metals in non-polluted soils

4.4.1 Correlation of heavy metals with soil properties of non-polluted soils

The results presented in the Table 4 clearly showed that most of the heavy metals were not significantly correlated with soil physical and chemical properties of non-polluted soils. Pb, Cd, Ni, Co, Cr and Mn metals showed negatively significant correlation with silt (-0.15, -0.07, -0.11, -0.39, -0.60 and -0.06 respectively). Except Mn, all the heavy metals showed positive correlation with sand particles. Co and Mn were positively correlated with clay, and only Cr showed positive correlation with pH(r= 0.02).

4.4.2 Correlation among heavy metals in non-polluted soils

Some of the heavy metals showed significant correlation with one another like: Co showed significant positive correlation with Pb (r = 0.59), Cr (r =0.10) and Ni (r = 0.60). Cd and Cr were negatively correlated (r=-0.05) showed in Table 5. The negative correlationship occurs because combined physiological possessions of two or more elements is less than the sum of their independent possessions, and positive correlationship occurs because the combined possessions of these elements is greater. (Olsen, 1972; Foy *et al.*, 1978).

Table 3.Total Pb, Cd, Ni, Co, Cr and Mn concentrations in non-polluted soil (Inside of BARI, Gazipur)

SL. NO.	Sampling plot/field	Concentrations(μg g^{-1})					
		Pb	Cd	Ni	Co	Cr	Mn
1.	Red amaranth	5.76	0.728	15.39	13.98	23.13	12.21
2.	Amaranth	4.93	0.697	14.87	12.78	21.99	11.1
3.	Spinach	5.27	0.732	15.1	13.12	22.91	11.93
4.	Cabbage	4.89	0.97	14.33	12.86	21.83	13.21
5.	Cauliflower	4.79	o.951	15.1	11.91	20.89	10.96
6.	Tomato	5.27	1.08	16.21	14.03	22.17	13.61
7.	Chili	4.1	0.721	15.13	12.17	21.89	12.88

8.	Bottlegourd	6.21	1.12	16.24	13.22	23.61	14.09
9.	Potato	5.37	0.972	15.14	12.23	20.89	12.92
10.	Onion	4.99	0.892	13.89	12.07	20.16	13.03
	Range	4.1-6.21	0.697-1.12	13.89-16.24	11.91-14.03	20.16-23.61	10.96-14.09
	Mean	**5.16**	**0.89**	**15.14**	**12.84**	**21.95**	**12.59**
	Standard deviation	0.57	0.16	0.72	0.76	1.08	1.03

Table 4 . Correlation of heavy metals with soil properties of non-polluted soils

Heavy metals	Physical properties			Chemical properties	
	Sand	Silt	Clay	pH	Organic carbon
	Correlation (r)				
Pb	0.33	-0.15	-0.39	-0.28	-0.37
Cd	0.16	-0.07	-0.21	-0.22	-0.10
Ni	0.24	-0.11	-0.27	-0.39	-0.25

Co	0.33	-0.38	0.11	-0.36	-0.53
Cr	0.63	-0.60	-0.08	0.02	-0.68
Mn	-0.05	-0.06	0.22	-0.26	-0.12

Table 5.Correlation among heavy metals of non-polluted soils

Elements	Pb	Cd	Ni	Co	Cr	Mn
Pb	-	0.43	0.52	0.59	0.56	0.35
Cd	-	-	0.40	0.10	-0.05	0.63
Ni	-	-	-	0.60	0.66	0.31
Co	-	-	-	-	0.75	0.29
Cr	-	-	-	-	-	0.21
Mn	-	-	-	-	-	-

4.5 Physical properties of polluted soils

The polluted soil samples were collected mainly from Gazipur sadar, Sreepur and Kapasia upazillas of Gazipur district showed in Table 6. The collected polluted soil samples of Gazipur disrict were mostly clay loam in texture presented in Table 6. Only 3 soil samples represented as silty clay and silt loam.

4.6 Chemical properties of polluted soils

All the soil samples except Red amaranth, Cauliflower and Bottlegourd plot were acidic in reaction (Table 6). Range of soil pH value was from 4.42-7.90. The Table 6 showed that the organic carbon in the soil samples varied widely, ranging between 0.38-1.12, with a mean value of 0.79%. The value of organic carbon present in soil samples clearly indicates that soils are low in organic matter content.

Table 6. Physical and chemical properties of polluted soil at Gazipur

Sl, No.	Sampling plot	Soil types	Physical properties				Chemical properties	
			Sand (%)	Silt(%)	Clay (%)	Textural class	Soil pH	Organic carbon (%)
1.	Red amaranth	DS	44	29	27	Clay loam	5.4	0.95
2.	Amaranth	DS	55	20	25	Clay loam	6.0	1.00
3.	Spinach	DS	40	30	30	Clay loam	6.24	0.82
4.	Cabbage	DS	30	20	50	Clay loam	7.00	0.75
5.	Cauliflower	RSS	60	25	15	Clay loam	5.82	0.65
6.	Tomato	RSS	50	30	20	Clay loam	7.90	0.77
7.	Chili	RSS	35	43	22	Silty clay	6.80	0.45
8.	Bottlegourd	BSS	42	23	35	Clay loam	4.42	0.38
9.	Potato	BSS	13	64	23	Silt loam	7.12	0.99
10.	Onion	BSS	10	70	20	Silt loam	6.62	1.12

Here, soil types; DS=Drain soil
RSS=Roadside soil
BSS=Bus stand soil

4.7 Heavy metal concentration

4.7.1 Lead (Pb) status of polluted soils

The total Pb concentration in polluted soils ranged between 6.63-7.99μg g^{-1}, averaging 7.33 μgg^{-1} showed in Table 7. Minimum concentration of Pb in polluted soils was recorded from Chili plot (6.63 μgg^{-1}) RSS (Road side soil) and the maximum concentration was found in the soils of Spinach plot(7.99 μgg^{-1}) DS (Drain soil). The soils from Cauliflower plot(6.81 $\mu gg^{-1)}$, RSS and Tomato(7.21 $\mu gg^{-1)}$ RSS contain almost statistically similar amount of Pb (6.81 and 7.21 μg g^{-1} respectively). All the collected soil samples cotain below or within typical values for uncontaminated soil range (0 - 500 mg kg^{-1}) (Appendix II). The status of Pb from polluted soils was lower than the maximum acceptable limit of 150 μg g-1 for crop production (Kabata and Pendias, 1992). Sultana Ahmed, (2000) have reported that, BAU(Bangladesh Agricultural University), Mymensingh soil contains 14.40 μg g^{-1} of Pb. Ahmed *et al.,* (2003) collected 23 soil samples from Bhaluka region of Mymensingh and reported that 12 – 34 ppm range of Pb. Sattar and Blume, (1999) reported that the total Pb concentrations of road dusts at city areas varied from 57.70 - 212 mg kg^{-1}, but from rural areas 6.20 – 17.10 mg kg^{-1}, low Pb was observed from rural area.

The status of Pb of present study falls within the safe limit resembles with the above findings. So, the Pb conc. is safe within the limit of being contaminated in the non-polluted soils as well as polluted soils. Results of this present study indicate that the mean concentration of Pb in non-polluted soils and polluted soils had a very little difference.

4.7.2 Cadmium (Cd) status of polluted soils

The total Cd concentration in polluted soils ranged between 2.13-2.68 μg g^{-1}, averaging 2.41μg g^{-1}showed in Table 7. Minimum concentration of Cd in polluted soils was recorded from Onion plot(2.13 $\mu gg^{-1)}$ BSS(Bus stand soil) and the maximum concentration was found in the soils of Potato plot(2.68 μg $g^{-1),}$ BSS. All the soil samples contain slight contaminated soil (1-3 mg kg^{-1}) (Appendix II). Ahmed *et al.,* (2003) reported that; 12 – 34 ppm of Cd at Bhaluka region of Mymensingh. Sattar and Blume (2000) stated that Cd content of twenty general soil types of Bangladesh at 0 – 15 depth was 0.69 – 1.00 mg kg^{-1}.

This present study resembles similarity with the findings. The observation indicate that the level of Cd in polluted soils was higher than non-polluted soils, and the level is within the safe limit. The difference may be occured because of municipal waste water, factory effluents and sewage sludge running through the drains of urban areas.

4.7.3 Nickel (Ni) status of polluted soils

The total Ni concentration in polluted soils found between 25.37-28.97 μg g^{-1}, averaging 27.36 μg g^{-1} Table 7. Minimum concentration of Ni in polluted soils was recorded from Tomato plot(25.37μg $g^{-1)}$ RSS (Roadside soil) and the maximum concentration was found in the soils of Cabbage plot(28.97 μg g^{-1}) DS(Drain Soil). All the soil samples contain below or within slight contaminated soil range (20- 50 mg kg^{-1}) (Appendix II). Ahmed *et al.*, (2003) found that 44 - 76 mg kg-1 range of Ni at Bhaluka region of Mymensingh.

This present study resulted that the mean concentration Ni in polluted soils is higher than that of non-polluted soils, this may occur because of municipal waste water, factory effluents and sludge, sewage sludge running through the drains of urban area.

4.7.4 Cobalt (Co) status of polluted soils

The total Co concentration in polluted soils ranged between 20.17-26.11μg g^{-1}, averaging 22.64μg g^{-1} showed in Table 7. Minimum concentration of Co in polluted soils was recorded from Amaranth plot(20.17μg $g^{-1)}$,DS and the maximum concentration was found in the soils of Tomato plot(26.11 μg $g^{-1)}$ RSS. Hoque (2003) stated that the mean concentration of Co in soils was 40.30μg g^{-1}. Chowdhury (2003) reported that Co in surface soils of Mymensingh district ranged between 20.66 – 39.51 mg kg^{-1}, respectively.

The mean concentration Co in polluted soils and non-polluted soils have a very little difference resulted in this present study. Cobalt contamination occurs mostly due to heavy industrialization, industrial sludge and wastes dump in the farm land can lead us to a divastating situation in future because industrialization is rising at higher scale in Bangladesh.

4.7.5 Cromium (Cr) status of polluted soils

The results presented in Table 7 showed that the total Cr concentration in polluted soils ranged between 29.99-32.91μg g^{-1}, averaging 31.32 μg g^{-1}.Minimum concentration of Cr in polluted soils was recorded from Potato plot BSS (Bus Stand Soil) and the maximum concentration was found in the soils of Red amaranth plot, DS.

All the soil samples contain below or within typical values for uncontaminated soil range (0 - 100 mg kg^{-1}) (Appendix II). Ahmed *et al.*, (2003) stated 80 - 117 ppm range of Cr at Bhaluka region of Mymensingh. Sattar and Blume, (2000) found that Cr content of twenty general soil types of Bangladesh depth was 42 - 74 mg kg^{-1}.

Result of this study indicates that the mean concentration Cr in polluted soils is higher than that of non-polluted soils. This occurs may be because of municipal waste water, factory effluents and mire, sewage sludge running through the drains of urban area and may because of rapid industrialization and urbanization around the urban areas.

4.7.6 Manganese (Mn) status of polluted soils

The total Mn concentration in polluted soils ranged between 14.99-19.97μg g^{-1}, averaging 17.83μg g^{-1} showed in Table7. Minimum concentration of Mn in polluted soils was recorded from Chili plot, RSS and the maximum concentration was found in the soils of Cabbage plot, DS. All the soil samples contain below or within the limit of within typical values for uncontaminated soil range (0 - 500 mg kg-1) (Appendix II). Jahiruddin *et al.*, (2002) stated that the mean Mn concentration of 20 soils at Narshindi district ranged from 444 - 457 μg g^{-1} . Sattar and Blume (2000) found that Mn content of twenty general soil types of Bangladesh depth was 26 – 716 mg kg^{-1}.

The status of Mn of present study falls within the safe limit correlate with the above findings. So Mn status found in this present study is well within the limit of being contaminated. The mean concentration of Mn in polluted soils is higher than that of non-polluted soils resulted in this present study.

Table 7.Total Pb, Cd, Ni, Co, Cr and Mn concentrations in polluted soils at Gazipur

Sl no.	Sampling plot	Soil types	Pb	Cd	Ni	Co	Cr	Mn
			Concentrations(µg g^{-1})					
1.	Red amaranth	DS	8.21	2.81	28.77	22.19	32.91	19.21
2.	Amaranth	DS	7.43	2.17	26.28	20.17	30.83	16.27
3.	Spinach	DS	7.99	2.39	28.37	21.70	30.13	18.81
4.	Cabbage	DS	6.99	2.47	28.97	21.99	32.07	19.97
5.	Cauliflower	RSS	6.81	2.38	27.13	21.03	30.61	17.62
6.	Tomato	RSS	7.21	2.32	25.37	26.11	32.18	18.13
7.	Chili	RSS	6.63	2.17	26.19	24.24	31.78	14.99
8.	Bottlegourd	BSS	7.83	2.61	27.23	23.19	32.61	17.88
9.	Potato	BSS	7.28	2.68	28.13	22.72	29.99	16.98
10.	Onion	BSS	6.92	2.13	27.19	23.03	30.10	18.13
	Range		6.63-7.99	2.13-2.68	25.37-28.97	20.17-26.11	29.99-32.91	14.99-19.97
	Mean		**7.33**	**2.41**	**27.36**	**22.64**	**31.32**	**17.83**
	Standard deviation		0.53	0.23	1.20	1.68	1.11	1.45

Here, soil types;

DS= Drain soil

RSS=Roadside soil

BSS= Bus stand soil

4.8 Correlation coefficient of heavy metals in polluted soils

4.8.1 Correlation of heavy metals with soil properties of polluted soils

Pb was positively correlated with sand (r = 0.19 and clay (0.25) but negatively correlated with silt (r = -0.31) showed in Figure 2,3,4. Besides Cd (r = 0.31) and Cr (r = 0.39) showed positive correlation with clay particles showed in Figure 5,6. Soil pH showed negative correlation with Ni (r = -0.26) and Cr (r =-0.27). Pb and Mn showed positive correlation with soil organic carbon (r = 0.14, and 0.220 respectively). Pb was positively correlated with sand but negatively correlated with silt that means Pb content increases with the increase of sand and Pb content increases with the decrease of silt particles. Ni and Cr were negatively correlated here with soil pH indicates that Ni and Cr concentrations decreases with soil pH increases.

4.8.2 Correlation among heavy metals of polluted soils

Cr showed weakly correlation with Pb (r = 0.28) and Cd (r = 0.39) showed in Figure 11,12. Mn showed significant positive correlation with Ni(r=0.65) in figure 13. Besides, Ni, Cd (r = 0.65) and Pb, Cd (r = 0.63) got positive significant correlation. The negative correlation occurs because of the combined physiological outcome of two or more elements is less than the sum of their independent outcome, and positive correlation occurs because the combined outcome of these elements is greater (Olsen, 1972; Foy *et al.*,1978).

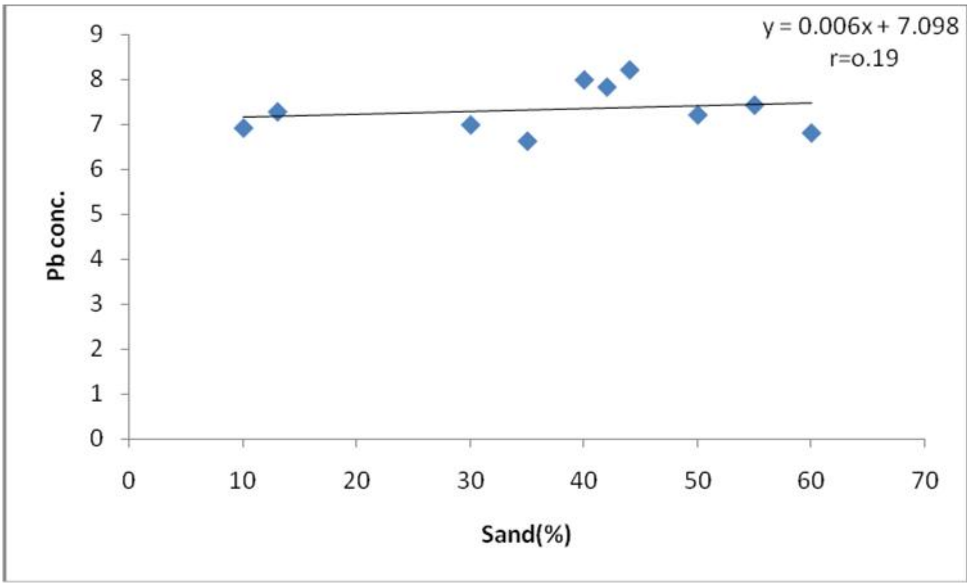

Figure 2: Correlation of sand particles with Pb concentration

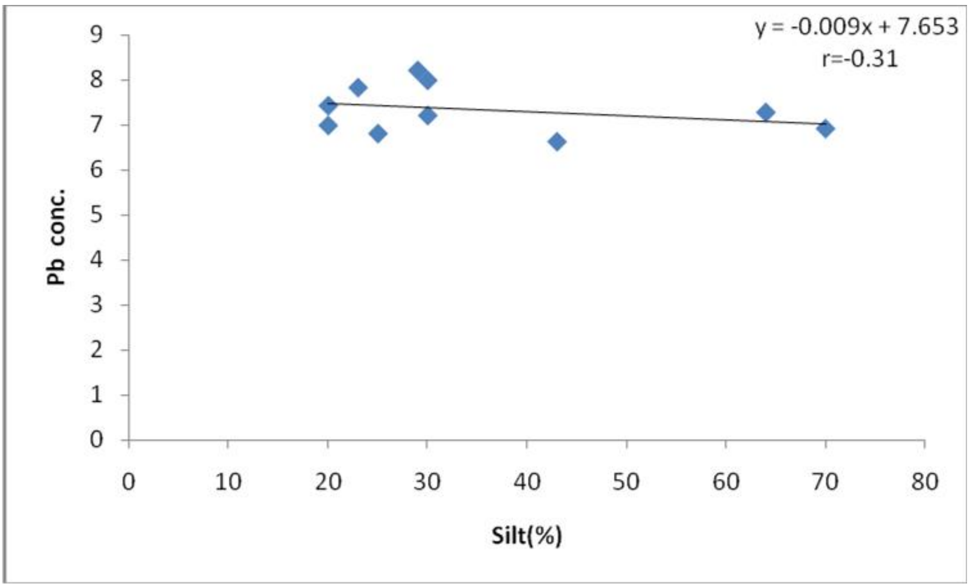

Figure 3: Correlation of silt particles with Pb concentration

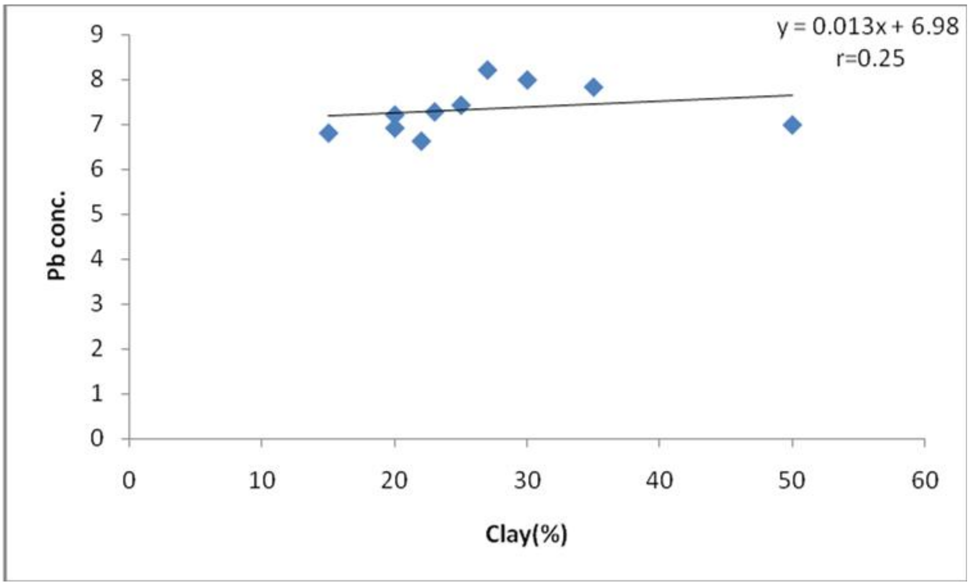

Figure 4: Correlation of clay particles with Pb concentration

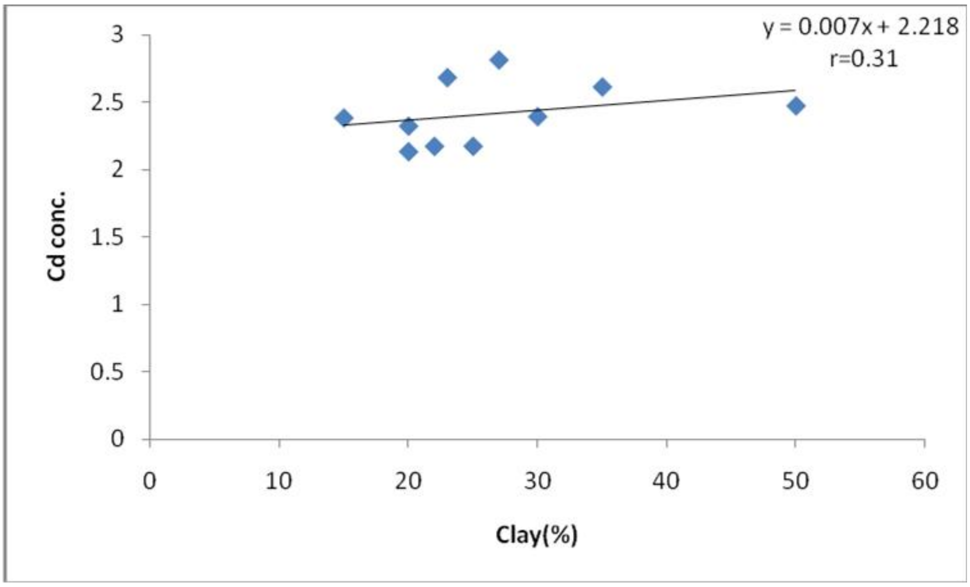

Figure 5: Correlation of clay particles with Cd concentration

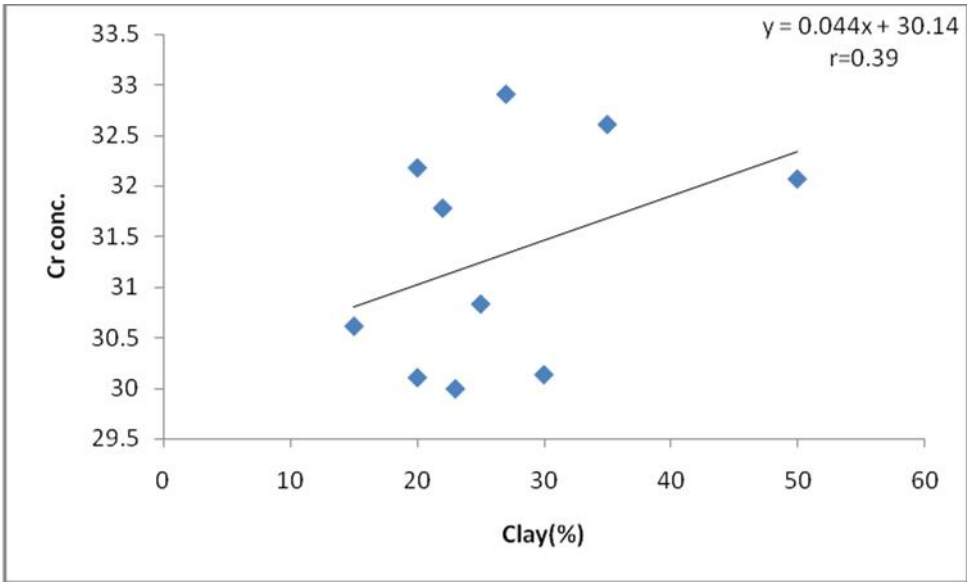

Figure 6: Correlation of clay particles with Cr concentration

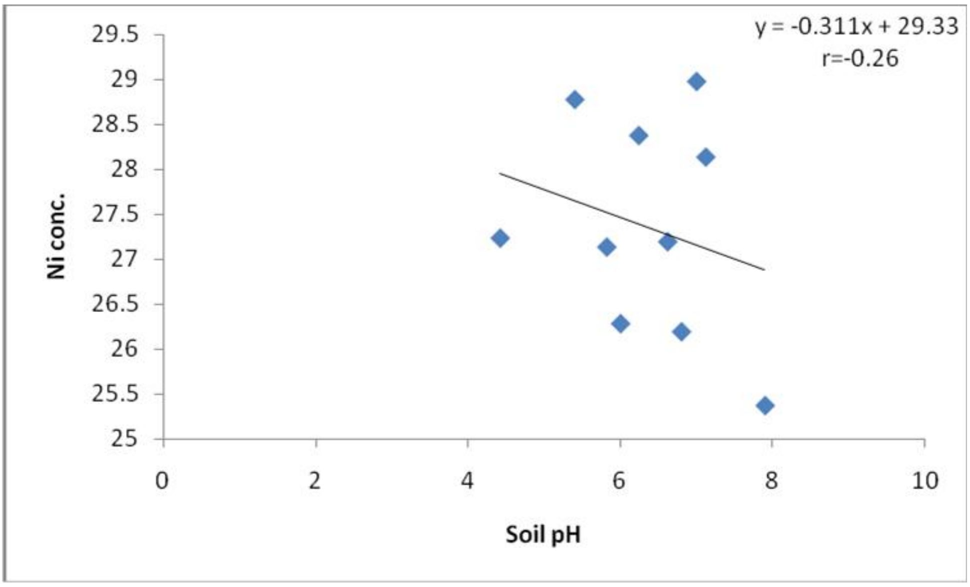

Figure 7: Correlation of soil pH with Ni concentration

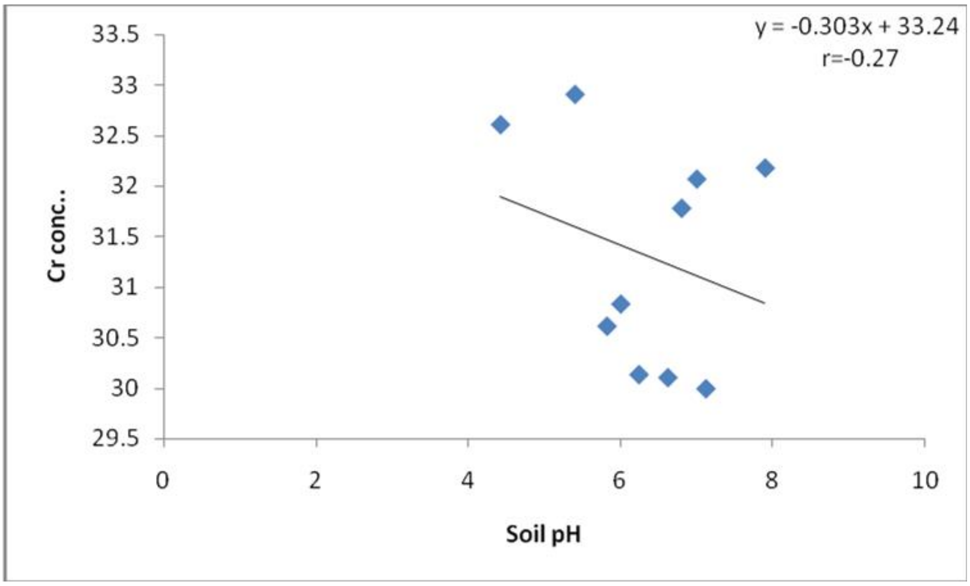

Figure 8: Correlation of Soil pH with Cr concentration

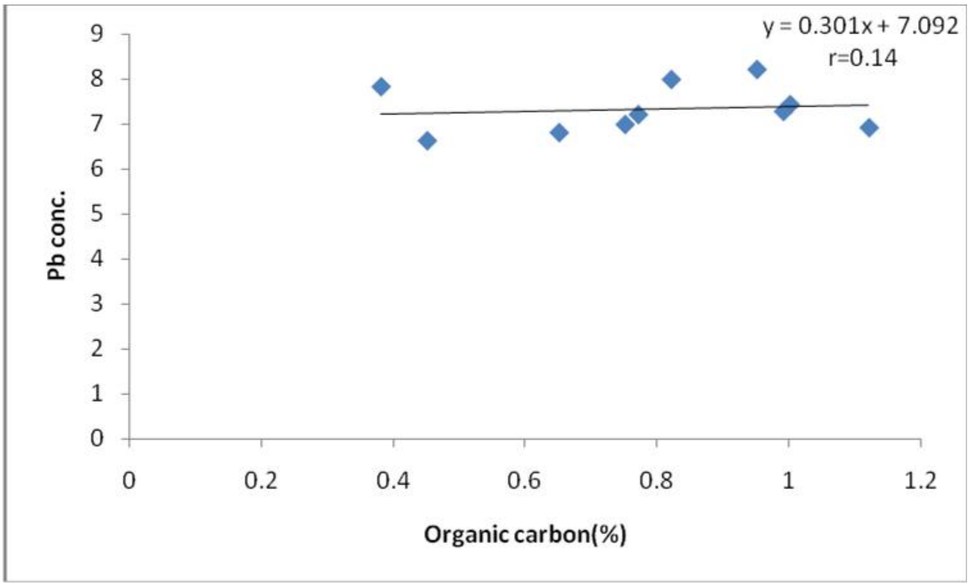

Figure 9: Correlation of organic carbon with Pb concentration

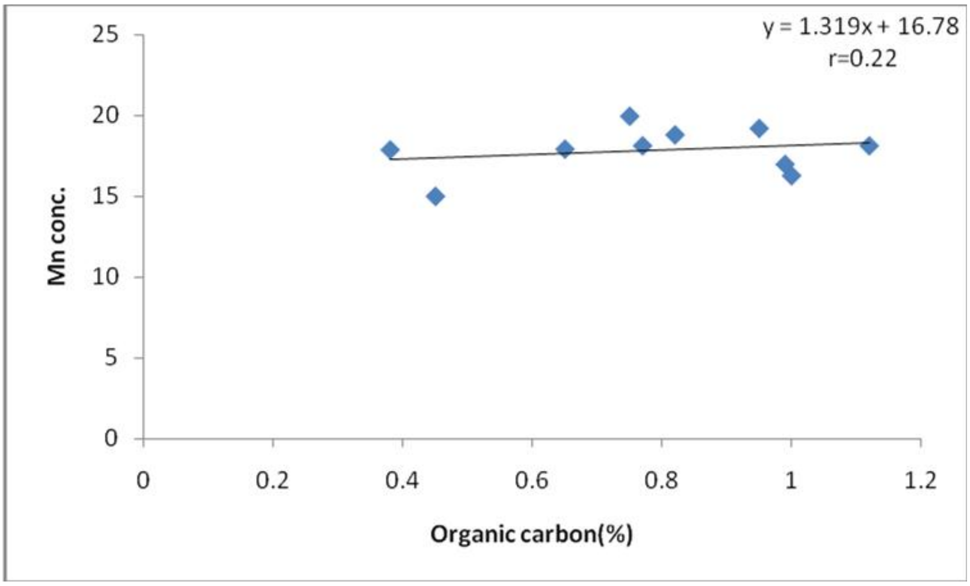

Figure 10: Correlation of organic carbon with Mn concentration

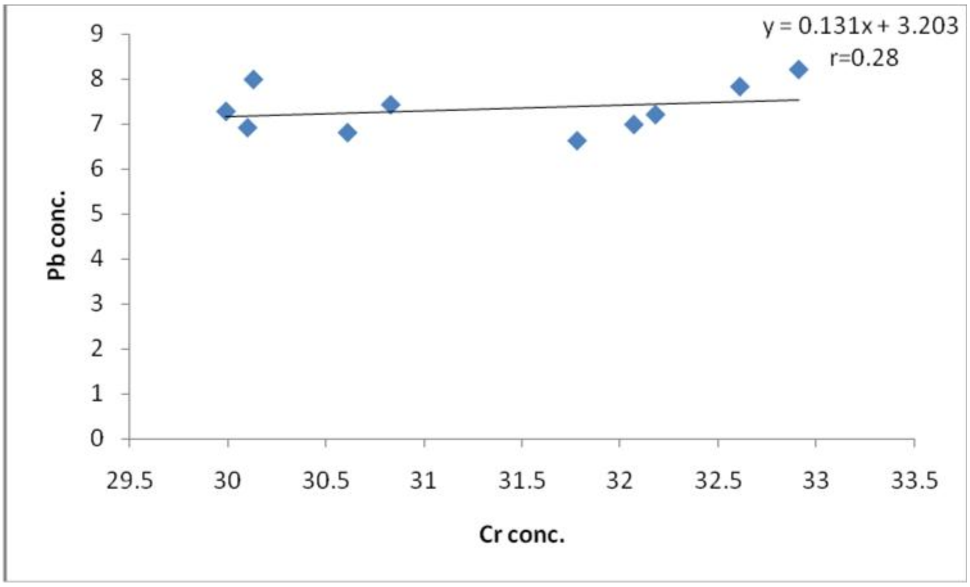

Figure 11: Correlation of Cr concentration with Pb concentration

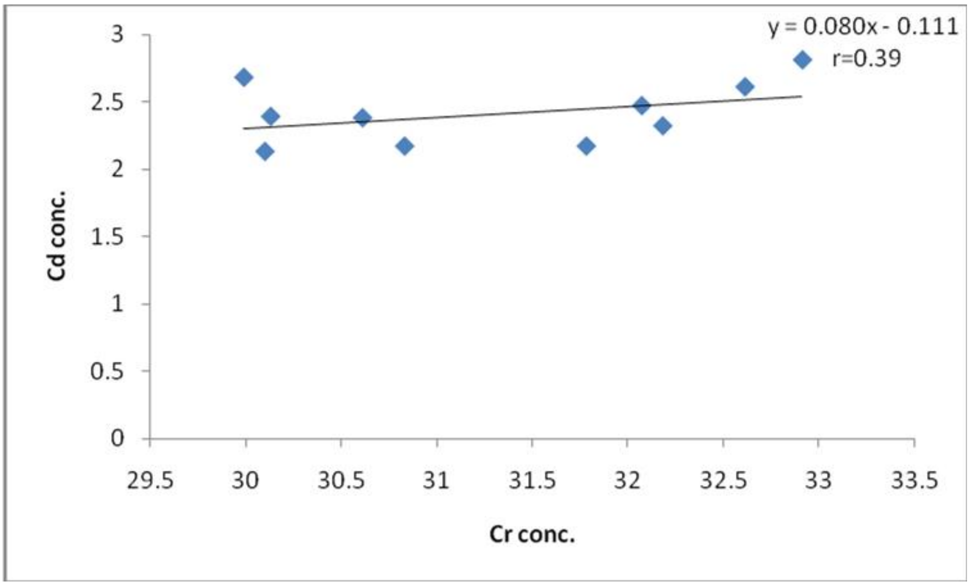

Figure 12: Correlation of Cr concentration with Cd concentration

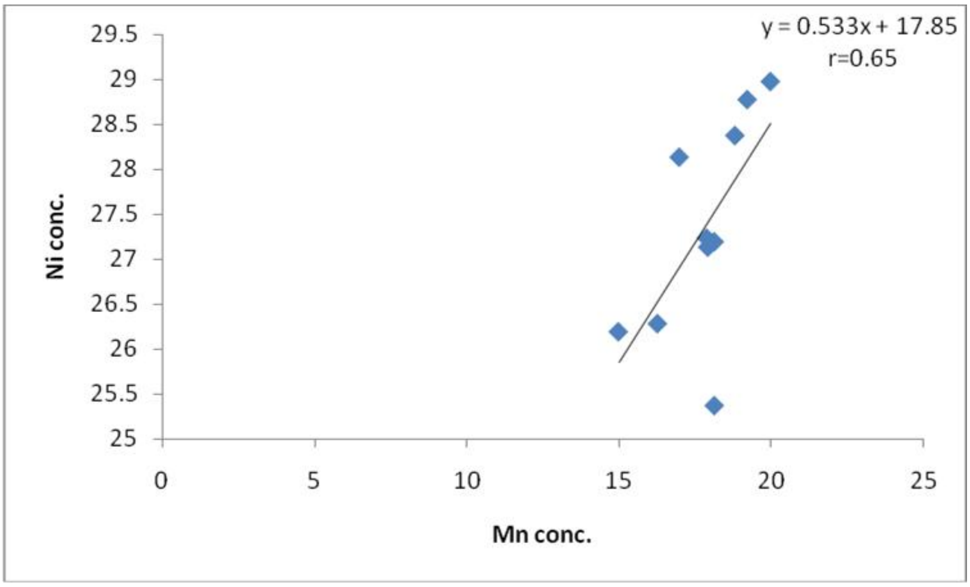

Figure 13: Correlation of Mn concentration with Ni concentration

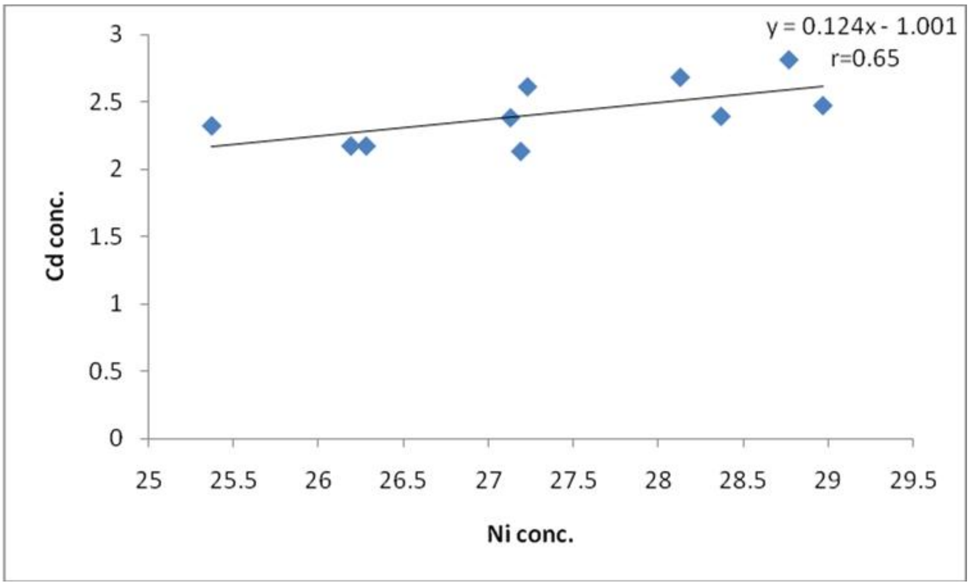

Figure 14: Correlation of Ni concentration with Cd concentration

Table 8. Total Pb, Cd, Ni, Co, Cr and Mn concentrations in vegetables of polluted areas at Gazipur

Sl. No.	**Name of vegetables**	**Concentrations(µg g^{-1})**					
		Pb	Cd	Ni	Co	Cr	Mn
1.	Red amaranth	0.893	0.376	5.10	1.41	6.79	7.92
2.	Amaranth	0.957	0.519	4.39	1.62	5.09	6.37
3.	Spinach	0.723	0.619	5.32	1.21	7.32	6.72
4.	Cabbage	0.516	0.411	4.90	1.39	4.39	9.33
5.	Cauliflower	0.612	0.539	4.13	1.28	9.37	6.28
6.	Tomato	0.312	0.129	3.12	1.09	3.78	8.12
7.	Chili	0.298	0.389	4.16	1.11	2.98	6.13
8.	Bottlegourd	0.587	0.223	5.32	1.21	3.68	7.19
9.	Potato	0.592	0.216	4.39	1.07	3.63	6.98
10.	Onion	0.397	0.128	3.99	1.32	4.38	5.74

4.9 Heavy metal concentrations of vegetables in non-polluted area at Gazipur(inside of BARI)

The soils inside of BARI are in developed condition. Various vegetables are cultivated here mostly for field experimentation. But for this present study; some vegetables were collected from these plots. The total Pb, Cd, Ni, Co, Cr and Mn concentration of the collected vegetables were below the limit of tissue generalized for various species and very well below the tolerable limit for agronomic crops (0.05-0.50mgkg^{-1}) (Appendix III).

4.10 Heavy metal concentrations in vegetables of polluted areas at Gazipur

4.10.1 Lead (Pb) concentration in vegetables

The maximum concentration of Pb in vegetables was found in Amaranth plot (1.67 µg g^{-1}) and the lowest Pb concentration was recorded in onion plot (0.521 µg g^{-1}) showed in Table 9.The Pb concentrations of leafy vegetables varied from 1.02 µg g^{-1} in Cabbage to 1.67 µg g^{-1} in amaranth. Average value was 1.34 µg g^{-1}. Among the fruity vegetables the Pb concentrations ranged from 0.528 µg g^{-1} in chili to 1.10 µgg^{-1} in cauliflower, average value was0.83 µg g^{-1} while in case of roots and tubers it ranged from 0.521 µg g^{-1} in onion to 0.937 µg g^{-1} in potato, average value was 0.73 µg g^{-1}. All the values of the vegetables were below the limit of excessive or toxic concentration level (30 - 300 mg kg^{-1}) in mature leaf tissue generalized for various species and very well below the tolerable limit for agronomic crops (0.5 – 10 mg kg^{-1}) (Appendix III).

The vegetables can be arranged in order of descending Pb concentrations (µg g^{-1}) asamaranth(1.67)>redamaranth(1.37)>spinach(1.28)>cauliflower(1.10)>bottlegourd(1.07)>cabbage(1.02)>potato(0.937)>tomato(0.629)> chili (0.528)>onion(0.521). All vegetable samples contain Pb below the maximum permissible level of 2 µgg^{-1} for vegetables (Lead in Food Regulations, 1961).

Thomas *et al.,* (1972) stated that the concentrations of Pb in potato, tomato, lettuce were and cabbage was in the range of 0.01 – 3.85 l µg g^{-1}. Alam and Chakrabarty (2000) found that the mean concentration of Pb in cabbage, cauliflower, tomato, potato, brinjal were 0.53, 1.13, 3.00, 0.38 and 0.08 µg g^{-1}, respectively. Hoque (2003) stated that the mean concentration of Pb in spinach, cabbage, tomato, bitter gourd, brinjal, bean, cauliflower, potato and onion were 0.70, 0.59, 0.17, 0.41, 0.55, 0.42, 0.03, 0.25, 0.31, 0.46 µg g^{-1}, respectively.

The status of Pb of this present study falls within the limit and all the vegetables contain Pb lower than the toxic limit and safe for human consumption resembles with references of these above findings.

The status of Pb in the collected vegetables in this study is not alarming yet or toxic or poisonous for health. The submission of limestone and phosphatic fertilizers and manures, use of excessive pesticides and abnormal use of waste material in agricultural land implies an inevitable corporation of heavy metals.

4.10.2 Cadmium (Cd) concentration in vegetables

The maximum concentration of Cd in vegetables was found in spinach (1.21µg g^{-1}) and the lowest Cd content was recorded in tomato (0.317 µg g^{-1}) showed in Table 9. The Cd concentrations of leafy vegetables varied from 0.987 µg g^{-1} in cabbage to 1.21 µg g^{-1} in spinach, average value was 1.10 µg g^{-1}. All the values of vegetables were below the limit of excessive or toxic concentration level (5 - 30 mg kg^{-1}) in mature leaf tissue generalized for various species and very well below the tolerable limit for agronomic crops (0.05 - 0.50 mg kg-1) (Appendix III).

Among the fruity vegetables, the Cd concentrations ranged from 0.317 µg g^{-1} in tomato to 1.08 µg g^{-1} in cauliflower average value was 0.63 µg g^{-1}. While in case of roots and tubers it ranged from 0.318 µg g^{-1} in onion to 0.396 µg g^{-1} in potato and average value was 0.36 µg g-1.

The vegetables can be arranged in order of descending Cd concentrations(µg g-1) as spinach (1.21)> red amaranth(1.12)> amaranth(1.09)> cauliflower (1.08)> cabbage (0.987)> chili (0.598)> bottlegourd (0.513) >potato (0.396) >onion(0.318)>tomato(0.317). Hadi *et al.*, (1995) stated that the concentrations of Cd in cabbage, red amaranth, potato, tomato, brinjal, cauliflower and bean were 0.35, 1.16, 0.35, 0.41, 0.30, 0.28 and 0.26µgg^{-1},respectively. Alamgir and Chakrabarty, (2000) found that the mean concentration of Cd in cabbage, cauliflower, tomato, potato, brinjal were 0.39, 0.31, 0.56, 0.46 and 0.26 µg g^{-1}, respectively. Hoque, (2003) stated that the mean concentration of Cd in spinach, cabbage, red amaranth, tomato, bitter gourd, brinjal, bean, cauliflower, potato and onion were 0.25, 0.29, 0.33, 0.28, 0.24, 0.28, 0.23, 0.13, 0.27, 0.21 µg g^{-1}, respectively.

The present study is very close to their above findings and all the vegetables contain Cd lower than the lethal limit and secure for human consumption in the study areas.

4.10.3 Nickel (Ni) concentration in vegetables

The maximum concentration of Ni in vegetables was found in spinach plot (8.19 μg g^{-1}) and the lowest Ni content was recorded in onion plot (5.12 μg g^{-1}) showed in Table 9.All the values of Ni in the collected vegetables were below the limit were excessive or toxic concentration level (10 - 100 mg kg^{-1}) in mature leaf tissue generalized for various species and well below the tolerable limit for agronomic crops (1 -10) (Appendix III) and also found below the critical concentrations level of growth depression (20 - 30 mg kg^{-1}) (Appendix IV).

The Ni concentrations of leafy vegetables varied from 6.78 μg g^{-1} in cabbage to 8.19 μg g^{-1} in spinach average value was 7.57 μg g^{-1}. Among the fruity vegetables, the Ni concentrations ranged from 5.78 μg g^{-1} in cauliflower to 7.79μg g^{-1} in bottlegourd, average value was 6.72μg g^{-1}. While in case of roots and tubers it ranged from 5.12 μg g^{-1} in onion to 7.22μg g^{-1} in potato, average value was μg g^{-1}.

The vegetables can be arranged in order of descending Ni concentrations(μg g^{-1}) as spinach (8.19)> red amaranth (7.93)> bottlegourd (7.79)> amaranth (7.39)> chili (7.31) > potato (7.22)> cabbage(6.78)> tomato(5.98)> cauliflower (5.78)> onion (5.12). Monjur morshed (2012) found that the Ni concentrations of leafy vegetables having an average of 19.46 μg g^{-1}. Naser *et al*., (2011) carried an experiment on leafy vegetables in BARI, Gazipur and found the Ni concentrations were within permissible limits.

The grade of Ni of the present study falls within the safe limit and all the vegetables contain Ni lower than the toxic limit and secure for human consumption in the studied areas resembles with these above findings.

4.10.4 Cobalt (Co) concentration in vegetables

The maximum concentration of Co in vegetables was found in red amaranth (3.27 μg g^{-1}) and the lowest Co content was recorded in bottlegourd (2.07 μg g^{-1}) showed in Table 9.All the values of Co in the collected samples were below the limit were excessive or toxic concentration level (5 - 30 mg kg^{-1}) in mature leaf tissue generalized for various species and well below the tolerable limit for agronomic crops (2.0) (Appendix III).

The Co concentrations of leafy vegetables varied from 3.27 μg g^{-1} in red amaranth to 2.18 μg g^{-1} in cabbage, average value was 2.53μg g^{-1}. Among the fruity vegetables, the Co concentrations ranged from 2.31 μg g^{-1} in cauliflower to 2.07μgg^{-1} in bottlegourd and average value was 2.15 μg g^{-1}. In case of roots and tubers the Co concentrations ranged from 2.10 μg g-1 in potato to 2.09 μg g^{-1} in onion and average value was 2.10 μg g^{-1}.

The vegetables can be arranged in order of descending Co concentrations(μg g-1) as red amaranth (3.27) > spinach (2.49) > cauliflower (2.31) > amaranth(2.19) > cabbage(2.18)>tomato (2.11) > potato(2.10) >chili,onion(2.09)>bottlegourd(2.07). Leafy vegetables contain more Co than fruity or roots and tuber vegetables resulted in this study. Application of organic fertilizers and manures and adoption of IPM can be a vital alternative to meet the requirement of nutrients and soil testing should make popular implementation among farmers. Among farmers awareness should be build against farming practices that can lead towards Co contamination.

4.10.5 Cromium (Cr) concentration in vegetables

The maximum concentration of Cr in vegetables was found in cauliflower(17.61μgg^{-1}) and the lowest Cr content was recorded in Chili (3.95 μgg^{-1}) showed in Table 9.All the values of Cr in the collected vegetables were below the limit were excessive or toxic concentration level (5 - 30 mg kg^{-1}) in mature leaf tissue generalized for various species and well below the tolerable limit for agronomic crops (2.0) (Appendix III) and also found below the critical concentrations level of growth depression (1 - 2 mg kg^{-1}) (Appendix IV).

The Cr concentrations of leafy vegetables varied from 10.03 μg g^{-1} in amaranth in to 13.12 μg g^{-1} in spinach, average value was 11.27 μg g^{-1}. Among the fruity vegetables, the Cr concentrations ranged from 3.95 μg g-1 in chili to 17.61 μg g^{-1} in cauliflower, average value was 8.62 μg g^{-1} . In case of roots and tubers the Cr concentrations ranged from 5.97μg g^{-1} in potato to 6.37 μg g^{-1} in onion and average value was 6.17

μg $g^{-1.}$ Monjur morshed (2012) found that, in case of roots and tubers the Cr concentrations having an average of 9.71 μg g^{-1} **.**

The vegetables can be arranged in order of descending Cr concentrations (μg g^{-1}) as cauliflower (17.61) > spinach(13.12) >red amaranth (11.62) >cabbage (10.31) > amaranth(10.03)>tomato(6.99)>onion(6.37)>potato(5.97)>bottlegourd(5.92)>chili(3.95).

The results clearly showed that leafy vegetables contain more Cr than fruit or roots and tuber vegetables. Use of organic fertilizers and manures and implementation of IPM can be a very vital substitute to meet the requirement of nutrients and soil testing should make popular among farmers. Awareness should be raised among farmers against farming practices that can lead towards Cr contamination.

4.10.6 Manganese (Mn) concentration in vegetables

The maximum concentration of Mn in vegetables was found in cabbage (17.10 μg g^{-1}) and the lowest Mn content was recorded in onion (9.37 μg g^{-1}) showed in Table 9.The Mn concentrations of leafy vegetables varied from 12.08 μg g^{-1} in spinach to 17.10 μg g^{-1} in cabbage and average value was 14.29 μg g^{-1}. Among the fruity vegetables, the Mn concentrations ranged from 11.82 μgg^{-1} in chili to 13.81 μg g^{-1} in cauliflower, average value was 12.56 μg g^{-1}; while in case of roots and tubers it ranged from 9.37 μg g^{-1} in onion to 13.97 μg g^{-1} in potato and average value was 11.67 μg g^{-1}. Monjur morshed (2012) found that, among the fruity vegetables, the Mn concentrations having an average of 39.88 μg $g^{-1.}$

The vegetables can be arranged in order of descending Mn concentrations(μg g^{-1}) as cabbage (17.10)> red amaranth(14.35)> potato(13.97)> cauliflower (13.81)> amaranth(13.61)>bottlegourd(12.68)>spinach(12.08)>tomato(11.93)>chili(11.82>onion (9.37) showed in Table 9.

Hoque (2003) stated that the mean concentration of Mn in spinach, cabbage, red amaranth, tomato, bitter gourd, brinjal, bean, cauliflower, potato and onion were 47.7, 28.89, 28.70, 40.78, 22.40, 26.28, 31.95, 28.76, 29.86 and 19.93 μg g^{-1}, respectively .

All the values of Mn were below the limit were excessive or toxic concentration level (400 - 1000 mg kg^{-1}) in mature leaf tissue generalized for various species and well below the tolerable limit for agronomic crops (300 mg kg^{-1}) (Appendix III).

Table9.Total Pb, Cd, Ni, Co, Cr and Mn concentration in vegetables of polluted areas at Gazipur

Sl no.	**Vegetables**	**Heavy metals concentration (µg g^{-1})**					
		Pb	Cd	Ni	Co	Cr	Mn
1.	Red amaranth	1.37	1.12	7.93	3.27	11.62	14.35
2.	Amaranth	1.67	1.09	7.39	2.19	10.03	13.61
3.	Spinach	1.28	1.21	8.19	2.49	13.12	12.08

4.	Cabbage	1.02	0.987	6.78	2.18	10.31	17.10
5.	Cauliflower	1.10	1.08	5.78	2.31	17.61	13.81
6.	Tomato	0.629	0.317	5.98	2.11	6.99	11.93
7.	Chili	0.528	0.598	7.31	2.09	3.95	11.82
8.	Bottlegourd	1.07	0.513	7.79	2.07	5.92	12.68
9.	Potato	0.937	0.396	7.22	2.10	5.97	13.97
10.	Onion	0.521	0.318	5.12	2.09	6.37	9.37
	Range	o.521-1.67	o.317-1.21	5.12-8.19	2.07-3.27	3.95-17.61	9.37-17.1
	Mean	**1.013**	**0.763**	**6.939**	**2.29**	**9.189**	**13.072**

CHAPTER V
SUMMARY AND CONCLUSIONS

Summary

Heavy metal contamination is one of the most serious ecological problems on a world scale and also in our country. A study was undertaken for the determination of the status of heavy metals in non-polluted soils and polluted soils, and vegetables both from non-polluted areas and also from intensively growing cropping areas of Gazipur. Around Sixty soil samples and Sixty vegetable samples were collected from Gazipur district. The polluted soil samples were collected nearly from drains, bus stands and also from railway station. The surface of vegetable samples were washed with water. The vegetable and soil samples were then brought to the Department of Soil Science laboratory, BARI, Gazipur. In the laboratory, the vegetable samples were slice into small pieces and air dried and finally, oven dried. Pb, Cd, Ni, Co, Cr and Mn concentration in soils and vegetables were determined by Atomic Absorption Spectrophotometer (AAS) and were analyzed for texture, pH and organic matter content.

In case of non-polluted soils, sandy loam was dominant textural class of most of the soil samples and clay loam was dominant in polluted soils. The polluted soils were slightly acidic to neutral in nature and the non-polluted soils were neutral to slightly alkaline in nature. Soil samples from both categories were low in organic carbon content. There was wide dissimilarity observed in the levels of Pb, Cd, Ni, Co,Cr and Mn in soils of both non-polluted and polluted soils. Most of the heavy metals in both non-polluted and polluted soils were positively correlated with sand and negatively correlated with silt. There was no significant correlation between heavy metal content with soil pH or organic matter in both non-polluted and polluted soils with very few exceptions. Most of the heavy metals tested do not have any significant correlation with each other but Cr showed significant correlation with maximum number of heavy metals in both non-polluted and polluted soils (Namely Pb, Cd, Ni, Co and Mn). The

negative correlation occurs because combined physiological outcome of two or more elements is less than the sum of their independent outcome, and positive correlation occurs because the combined outcome of these elements is greater. (Olsen, 1972; Foy *et al.*,1978).

There was a wide variation observed in Pb, Cd, Ni, Cr,Co and Mn concentration of different types of vegetables tested. The mean Pb concentration in leafy vegetables was 1.34 μg g^{-1}, 0.83 μg g^{-1} in fruits and 0.73 μg g^{-1} in roots and tubers, mean Cd concentration in leafy vegetables was 1.10 μg g^{-1}, 0.63 μg g^{-1} in fruits and 0.36 μg g^{-1} in roots and tubers, mean Ni concentration in leafy vegetables was 7.57 μg g^{-1}, 6.72 μg g^{-1} in fruits and 6.17 μg g^{-1} in roots and tubers, mean Cr concentration in leafy vegetables was 11.27 μg g^{-1}, 8.62 μg g^{-1} in fruits and 6.17 μg g^{-1} in roots and tubers , mean Co concentration in leafy vegetables was 2.53μg g-1, 2.15μg g^{-1} in fruits and 2.10 μg g^{-1} in roots and tubers, mean Mn concentration in leafy vegetables was 14.29μg g^{-1}, 12.56 μg g^{-1} in fruits and 11.67 μg g-^{1} in roots and tubers.

However, findings of this present study indicate that no element exceeded the maximum acceptable concentration (MAC) for crop production or below the contamination level for soils and for crop production. Heavy metal concentrations in all the tested vegetable samples were below the tolerable limit or below the toxic or excessive levels considered to be harmful for human consumption in the studied areas. So, it can be concluded that the findings of the study are not alarming yet but still care should be taken properly so that it cannot go above the critical level.

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Conclusion

- ✓ Most of the heavy metals (Pb, Cd, Ni, Co, Cr and Mn) concentration was found lower both in soil and vegetables except Cr which found higher in concentration.
- ✓ The concentration of heavy metals in leafy vegetables was higher compared to fruit, tuber and root vegetables.
- ✓ The heavy metals showed significant positive and negative relationship with each other.

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Appendix 1. Ranges of Maximum Allowable Concentrations (MAC) for Trace Metals in Agricultural Soils (mg kg^{-1})

SL. No.	Metal	MAC a
1.	Cd	1–5
2.	Cr	50-200
3.	Ni	20–60
4.	Pb	20–300
5.	Mn	1500-3000

a Ethics reported most commonly in the literature, compiled from Kabata Pendias A., Sadurski W.2004. Elements and their compounds in the environment, 2 ed. 79–99, Wiley-VCH, Weinheim; Chen Z.-S. 1999. Selecting indicators to evaluate soil quality. Accessed April1999: http://www.fftc.agnet.org

Appendix 2. Guidelines for contaminated soils – suggested range of values (mg kg^{-1} on air dried soils, except for pH)

Parameter	**Typical values for uncontaminated soil**	**Slight contamination**	**contaminated**	**Heavy contamination**	**Usually Heavy Contamination**
Cadmium	0-1	1-3	3-10	10-50	50
Chromium	0-100	100-200	200-500	500-2500	2500
Lead	0-500	500-1000	1000-2000	2000-1.0 %	1.0%
Nickel	0-20	20-50	50-200	200-100	1000
Manganese	0-500	100-200	200-500	500-2500	1.0%

Source: information compiled from the text book , “A textbook of environmental science”(part 1). Sattar , M.A. 1996. Mymensingh.

Appendix 3. Approximate concentrations of trace elements in mature leaf tissue generalized for various species (mg kg^{-1})

SL. No.	Element	Excessive or Toxic	Tolerable in Agronomic Crops*
1.	Cd	5-30	0.05-.5
2.	Cr	5-30	2
3.	Mn	400-1000	300
4.	Ni	10-100	1-10
5.	Pb	30-300	0.5-10

Source:

- Kabata-Pendias, A. and Pendias, H., Biogeochemistry of Trace Metal Elements, 2nd ed., Wyd. Nauk PWN, Warsaw, 400, 1999 (Po).

➢ Macnicol, R. D. and Beckett, P. H. T., Critical tissue concentrations of potentially lethal elements, *Plant Soil*, 85, 107, 1985.

Appendix 4. Critical Concentrations of Trace Metals in Plant Tissues (mg kg^{-1})

Metal	Levels of Growth Depression	
	Insensitive Plant Species[1]	For 10% Yield Loss[2]
Cd	5-10	10-20
Cr	1-2	1-10
Ni	20-30	10-30

Source: Information compiled from Kabata-Pendias, A. 2011. Trace Elements in Soils and Plant, 4th ed., CRC press, Boca Raton. 5: 115

1. Kloke *et al.* (1984)
2. Macnicol and Beckett (1985)

Appendix 5: Climatic conditions at Gazipur from November, 2016 to January 2017

Temperature(centigrade)		Humidity (%)		Annual rainfall(mm)
Nov-Dec	**January**	**Nov-Dec**	**January**	
16-18(max.)	15-16(max.)	55(max.)	50(max.)	1547
14(min.)	13.6(min.)	51(min.)	48(min.)	

Source: Meteorological Department, Gazipur.

Plate 1: Sample collection from Amaranth plot (non-polluted area)

Plate 2: Sample collection from Red amaranth plot (non-polluted area)

Plate 3: Sample collection near from a wastage dump (Polluted area)

Plate 4: Sample collection near from a drain (polluted area)

Plate 5: Sample collection near from a submerge pond (polluted area)

Plate 6: Sample collection near from an industrial area (polluted area)