ASSESSMENT OF DIFFERENT HEAVY METALS OF WINTER VEGETABLES GROWN AT DIFFERENT PLACES OF SAVAR THANA UNDER DHAKA DISTRICT

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CERTIFICATE

This is to certify that the thesis entitled "ASSESSMENT OF DIFFERENT HEAVY METALS OF WINTER VEGETABLES GROWN AT DIFFERENT PLACES OF SAVAR THANA UNDER DHAKA 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 in Agricultural Chemistry, embodies the result of a piece of bona fide research work carried out by MD. MURADUL ISLAM, Registration No. 11-04620 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.

Dated:
Dhaka, Bangladesh

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Dedicated to my beloved Parents

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The Author

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ABSTRACT

The experiment was conducted in the Agro- Environmental Chemistry laboratory of the Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka-1207 during the the period from December 2016 to May 2017 to assess different heavy metals of winter vegetables grown at different places of Savar thana under Dhaka district in Bangladesh. Eleven vegetable samples were collected from four intensively growing areas of Savar thana such as Sadapur kazi para, Nama Genda, Pathalia and Vagolpur and nearest two local market ie. Savar thana bazar and Genda bazar under Dhaka district. Different types (red amaranth, radish, radish spinach, carrot, tomato, brinjal, bottle gourd spinach, fenugreek leaves, bottle gourd, turnip and spinach) of vegetable samples were collected randomly from each selected location. Vegetables were collected at the stage of harvesting from farmers field and nearest local markets. Concentrations of five heavy metals (chromium, cadmium, lead, copper, and zinc) in vegetables were estimated. The analyzed metals varied from species to species. The highest mean concentration of Pb (3.89 mg/kg) was observed in radish spinach which exceeded the permissible level (0.1 mg/kg) recommended by FAO / WHO (2011). The highest mean concentration of Cr (1.37 mg/kg) was found in red amaranth which was lower than the permissible level (2.3 mg/kg) recommended by FAO / WHO (2011). The highest mean concentration of Cd (0.20 mg/kg) was found in bottle gourd which was higher than the permissible level (0.05 mg/kg) recommended by FAO / WHO (2011).The maximum Zn concentration (2.07mg/kg) was obtained in fenugreek leaves.The highest mean concentration of Cu (1.29 mg/kg) was observed in red amaranth which was lower than the permissible level (40 mg/kg) recommended by FAO / WHO (2011).

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LIST OF ACRONYMS

Br	Bromine
Co	Cobalt
Cs	Cesium
Cr	Chromium
Cd	Cadmium
0C	Degree Celsius
DIM	Daily Intake of Metals
DDI	Daily Dietary Intake
DO	Dissolved oxygen
EC	Emulsifiable Concentrate
et al	And others
FAO	Food and Agriculture Organization
fw	fresh weight
Hg	Mercury
HQ	Hazard Quotient
INAA	International Neutron Activation Analysis
Kg	Kilogram
Li	Lithium
Mo	Molybdenum
Mn	Manganese
mg	Milligram
MAC	Maximum Allowable Concentration
Ni	Nickel
Pb	Lead
PM	Particulate matter
ppm	parts per million
PTDI	Provisional Tolerable Daily Intake
Rb	Rubidium
Sd	Standard deviation
Sb	Antimony
Sc	Scandium
Se	Selenium
Sr	Strontium
Th	Thorium
TDS	Total dissolved solids
WHO	World Health Organization
Zn	Zinc
%	Percentage

CHAPTER I
INTRODUCTION

Vegetables are part of daily diets in many households forming an important source of vitamins and minerals required for human health. They also act as neutralizing agents for acidic substances formed during digestion (Thomson and Kelly, 1990). Along with other food alternatives, vegetables are considered the cheap source of energy. Vegetables are very rich sources of essential nutrients such as carotene, protein, vitamins, calcium, iron, ascorbic acid and palpable concentration of minerals (Jimoh and Oladiji, 2005). Minerals are inorganic substances, present in all body tissues and fluids and their presence is necessary for the maintenance of certain physicochemical processes which are essential to life (Hays and Swenson,1985). Minerals may be broadly classified as macro (major) or micro (trace) elements. The macro-minerals include calcium, phosphorus, sodium and chloride, while the micro-elements include iron, copper, cobalt, potassium, magnesium, iodine, zinc, manganese, molybdenum, fluoride, chromium, selenium and sulfur (Eruvbetine, 2003). The macro-minerals are required in amounts greater than 100 mg/dL and the micro-minerals are required in amounts less than 100 mg/dl (Murray *et al*., 2000). The concentrations of these trace minerals in vegetables may vary depending on the inherent (varieties, maturity, genetics, and age) and environmental (soils, geographical locations, season, water source and use of fertilizers) conditions of plants and animals and on methods of handling and processing (Pennington and Calloway, 1973).

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). But pollution and contamination of vegetables with heavy metals such as Cadmium (Cd), Mercurry (Hg), Cobalt (Co), Nickel (Ni), lead (Pb) etc. are a serious threat because of their toxicity, bioaccumulation and bio magnifications in the food chain (Eisler, 1988). Heavy metals are very harmful because of their non-biodegradable nature, long biological half-lives and their potential to accumulate in different body parts. Most of the heavy metals are extremely toxic because of their solubility in water. Even low concentrations of heavy metals have damaging effects to man and animals because there is no good mechanism for their elimination from the body. Nowadays heavy metals are ubiquitous because of their excessive use in industrial applications. Wastewater contains substantial amounts of toxic heavy metals, which create problems (Chen *et al*., 2005).

Excessive accumulation of heavy metals in agricultural soils through wastewater irrigation may not only result in soil contamination, but also affect food quality and safety (Muchuweti *et al*., 2006). Food and water are the main sources of our essential metals; these are also the media through which we are exposed to various toxic metals. Heavy metals are easily accumulated in the edible parts of leafy vegetables, as compared to grain or fruit crops (Mapanda *et al*., 2005). Vegetables take up heavy metals and accumulate them in their edible and inedible parts in quantities high enough to cause clinical problems both to animals and human beings consuming these metal-rich plants (Alam *et al*., 2003).Generally, humans are exposed to these metals by ingestion (drinking or eating) or inhalation (breathing). Metals like iron, copper, zinc and manganese are required for metabolic activities in organisms, whereas arsenic, cadmium, chromium, mercury, nickel and lead are cumulative poisons. They have been reported to be exceptionally toxic (Ellen *et al*., 1990). Lead has been associated with intoxications leading to problems in the kidney and liver, the central nervous system, reproductive organs and anemia (IOCCC, 1996). So, these metals have been included in the regulations for hazardous metals. A big portion of our population is derived from the knowledge of including vegetables in the daily meal. Though the vegetables are comparatively cheap form the foods of animal origin and affordable by the much population, the lack of knowledge about its importance in meeting the daily micronutrients requirement is one of the principle reason behind the wide spread prevalence of malnutrition. On the other hand, lack of scientific knowledge and cultivation land, some people using abundant places, waste water, pesticides, fertilizers etc. which are significant source of heavy metals and thus contaminating vegetables grown in that condition. Now a day, people are searching alternative safe food source. So that, they tend to consume wild vegetables because, wild vegetables grow plenty naturally, need not require land to cultivate and labor. Another is they strongly believe that, wild vegetables have medicinal property and without any confusion they are consuming locally available wild plant as vegetable though nutrient content of many of which are still unknown, and people do not have adequate knowledge either those are beneficial or not, have any toxic effect on body or not. Focusing on malnutrition, food safety aspect, heavy metal contamination, nutrient composition providing and adequate nutritional information it should be a logical task to carry out a study on wild, waste water cultivated and common vegetables because it shows a great importance on broad term. So in the present study, an attempt has been taken to assessment of different heavy metals of winter vegetables in Bangladesh.

The present study was therefore, undertaken with the following objectives.

1. Determination of amount of different heavy metals (Cr, Cd, Pb, Cu and Zn) from collected vegetable samples and
2. Interpretation of the results from the level of contamination and food safety hazard points of view by comparing values with the maximum permitted levels.

CHAPTER II

REVIEW OF LITERATURE

The purpose of this chapter is to review the past research works which are related to the present study. An attempt has been made in this chapter to represent a brief review of research information to assess different heavy metals of winter vegetables grown at different places of Savar thana under Dhaka district. Since, review of literature forms a linkage between the past and present research works related to problem which helps an investigation to draw a satisfactory conclusion. The most relevant studies, which have been conducted in the recent past related to the present research work, are presented below-

2.1 Heavy metals concentrations in vegetables

The trace elements, at concentrations exceeding the physiological demand of the plants, not only could administer toxic effect in them but also could enter food chains, get biomagnified and pose a potential threat to human health (Sugiyama, 1994).

Some heavy metals such as Cu, Zn, Mn, Co and Mo act as micronutrients for the growth of animals and human beings when present in trace quantities, whereas others such as Cd, As and Cr acts as carcinogens (Freig *et al*., 1994; Trichopoulos *et al*., 1997).

Some investigations have been carried out in Bangladesh on the trace elements concentration in vegetables. Alam *et al*. (2003) analyzed vegetable samples from Samta village of Jessore district. Average Cu concentrations in leafy and non-leafy vegetables were 15.5 and 8.51 μg g^{-1}, respectively. The Zn concentrations in vegetables were in the range of 10.0- 55.0 μg g^{-1}. Lady‘s finger had the highest Zn concentration while ash gourd had the lowest Zn concentration. Islam *et al*. (2005) carried out an experiment to determine the extent of trace elements in 24 different types of vegetables grown on five intensively vegetable growing areas of Chapai Nawabganj of Bangladesh. A wide variation in concentrations of Fe and Zn among the vegetables was observed. Zinc concentrations of leafy vegetables, fruity vegetables and root & tuber vegetables ranged from 5.81-25.40 μg g-1, 9.61-30.48 μg g^{-1} and 1.98-18.5 μg g^{-1}, respectively. The average Fe concentrations of leafy vegetables (281 μg g-1) were statistically higher compared to those found in root & tuber vegetables (222 μg g^{-1}) and fruity vegetables (129 μg g^{-1}).

The concentrations of Cu, Ni, Mn and Zn in different food samples of Murshidabad district of West Bengal, India as reported by Roychowdhury *et al.* (2003) varied from 0.33-14.1μg g-1, 0.0002-7.68μg g-1, 0.22-101 μg g-1 and 0.84-64.9 μg g-1, respectively.

Arora *et al*. (2009) reported various metals in wastewater-irrigated plants as 116-378, 12-69, 5.2-16.8 and 22-46 mg kg-1 for Fe, Mn, Cu and Zn, respectively. The highest mean levels of Fe and Mn were detected in mint and spinach whereas the levels of Cu and Zn were the highest in carrot. The values of these metals were below the recommended maximum tolerable levels proposed by the FAO/WHO (2002). However, regular monitoring of levels of these metals from effluents and sewage, in vegetables and in other food materials is essential to prevent excessive build-up of these metals in the food chain.

The nutritive potential of each ingredient, in terms of trace element contents, was evaluated using instrumental neutron activation analysis (INAA). Four minor (Na, K, P and Cl) and 16 trace elements (Br, Co, Cr, Cs, Cu, Fe, Hg, Mn, Mo, Rb, Sb, Sc, Se, Sr, Th and Zn) were determined in six cereals, nine vegetables and 20 spices and condiments, including two betel leaves (Singh and Garg, 2006). None of the carbohydrate-rich cereals or potato was rich in any of the essential elements but leafy vegetables showed higher contents of Fe and other nutrients; Fe/Zn was well correlated with Fe contents in cereals and spices. Out of various spices, cinnamon was most enriched in Fe, Co, Cr, Na, K, P and Zn, whereas turmeric and curry leaves were found to be particularly rich in Se. Cumin and mustard seeds were rich in Cu. Some environmental contaminants, such as Hg, Cr, Br and Th, were also present in significant amounts. An attempt was made to evaluate the contribution of essential elements (Cr, Cu, Fe, Mn, P, Se and Zn) in spices to the daily dietary intake (DDI) through an Indian vegetarian diet. For a typical mixture of six commonly used spices, contributions of Cr, Fe, Mn and Zn, were found at 7.5% of DDI in each case.

Al-Rmalli *et al*. (2011) reported that betel quid chewers had a significantly higher mean Mn concentration in urine (1.93 µg L-1) compared to non-chewers (0.62 µg L-1). High levels of Mn were detected in piper betel leaves with an overall average of 135 mg kg-1 (range 26 -518 mg kg-1). The mean concentration of Mn in betel quid was 41 mg kg-1 and the daily intake of Mn in the Bangladeshi population was estimated to be 20.3 mg day-1. Chewing six betel quids could contribute up to 18% of the maximum recommended daily intake of Mn.

Spallholz *et al*. (2008) determined that concentrations of Se in rice, vegetables and fishes from different areas of Bangladesh. The average Se concentration of rice was 0.111 ±0.015 mg/kg with a range of 0.07-0.16 mg kg-1. Such levels were similar to See levels in rice from China (Chien et al. 2002) but are low in comparison to the reported Se levels in rice from Louisiana in the U.S., reported to contain 0.46 mg Se kg-1. The mean Se value for rice from Bangladesh was higher than Se values of 0.012 mg kg-1 of rice from the Keshan diseased areas of China. Gourds and potatoes from Jessore averaged 0.471 and 0.181 mg Se kg-1, respectively.

Lithium is taken up by all plants, although it appears not to be required for their growth and development. However, this question is not yet completely resolved, since, in the ppb range, stimulatory effects of lithium on plant growth have been observed (Schweigart, 1962). At high levels in the soil, Li is toxic to all plants, causing a chlorosis-like condition. Uptake and sensitivity to lithium are species dependent. Some plants, notably *Cirsium arvense* and *Solanum dulcamera*, accumulate Li three- to six-fold over other plants. Halophilic plants such as *Carduus arvense* and *Holoschoenus vulgaris* may reach lithium contents of 99.6–226.4 μg g^{-1} (Tolgyesi *et al*., 1983). Lithium is relatively toxic to citrus plants; nightshade species are remarkably lithium tolerant and may reach lithium contents of up to 1000 μg g^{-1}.

Although Cu is an essential micronutrient for normal plant metabolism, playing an important role in a large number of metallo enzymes, photosynthesis-related plastocyanin, and membrane structure, copper has been reported to be among the most toxic of heavy metals (Li and Xiong, 2004). Excess Cu inhibits plant growth and seed germination, induces chlorophyll degradation, and interferes with photosystem activity (Caspi *et al*., 1999).

Samples of vegetables, water, and soil were collected from four vegetables farms in Addis Ababa to evaluate the extent and trend of metal accumulation in these systems and health risk concerns to consumers (Weldegbriel, *et al.,* 2012). The concentrations of Cd (0.012-1.13 mg kg-1) and palladium (Pd) (011-0.89 mg kg-1) in the vegetables surpassed the maximum recommended levels. The total metal concentrations in soils were (mg kg-1): Cr, 9.9-22.8; Co, 28.0-47.3; Cu, 25.1-51.4; Mn, 1000-1054; Ni, 16.4-

55.8; Zn, 146-149; Cd, 1.4-1.8 and Pb, 220-50.7. The trace metals Cd, Co, Cu, Mn and Ni in most of the water samples also surpassed irrigation guidelines limits, which might be a case for high accumulation of metals in Addis Ababa soils.

Naturally, Mn occurs in many food sources, such as leafy vegetables, nuts, grains and animal products (IOM, 2002). Typical ranges of Mn concentrations of nuts and nuts products are from 18.21 to 46.83 mg kg-1, grains and grain products from 0.42 to 40.70 mg kg^{-1}, legumes from 2.24 to 6.73 mg kg^{-1}, fruits from 0.20 to 10.38 mg kg^{-1}, vegetables and vegetable products from 0.42 to 6.64 mg kg^{-1}, respectively (ASTDR, 2000).

Chemically, trivalent Cr is non-toxic and necessary for humans, while the hexavalent form is toxic. Vegetables and fruits that contain high amounts of chromium are tomato, spinach, broccoli (11 mcg chromium in half cup), onion, garlic, dry basil leaves (2 mcg in 1 tbsp), lettuce, fresh chili, green pepper, beet, mushroom, rye, apple (1 mcg in 1 cup), orange juice (2 mcg in 1 cup) and grape juice (8 mcg in 1 cup) (ATSDR, 1989).

Islam *et al*. (2012) observed the amount of Zn in different arums, bananas, vegetables and pulses which are locally available in Chittagong region of Bangladesh. The amount of Zn in twenty samples of arums was found to vary from 0.3174-9.0755 μg g^{-1}. The highest and lowest value was found in arums of *Typhonium trilobatum* (Patiya) and *Amorphophallus campanulatus* (Satkaniya) respectively. In bananas the concentration of Zn varied from 0.1430 to 2.7360 μg g-1. The highest and lowest value was found in banana of *Musa acuminata*in Satkania and Ramgarh upazila respectively. The amount of Zn in vegetables was found to vary from 0.92-7.59 μg g-1. Zinc in pulses was found to vary from 1.29-29.50 μg g-1. The highest and lowest values were found in *Lathyrus sativus* and *Phaseolus aureus*, respectively. From four types of food, the highest value of Zn was found in pulse species of *Lathyrus sativus* and the lowest value of Zn in banana species of *Musa acuminate* respectively of Chittagong region, Bangladesh.

Concentrations of Cu, Zn, Pb, Cr, Cd, Fe, and Ni have been estimated in soils and vegetables grown in and around an industrial area of Bangladesh. The order of metal contents was found to be Fe >Cu >Zn >Cr >Pb>Ni >Cd in contaminated irrigation water, and a similar pattern Fe >Zn >Ni >Cr >Pb>Cu >Cd was also observed in arable soils. Metal levels observed in different sources were compared with WHO, SEPA, and established permissible levels reported by different authors. Mean concentration of Cu, Fe, and Cd in irrigation water and Cd content in soil were much above the recommended level. Accumulation of the heavy metals in vegetables studied was lower than the recommended maximum tolerable levels proposed by the Joint FAO/WHO Expert Committee on Food Additives, with the exception of Cd which exhibited elevated content. Uptake and translocation pattern of metal from soil to edible parts of vegetables were quite distinguished for almost all the elements examined (Ahmad and Gani, 2010).

Naser, *et al*. (2011) conducted to compare and investigate the concentration levels of heavy metals in leafy vegetables with growth stage and plant species variations on an experimental field near the net house of Soil Science Division, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur, Bangladesh during November 2008 to January 2009. Seeds of spinach (*Spinacia oleracea*), red amaranth (*Amaranthus tricolor*) and amaranth (*Amaranthus oleraseus*) were sown on 14 November 2008. Plant and soil samples were collected at different growth stages, such as at 20, 30, 40, and 50 days after sowing (DAS). The concentrations of lead (Pb), cadmium (Cd), nickel (Ni), cobalt (Co), and chromium (Cr) in plant increased with the age of the plant, but the increase was not linear. The rate of increase of concentration of these metals at 20 to 30 DAS was found lower than that at 30 to 40 DAS, except Cr. Heavy metal content gradually increased at the early growing stage and fall during later stages of growth. The significant differences ($P < 0.01$) were observed between the mean metal concentrations in the three vegetables species. The Pb and Co concentrations in amaranth were found higher compared to those found in spinach and red amaranth. Spinach exhibited higher levels of Cd and Cr than those of other vegetables. However, the three vegetables did not differ significantly in its Ni concentration. The order of heavy metal level in different vegetables was Cd<Co<Pb<Ni<Cr. In vegetable species in respect of heavy metal concentration Cd, Ni, and Cr was highest in spinach and amaranth showed highest concentration in Pb and Co. The highest correlation between soil-plant was found for Cd, while the lowest for Ni. Metal concentrations in the vegetables studied were found lower than the maximum allowable level in India but the concentrations of Cd and Cr were higher than the allowable levels set by the World Health Organization (WHO).

Islam and Hoque. (2014) conducted to evaluate the concentration of heavy metals in eight different vegetables species around industrial area of Dhaka city Bangladesh. Metals were measured by inductively coupled plasma mass spectrometry after microwave digestion system. The levels of Cr, Ni, Cu, Zn, As, Cd and Pb in vegetables were 0.61 to 3.0, 1.6 to 12, 8.3 to 34, 16 to 119, 0.007 to 0.24, 0.009 to 1.0 and 0.06 to 3.5 mg/kg fw, respectively. There were differences in the concentrations of metals between vegetables species. Potential health risks of heavy metals to the local population via vegetables consumption were estimated. The health risks of Cr, Cu, As, Cd and Pb should be of great concern due to vegetables consumption.

Linkon *et al.* (2015) was carried out to assess minerals and heavy metals content of some non-conventional wild vegetables, commonly edible vegetables from fresh water cultivated unknown sources and waste water irrigated vegetables available in Dhaka city, Bangladesh. In total of 16 vegetables samples were analyzed by using standard analytical methods of atomic absorption spectrophotometer, UV spectrophotometer and flame emission spectrophotometer. Vegetable samples were collected from three sites and analyzed for their minerals and metals concentrations. Results reveal that the essential mineral Ca, Na, K, Mg and essential trace element Fe, Zn found were ranged from 171.01 - 932.69 , 91.26 - 655.62 , 107.50 - 864.28 , 56.49 - 920.67 and 3.5-74.92 , 0.8429.45mg/100 grespectively in three types of vegetables. In case of heavy metals Cu, Cr and Ni were found in all samples ranged from0.284-7.55, 0.034-1.10, 0.25-1.506 and 0.25-1.506 mg/100g respectively. Cd was found in waste water irrigated and fresh water cultivated vegetables ranged from 0.005-0.009 and 0.01-0.015mg/100g respectively. Pb was found in wild vegetables and the range was 0.12-0.96 mg/100g. A significant increase ($p<0.05$) in Cu, Cr, Ni, Cd and Pb were found when compared to WHO/ FAO permissible value. Hg and Co were absent in all kind of vegetables.

Concentrations of six heavy metals (chromium, nickel, copper, arsenic, cadmium, and lead) in fish and vegetables were estimated to evaluate contamination levels and health risks for Bangladeshi adults by Islam et al. (2015). Metals like Ni, Cd, and Pb in fish species were higher than the respective maximum allowable concentrations (MAC), whereas As, Cd, and Pb in some species of vegetables exceeded the MAC. Health risks associated with these metal intakes were evaluated in terms of dietary intake and target hazard quotients (THQs). The THQ values for individual metals were below 1 (except As for some species), suggesting that people would not experience significant health hazards if they ingest a single metal from one species of fish and/or vegetable. However, total metal THQ (TTHQ) signifies the potential non-carcinogenic health hazard to the highly exposed consumers in Bangladesh. Also, the estimation showed that the carcinogenic risk (TR) of arsenic and lead were within the acceptable range for fish but exceeded the accepted risk level for vegetables. From the health point of view, this study showed that the inhabitants who consume contaminated fish and vegetables are exposed chronically to metal pollution with carcinogenic and non-carcinogenic consequences.

Gouttormensen *et al.* (1995) have reported that those vegetables particularly leafy crops, grown in heavy metals contaminated soils have higher concentration of heavy metals than those grown in uncontaminated soil.

Voutsa *et al*. (1996) have reported that there have been a number of studies which have investigated atmospheric deposition of heavy metals in soil and/or vegetables growing in vicinity of industrial areas. These studies indicate high concentration of heavy metals in vegetables grown in the vicinity industries and identify leafy vegetables as greatest risk of accumulating elevated concentrations.

Anonymous. (2001) studied the high concentration of heavy metals in vegetables grown in the vicinity of industries and identify leafy vegetables at greatest risk of accumulation elevated concentrations. The national environment protection (Assessment investigation levels (ML) measures identifies environmental investigation levels (ML) also exist for Cd and Pb in vegetable crops (fresh weight basis), and are applied by the Australian and New Zealand food authority (ANZFA). Broad leafy vegetables and herbs accumulated greater concentration of most heavy metals.

Lark *et al*. (2002) reported that the content of the metals are always higher for the vegetables which have been water was replaced with tube well water some ten year before. The comparative study of the metal continuously irrigated with the sewage water alone as compared to the vegetables where irrigation with the sewage contents In the soils of the two kinds of fields gives roughly the differential accumulation of the metals in the last ten years, which results in corresponding much higher content of metals in the vegetables.

Aboaba *et al*. (2004) reported that it is important to determine the metal contents of vegetables from health, food nutrition perspective and for crop yield technology point of view. Metal accumulation in edible portions of plants varies and depends on both soil composition and rate of uptake by each plant. For good health and optimum human performance, adequate intake of essential elements and nutrients is crucial.

Kachenko and singh (2004) conducted a study on industrial activities such as smelters are a leading cause of metal emissions, often associated with elevated soil and plant metal concentrations in adjacent regions. The accumulation of Cd, Cu, Pb and Zn in soils and vegetables in the vicinity of 2 industrial regions, Port Kembla and Boolaroo, were investigated. Soil samples (n=37) were collected at depths of 0-30 and 60-90 cm, air dried and sieved to obtain 2mm fraction. Soil properties including pH, EC, organic carbon, total cation exchange capacity and total metal content were determined. Vegetable samples (n=40) predominantly leafy, included - lettuce, spinach, leek, mint and parsley. The plant samples were oven dried and analyzed for total metal content. Soil metal concentrations decreased with depth at the two sites, suggesting anthropogenic sources of contamination. The soils at Boolaroo contained the highest levels of Cd, Pb and Zn. Vegetable samples collected from Boolaroo recorded very high levels of Cd and Pb, and ≥ 95% of the samples had Cd and Pb levels exceeding the maximum level (ML) set by the Australian and New Zealand Food Authority (i.e. both Cd and Pb MLs are 0.01 mg kg -1 fresh weight). At Port Kembla 17% of the vegetable samples exceeded the ML of Cd and 44 % exceeded the ML of Pb. Correlation analysis identified a strong relationship between soil and vegetable Cu concentrations, and was strengthened by the determination of transfer coefficients. The results of this study suggest that vegetables grown in the vicinity of industrial sites are subject to atmospheric deposition of heavy metals and pose a risk to humans if consumed.

Navneet *et al.* (2005) conducted a study to investigate the presence of heavy metal and bacterial pathogen in randomly collected samples and from agricultural areas in and around Patiala. In palak (*Beta vulgaris L*), fenugreek (*Trigonellafoenum-graecum*) and coriander (*Coriandrum sativum*) heavy metals Fe, Zn, Cd, Cr, Ni and Pb were analysed by wet digestion method and total bacteria and coliforms were enumerated on TSA (Tryptone Soya Agar) and VRBA (Violet Red Bile Salt Agar) media. All vegetables had metal content in the order Fe> Zn>Pb> Cr> Ni> Cd. Only 32% palak, 26% of coriander and 23% of fenugreek samples contained Pb concentration below the permissible limit of 2.5 mg/Kg as per Indian Standard of Food Adulteration Act (PFA), 1954. Among all green leafy vegetables nearly 67-76% of samples were high in Pb, 18-39% samples were high in Zn, which crossed Indian permissible limit of 50 mg/Kg, and 6-9% samples were high in Cd, which was beyond 1.5 mg/Kg. The results indicate that the consumers are purchasing vegetables with high level of heavy metals (HMs). The total bacterial count in vegetables ranged between 250-109 cfu x104 and 5.7-6.0 log cfu/g and coliforms were in the range of 29-87 cfu x 104 and 4.8-5.6 Log cfu/g, which is an indication of improper pre harvest and post-harvest handling. The metal content in vegetables from agricultural areas indicate high levels of soil contamination and there is a potential danger of heavy metal accumulation particularly Pb and Cd in vegetables grown in vicinity of Main Village, Bahadurgarh, Sullar road, Khusropur, Bhanari and Thapar Technology Campus. Pot culture experiment showed that heavy metals were accumulated at high levels in these vegetables when irrigated with synthetic water containing high concentration of heavy metals.

Dikinya and Areola (2010) have reported that wastewater for irrigation is a relatively recent innovation in Botswana and knowledge is still limited on its impact on soil heavy metal levels. The aim of this study is to analyze and compare heavy metal concentration in secondary wastewater irrigated soils being cultivated to different crops: olive, maize, spinach and tomato in the Glen Valley near Gaborone City, Botswana. The studied crop plots have been cultivated continuously under treated wastewater irrigation for at least 3 years. Most crop farms have sandy loam, loamy sand soils. Based on food and agriculture organization, heavy metal threshold values for crop production have been studied. Results showed that the wastewater irrigated soils in the Glen Valley have higher cadmium, nickel and copper than desirable levels, while the levels of mercury, lead and zinc are lower than the maximum threshold values recommended for crop production. The control sites show that the soils are naturally high in some of these heavy metals (e.g copper, zinc, nickel) and that crop cultivation under wastewater irrigation has actually lowered the heavy metal content. Comparing between the crops, mercury and cadmium levels are highest in soils under maize and decline linearly from maize to spinach to olive to tomato and control site. By contrast, concentrations of the other metals are at their lowest in maize and then increase from maize to spinach to olive to tomato and to control site.

Iqbal *et al*. (2011) conducted a study to assess the accumulation of heavy metals (Ni, Cu, Cd, Cr, and Pb) in agricultural soils and their uptake in spring seasonal plants being irrigated by industrial waste water. For this purpose three peri-urban agricultural areas of Central Punjab Province were selected where irrigation is usually done by waste water or industrial sewage. Ten samples each of soil, waste water and plants were collected from the selected areas and were analyzed for pH, EC, Cr, Cd, Pb, Cu, and Ni by pH meter, Conductivity meter and atomic absorption spectrophotometer respectively. The results were compared with international standards. The spring seasonal plants did not show any sign of contamination regarding the selected metals, except chromium. This may be due to the higher pH and fine texture of soils which do not support the uptake of selected metals to plants, making the plants safe for consumption.

Safi *et al*. (2011) have measured the concentration of Cadmium (Cd), Copper (Cu), Lead (Pb), and Zinc (Zn) and of faecal pathogens like Coliforms, *Salmonella* spp., *Shigella* spp., and pinworms in soil, irrigation water and marketed vegetables. Pb and Zn concentrations of leafy vegetables were with 1–5 and 33–160 mg kg −1dry weight (DW) several-fold above respective international thresholds of 0.3 mg Pb/ kg 1and 50 mg Zn kg−1. The concentration of Cu in tissue was below threshold limits in all samples except for spinach. Above-threshold loads of microbes and parasites on vegetables were found in five out of six gardens with coliforms ranging from 0.5 – 2 × 107 cells 100 g−1fresh weight (FW), but no Salmonella and Shigella were found. Contamination with 0.2 × 107 eggs 100g−1FW of Ascaris was detected on produce of three farms and critical concentrations of Entamoeba in a single case, while *Oxyuris vermicularis*, and *Enterobius vermicularis* were found on produce of three and four farms, respectively. Irrigation water had Ascaris, Coliforms, Salmonella, Shigella, Entamoeba.

Boamponsem *et al*. (2012) have reported that the heavy metal pollution is a major environmental problem especially in mining areas. The study was carried out to quantify heavy metal levels and compare their accumulation in the stems, leaves and roots of *Lactuca sativa* (lettuce), *Brassica oleracea L. varcapitata* (cabbage) and *Daucuscarrotavar sativa* (carrot) irrigated with wastewater from Nagodi mining site. Pot experiment was conducted using surface soil (0-20cm). Differential accumulation and translocation of copper (Cu), lead (Pb), iron (Fe), manganese (Mn) cadmium (Cd) and zinc (Zn) in the root, stem and leaf of vegetables were investigated using atomic absorption spectrophotometer. Cd concentration in the various parts of *D. carrota* was in the range of 0.070 -0.090 mg/Kg. The highest concentration (17.30 mg/Kg) of Mn was found in the stem of *L. sativa*. Fe was highly absorbed (139.6 mg/Kg) by *B. oleracea* roots. The highest concentration (0.221 mg/Kg) of Cu was found in D. carrot roots and the highest concentration (35.35 mg/Kg) of Zn was found in the roots of Brassica. Cd accumulation in *L. sativa* and *B. oleracea* was below detection limit (< 0.002 mg/Kg). Pb absorbed by the three genotypes was below detection limit (< 0.005 mg/Kg). Though heavy metals were absorbed, their concentrations were below WHO/FAO recommended limits; vegetables cultivated with such wastewater may be considered safe for consumption.

Bvenura *et al.* (2012) conducted a study to examine the accumulation of some essential (copper, manganese and zinc) and toxic metals (lead and cadmium) in cultivated vegetables – *Brassica oleracea* (cabbage), *Daucuscarota* (carrot), *Allium cepa* (onion), *Spinacia oleracea* (spinach) and *Solanum lycopersicum* (tomato). The vegetables were locally cultivated in home gardens in Alice, a small town in the Eastern Cape Province of South Africa. Samples of these vegetables were randomly collected from residential areas, dried, digested and analyzed for the heavy metals using inductively coupled plasma optical emission spectrometry. The concentrations of heavy metals in the vegetables were in the range of 0.01 mg/kg – 1.12 mg/kg dry weight for cadmium, 0.92 mg/kg – 9.29 mg/kg for copper, 0.04 mg/kg – 373.38 mg/kg for manganese and 4.27 mg/kg – 89.88 mg/kg for zinc. Lead was undetectable in all the samples. Results of analysis of soils from the area revealed that cadmium in soil was in the range of 0.01 mg/kg – 0.08 mg/kg, copper levels were 4.95 mg/kg – 7.66 mg/kg, lead levels were 5.15 mg/kg – 14.01 mg/kg and zinc levels were 15.58 mg/kg – 53.01 mg/kg. The concentration of manganese was the highest of all the metals, ranging between 377.61 mg/kg and 499.68 mg/kg, at all three residential sites. Although the concentrations in soils and vegetables of the critical heavy metals, such as lead and cadmium, may not pose a threat (according to FAO/WHO standards), the concentration of manganese was very high in spinach and soils, whilst that of zinc exceeded safe levels in spinach, onions and tomatoes. However, neither the soils nor the vegetables were consistently found to pose a risk to human health.

Guerra *et al.* (2012) have elevated that ingestion of vegetables containing heavy metals is one of the main ways in which these elements enter the human body. Once entered, heavy metals are deposited in bone and fat tissues, overlapping noble minerals. Slowly released into the body, heavy metals can cause an array of diseases. This study aimed to investigate the concentrations of cadmium, nickel, lead, cobalt and chromium in the most frequently consumed foodstuff in the São Paulo State, Brazil and to compare the heavy metal contents with the permissible limits established by the Brazilian legislation. A value of intake of heavy metals in human diets was also calculated to estimate the risk to human health. Vegetable samples were collected at the São Paulo General Warehousing and Centers Company, and the heavy metal content was determined by atomic absorption spectrophotometry. All sampled vegetables presented average concentrations of Cd and Ni lower than the permissible limits established by the Brazilian legislation. Pb and Cr exceeded the limits in 44 % of the analyzed samples. The Brazilian legislation does not establish a permissible limit for Co contents. Regarding the consumption habit of the population in the São Paulo State, the daily ingestion of heavy metals was below the oral dose of reference, therefore, consumption of these vegetables can be considered safe and without risk to human health.

Farooq *et al.* (2008) performed an experiment with vegetables irrigated with waste water from different industries in Faisalabad and analyzed the presence of various heavy metals. They found that the concentration of Cadmium, Copper, Chromium, Lead and Zinc was less than the suggested maximum tolerable levels (0.01mg kg-1, 10.00 mg kg-1, 1.30 mg kg-1, 2mg kg-1 and 5.00 mg kg-1 respectively). There was greater accumulation of heavy metals in leaves than in their respective fruits. Concentration of Manganese in plants was much elevated than those of Cobalt and Cadmium. The accumulation of metals beyond tolerable limits was found in edible parts i.e. fruits or leaves in spite of the fact that the soils contained them within permissible range

Khan *et al.* (2009**)** assessed health risk of heavy metals for population via consumption of vegetables which is one of the problems that arise due to the increased uses of fertilizers and other chemicals to meet the higher demands of food production for human consumption. Health risk assessment for heavy metals of the population is a very good technique because such assessment would be useful to give information about any threat regarding heavy metals contamination in vegetables. For health risk assessment different methods are used by different researchers. These methods include the daily intake of metals (DIM), daily dietary index (DDI), Provisional tolerable daily intake (PTDI), along with the methods used for the health assessment. The health risk assessment methods include hazard quotient (HQ) and health risk index (HRI).

Singh *et al.* (2010**)** conducted a study in certain areas of Varanasi city, waste water from Dinajpur sewage treatment plant is used for irrigating vegetable plots. We quantified the concentrations of heavy metals, viz. Cd, Cr, Cu, Ni, Pb and Zn in soil, vegetables and the waste water used for irrigation. The waste water used for irrigation had the highest concentration of Zn followed by Pb, Cr, Ni, Cu and Cd. Continuous application of waste water for more than 20 years has led to accumulation of heavy metals in the soil. Consequently, concentrations of Cd, Pb and Ni have crossed the safe limits for human consumption in all the vegetables. Percent contribution of fruit vegetables to daily human intake for Cu, Ni, Pb and Cr was higher than that of leafy vegetables, while the reverse was true for Cd and Zn. Target hazard quotient showed health risk to the local population associated with Cd, Pb and Ni contamination of vegetables. Therefore, to reduce the health risk and the extent of heavy metal contamination, steps must be taken for efficient treatment of sewage. Regular monitoring of heavy metals in the vegetables grown in waste water irrigated areas is also necessary.

Ghosh *et al.* (2011) have studied the eight road side markets and two organized markets were demarcated for vegetables through purchasing. The present study was focused on site -1 to site-4 only. Six vegetables out of thirteen showed higher metal pollution index in site-3 and site-4. All sites showed several fold higher concentration of Lead (Pb), than the permissible PFA limit. Site-4 contains significantly higher concentration of Pb ($P<0.001$) than all other sites. The present study has generated data on heavy metal pollution in and around Ranchi city, Capital of Jharkhand and associated risk assessment for consumer's exposure to the heavy metals.

Lawal *et al.* (2011) have reported that the use of industrial and domestic wastewaters for irrigation on vegetable gardens is a public health concern. Using atomic absorption spectrophotometry (AAS), concentrations of Cr, Co, Cu, Ni, Pb and Zn were determined in four different vegetables, including, spinach, okra, onions and tomatoes, grown in effluent irrigated fields at Sharada, Kwakwachi and Jakara in the Kano metropolis, Nigeria. Similar vegetable samples from another irrigated field at Thomas Dam, in the remote part of Kano, were used as control. Samples were collected during dry and rainy seasons. The mean level of metals obtained ranged widely from 0.28 mg/Kg Cr to 18.89 mg/Kg Zn. Samples from Jakara garden indicated highest mean levels of Co (1.14±0.17 mg/Kg), Cu (7.50±1.08 mg/Kg), Zn (18.89±1.93 mg/Kg) and Cr (0.85±0.10 mg/Kg) while those from Sharada indicated highest levels of Ni (2.02±0.35 mg/Kg) and Pb (1.60±0.53 mg/Kg). Comparison of results with the control showed significant levels ($p<0.05$) of all the metals analyzed in the vegetable samples obtained from the effluent irrigated gardens. However, the levels were within the National Agency for Food and Drug Administration and Control (NAFDAC) tolerable limits for metals in fresh vegetables.

Akbari *et al.* (2012) conducted a study to assess the heavy metals accumulation and nutritional value of bean in three areas of Tehran's south based on completely randomized block design in the form of split plot with 3 replications in 2007. The main factor was included in three levels as sewage canals in Salehabad, Talebabad and Dehkheir areas; sub factor in two levels was involved sewage and aqueduct water (control). Use of Talebabad's sewage increased heavy metals assembling in different parts of bean, especially in root compared to sewages of Salehabad and Dehkheir. In three areas, irrigation with sewage in comparison with aqueduct water had no high effects on heavy metals except of Fe and Cr. In bean's pod and seed, only Fe and Cr were higher than standard limit and most of the other metals accumulated like aqueduct water. Heavy metals accumulation in bean's root and leaves were almost high, but high control of bean's pod and seed caused lower quantities of transported heavy metals ratio to grain than root and leaves. So, in respect of heavy metals assembling, using of bean's green pod and grain will not be resulted in problem.

Chandran *et al.* (2012) have reported that increasing scarcity of freshwater resources is driving many countries in the arid and semi-arid regions to use marginal quality water for agriculture and related activities. While the nutrients contained in the wastewater is considered as beneficial to agriculture, the contaminants present in the wastewater pose health risks directly to agricultural workers and indirectly to consumers of the wastewater grown produce (fodder crops, greens and vegetables), as the long term application of the wastewater may result in the accumulation of toxic compounds such as heavy metals in soil and plants. In this way the heavy metals enter the food chain of animals and human beings, which could cause health hazards. Heavy metal accumulation in plants depends upon plant species. The efficiency of different plants in absorbing metals is evaluated by either plant uptake or soil-to-plant transfer factors of the metals. This emphasizes the need for understanding the heavy metal uptake by plants in wastewater irrigation. The objective of this paper is to analyze the heavy metal uptake in wastewater irrigated plants such as Guinea grass (*Panicum maximum*), *Ponnankannikeerai* (*Alternantherasessilis*) and *Solanum melongena* in Avaniapuram Sewage Farm, Madurai, Southern part of India, where sewage irrigation is practiced since 1924.The results revealed a higher cadmium accumulation in all the three plants, which may be due to the presence of heavy metals in the source itself. A marginal accumulation of chromium and lead was found in the three species. Therefore the study recommends a pre- treatment of waste water before land application, to avoid entrance of metals into the food chain.

Ramesh *et al.* (2012) conducted a study to randomly collected waste water, soil and green leafy vegetable samples were from five stations of Bangalore urban district were analyzed for the heavy metals namely Copper, Zinc, lead, Chromium, Cadmium and Magnesium using Atomic absorption spectrophotometer. Present study explains the extent of heavy metal contamination in two leafy vegetables viz., palak (*Beta vulgaris*) and coriander (*Coriandrumsativum*). Results showed that, palak leaves contain Cooper, Zinc, lead, Chromium, Cadmium and Magnesium n all the sampling points. Cr at S1, S2 and S5 stations crossed safe value limit recommended by FAO/WHO. In coriander leaves Cu, Zn and Mn found in all stations. Pb concentration was exceedingly high in palak (28.43ppm to 149.50ppm) and coriander (54.69ppm to 75.50ppm) in all sampling stations. Cd was detected only at two stations in S2 (0.81ppm) and S4 (1.50ppm). Cr was detected at S1, S2 and S3 stations and at S2 station, Cr content in palak (70.79 ppm) and coriander (127.27ppm) was alarmingly exceeding the allowable limit. Soil samples do not revealed any appreciable increase in the concentration of heavy metals and found within the permissible limits but values were higher than control that shows contamination was mainly due to automobile exhaust, pesticides and industrial exhaust.

Pb was detected in all the waste water samples and in S1 (<0.05 ppm) and S2 (<0.05 ppm) traces of Cd was detected. Physicochemical parameters of waste water were also determined and factors such as pH, EC, TDS and DO found to exceed the drinking and irrigation water standards.

Aktaruzzaman *et al.* (2013) have reported that accumulation of heavy metals in environmental matrices is a potential risk to living system due to their uptake by plants and subsequent introduction into the food chain. A study was conducted to investigate the heavy metals concentration in soils and leafy vegetables samples along the Dhaka Aricha Road to assess their potential ecological risk. Heavy metals concentration was analyzed by Atomic Absorption Spectroscopy. Concentrations of all the tested heavy metals except Cd in soil samples were below the permissible level. The mean concentration of Cd was found 3.99±1.85 mg kg-1. Concentrations of all the tested heavy metals except Cd and Cr in vegetables samples were lower than recommended level. Mean concentration of Cd and Cr were found 1.00 ± 0.68 mg kg-1 and 2.32±0.84 mg kg-1, respectively. Based on the Potential Ecological Risk Index, Cd posed very high risk to the local ecosystem due to its higher Risk Factor, >320 and based on Transfer Factor of Pb and Cd were found higher accumulator among the tested metals. The results of present study revealed that the bio concentration of heavy metals along the Dhaka Aricha Road posed high risk to the ecosystem. Considering the Transfer Factor of Cd and Pb it can be suggested that plants and leafy vegetables grow in the soil near Dhaka Aricha Road should not be used as food or feed.

Jadoon *et al*. (2013) have reported that Faisalabad is known for its various industries such as textile, ghee, paper and tanneries etc. There is scarcity of water so irrigation in Faisalabad is mostly done by recycle waste water from these industries. This review focuses on effects of different industrial effluents on various vegetables grown in the Faisalabad city. Waste water from different industries such as textile and paper industries etc. is discharged into streams and land with or without any secondary or tertiary treatment. This results in severe effect on the surface and underground water and also affects the quality of crops. Under different amounts of effluents there are improved seedling and root lengths of various vegetables and on the other side at high concentration of numerous effluents there is a decreased germination and reduced growth. Untreated textile effluent decreased biomass of root and shoot but treated textile effluent resulted in a prominent growth, increase sugar and protein percentage. Waste water from textile, ghee and various industries contains heavy metals that accumulate in vegetables and has negative impacts on vegetables grown. Heavy metals such as Ni, Cr, Zn, Cd, Cu, As and Pb results in inhibition of root growth, reduced yield due to less uptake of water and nutrients and reduced plant growth and seed germination.

Parashar *et al*. (2013) have reported that heavy metal contamination of soil resulting from sewage irrigation is a cause of serious concern due to the potential health impacts of consuming contaminated products. In this study an assessment made of the impact of sewage irrigation on heavy metal contamination of Spinach, Cabbage, Beetroot, Reddish, Okra, Tomato, and Cucumber is widely cultivated and consumed in urban India, particularly by the poor. A field study was conducted at seven major sites that were irrigated by either treated, (Dhandupura) or untreated wastewater in the suburban areas of Agra, India. Samples of irrigation water, soil, and the edible portion of all the vegetables were collected monthly during the winter seasons and were analyzed for Fe, Cd, Cu, Zn, and Pb. Heavy metals in irrigation water were below the internationally recommended (WHO) maximum permissible limits set for agricultural use for all heavy metals except Cd at all the sites. Similarly, the mean heavy metal concentrations in soil were below the Indian standards for all heavy metals, but the maximum value of Cd recorded during January was higher than the standard. However, in the edible portion of spinach, the Cd concentration was higher than the permissible limits of the Indian standard during summer, whereas Pb concentrations were higher in winter seasons. Results of correlation analysis were computed to assess the relationship between individual heavy metal concentration in the vegetable samples. The study concludes that the use of treated and untreated wastewater for irrigation has increased the contamination of Cd, Pb in edible portion of vegetables causing potential health risk in the long term from this practice. The study also points to the fact that adherence to standards for heavy metal contamination of soil and irrigation water does not ensure safe food. Fe was measured abundant in soil whereas Pb and Cd were found more in untreated sites as compared to treated site. Correlation, paired T-test and ANOVA were also carried out for pre post harvested soil and vegetables.

Lokeshwari and Chandrappa (2006) have conducted as study to assess the extent of heavy metal contamination of vegetation due to irrigation with sewage-fed lake water on agricultural land. Samples of water, soil and crop plants have been analyzed for several heavy metals viz. Iron, Zinc, Copper, Nikel, Chromium, lead and Cadmium using atomic absorption spectrophotometer. The results show the presence of some of heavy metals in rice and vegetables, beyond the limits of Indian standards. Metal transfer factor from soil to vegetation are found significant for Zn, Cu, Pb and Cd. Comparing the results of heavy metals in water, soil and vegetation with their respective natural levels, it is observed that impact of lake water on vegetation was found to be more than the soil.

Shuval *et al.* (1991) have revealed that irrigation with wastewater has been practiced for centuries, the first health regulations were developed in the early 20th century. With the growing awareness and fear of transmission of communicable diseases, strict guidelines were set. However, these first health regulations lacked an epidemiological base and were too strict. In1989 WHO set more realistic guidelines, based on epidemiological evidence, However, recent evaluations show that these guidelines protect crop consumers, but not necessarily field workers and their families, especially children (Blumenthal *et al*. 2000). Therefore, new guidelines are in the development stage. Besides the microbiological contamination, chemical and organic pollutants, which are toxic for humans can also be present in wastewater. Of main public health concern are organic chemicals including pesticides and heavy metals such as lead and cadmium which can accumulate in crops, soil and groundwater (Hespanhol 1993). Although these chemical and organic pollutants can cause health problems, the emphasis of this study was on health hazards from microbiological contamination of wastewater.

Adhikari *et al.* (1993) have reported that increasing in concentration of trace metals Cd, Pb, Zn, Cu, Mn and Fe in surface soils irrigated with untreated sewage and industrial effluents

Kibria *et al.* (2012) reported that the concentrations of heavy metals in soils of the investigated areas are high, especially Cd is above the worldwide natural background concentration of surface soils. To study the effects of Chittagong city waste water irrigation on the heavy metal contamination of soils and their uptake by plants, soil and plant samples were collected from sixteen wastewater irrigated sites belonging four locations namely Syedpara, Hazipara, Jungalpara and Nazirpara and from another four sites belonging the location namely Chalidatoli selected as control location. Mean total Cd, Pb, Zn, Cu, Mn and Fe content in 0-15 cm depth of the study area ranged between 0.08 to 2.39, 13.96 to 50.29, 14.73 to 21.12, 27.07 to 59.13, 116.25 to 326.63 and 1523 to 2798 mg kg^{-1}, respectively. The metals content in 15-30 cm depth was in the ranges 0.01 to 1.98, 8.96 to 33.29, 51.44 to 267.31, 18.63 to 43.79, 68.89 to 271.74 and 1126 to 2054 mg kg^{-1}, respectively. Total and 0.1 N HCl extractable Cd, Pb, Zn, Cu, Mn and Fe contents of soils were significantly higher in wastewater irrigated location than those in the control location. Total Cd, Pb, Zn and Cu contents of surface soil in waste water irrigated locations were above the normal ranges of these metals for soils. Concentration of Cd, Pb, Zn, Cu, Mn and Fe in different plants (plant parts of rice, radish and aurum) varied from 0.02 to 16.65, 0.08 to 35.55, 0.84 to 102.75, 0.86 to.32.67, 0.95 to 185.50 and 3.23 to 485.23 mg kg-1, respectively. Bioaccumulation coefficient of Cd, Pb, Zn, Cu, Mn and Fe in plants ranged from 0.20 to 13.91, 0.008 - 0.72, 0.006-1.60, 0.03-0.64, 0.01-0.73 and 0.002-0.18, respectively. An establishment of soil quality standards for heavy metals to predict human induced soil pollution in Bangladesh is needed.

Kapungwe *et al.* (2013) revealed that studies on peri urban farming in Zambia have not adequately tackled the issues pertaining to heavy metal contaminated wastewater irrigation farming. The study investigated heavy metal contamination of water, soils and crops at two peri urban areas in Zambia. Two study sites were New Farm Extension in Mufulira Town in the Copper belt Province and Chilumba Gardens in Kafue Town in Lusaka Province. The heavy metals investigated were lead, copper, cobalt, nickel and chromium. These heavy metals were found to be higher than acceptable limits in wastewater used to irrigate crops and there are potential human health risks associated with consumption of heavy metal contaminated food crops which have implications on the livelihoods of people. Samples of water, soil and crops were collected and analysed for lead (Pb), copper (Cu), chromium (Cr), cobalt (Co) and nickel (Ni) using the Atomic Absorption Spectrometer (AAS). The data on heavy metals was analysed using mean, standard error and T-test. The results indicated that the levels of heavy metals in wastewater, soil and food crops were above acceptable limits at two study sites. It can be concluded that there was heavy metal contamination of wastewater, soil and food crops at the two peri-urban areas in Zambia. The study highlighted the actual levels of heavy metal contaminant uptake in food crops consumed by the peri urban population. The information from this study can be used by the relevant authorities to develop appropriate measures for monitoring and control of heavy metal contamination in wastewater irrigation farming systems in peri urban areas in Zambia.

Sardar *et al.* (2013) revealed that heavy metals are toxic metals having density five times greater than water. They are toxic for all living organisms. In humans they enter into body through various ways like ingestion, absorption etc. They become harmful when their accumulation rate is more than their discharge. They accumulate gradually in body over a long time and are toxic. Heavy metal contamination is a major problem in environment and of medium sized cities due to anthropogenic activities. Human activities may contribute largely in their production such as burning of fossil fuel, mining and use of many chemical for crop growth etc. Waste water also contains heavy metal and when it is applied to crops it can cause threat to soil and plants growing in that soil. Waste water health risks can be determined by different indices. Generally, heavy metals cannot be removed from waste water and when they enter into the soil, interfere with the plant roots - these plants when eaten by animals or humans they enter into food chain. Plants along with other nutrients also uptake lead and cadmium; their accumulation may be effected by the concentration time of exposure and climatic factor. Heavy metals affect the quality and production of crop and influence atmospheric and water quality. These contamination are important and of concern because of increasing demand for food safety. There are different sources for heavy metal such as natural and manmade, as industries and air borne sources. These heavy metals have severe effects on plants, animals, humans and ultimately on environment.

Mustapha *et al*. (2014) investigated the quality of municipal waste water used for irrigation of spinach for its heavy build-up. The municipal waste water used for irrigation and the irrigated spinach sample were collected and analyzed for their heavy metal concentrations. The result indicated that the municipal waste water used was contaminated with copper (1.90 mg/L), lead (0.09 mg/L) and iron (25 mg/L) and the municipal irrigated spinach was contaminated with manganese (95 mg/L) and cadmium (0.03 mg/L). the results of this investigation was compared with world health organization (WHO) and Food and Agriculture Organization (FAO) heavy metal standards for irrigation water quality and permissible levels of metals in food and water. It revealed that the heavy metal concentration were above the recommended threshold limits. High concentration of these metals is very detrimental to the health of the inhabitants and crop consumers. Regular monitoring for safe practice is strongly recommended in order to avert terminal diseases in the area.

Bharose *et al.* (2014) conducted the field experiments at the crop growing farm in the south east part of northern region of India during Rabi season 2006-2007 and 2007-08 to study the “Effect of deferent levels of sewage water on accumulation of heavy metals in soil, plants and bulbs of onion crop (*Allium cepa L*.). The study site is located, along the Yamuna River and 98 meter above the mean sea level. The mean temperature during the growing period was 37.2 to 4.7 0C due to subtropical and semi-arid climate. The soil of experimental area falls in order Inceptisol and the experimental field is alluvial in nature. The Nickel, lead, Cadmium, Chromium and Copper mg kg-1 of post-harvest soil of onion grown plot was found to be significant in both the experiments. The Nickel, lead, Cadmium, Chromium and Copper mg kg-1 of post-harvest soil of onion grown plot were recorded in order of T_0, $<T_1$, $<T_2$, $<T_3$ during the entire growth and development. The afore mention heavy metals in T_3 treatment tended to be significantly greater than the remaining treatments and decreased with increase in depth in both tube well and sewage irrigated soil. Plant samples of onion crop were collected at 60 days after transplanting, from field, irrigated with sewage as well as with tube well water and the data on Nickel, lead, Cadmium, Chromium and Copper mg kg^{-1} in plants and bulbs of onion crop was found to be significant at 60 days after transplanting in both the experimental years.

Chang *et al.* (2014) investigated the extent of heavy metal accumulation in leaf vegetables and associated potential health risks in agricultural areas of the Pearl River Delta (PRD), South China. Total concentrations of mercury (Hg), cadmium (Cd), lead (Pb), chromium (Cr) and arsenic (As) were determined in 92 pairs of soil and leaf vegetable (flowering Chinese cabbage, lettuce, pakchoi, Chinese cabbage, loose-leaf lettuce, and Chinese leaf mustard) samples collected from seven agricultural areas (cities). The bio concentration factors (BCF) of heavy metals from soil to vegetables were estimated, and the potential health risks of heavy metal exposure to the PRD residents through consumption of local leaf vegetables were assessed. Results showed that among the six leaf vegetables, pakchoi had the lowest capacity for heavy metal enrichment, whereas among the five heavy metals, Cd had the highest capacity for transferring from soil into vegetables, with BCF values 30-fold those of Hg and 50-fold those of Cr, Pb and As. Sewage irrigation and fertilization were likely the main sources of heavy metals accumulated in leaf vegetables grown in agricultural areas of the PRD region. Different from previous findings, soil pH had no clear effect on metal accumulation in leaf vegetables. Despite a certain degree of metal enrichment from soil to leaf vegetables, the PRD residents were not exposed to significant health risks associated with consumption of local leaf vegetables. Nevertheless, more attention should be paid to children due to their sensitivity to metal pollutants.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted in the Agro-Environmental Chemistry laboratory of the Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka-1207. It was done during the period from December 2016 to May 2017. This chapter deals with a detail description of the sampling site, location, collection of vegetables, data recording, chemical analysis and procedure of statistical analysis etc.

3.1 Sampling site and location:

Different vegetables samples were collected from intensively growing areas of Savar thana such as Sadapur kazipara, Nama Genda, Pathalia and Vagolpur and nearest local market ie. Savar thana stand bazar and Genda bazar under Dhaka district .

3.2 Collection of vegetables samples:

Different types (red amaranth, radish, radish spinach, carrot, tomato, brinjal, bottle gourd spinach, fenugreek leaves, bottle gourd, turnip and spinach) of vegetables samples were collected randomly from each selected location. Vegetables were collected at the stage of harvesting from farmers field and nearest local markets.. Each vegetable samples were collected three times form particular areas. The samples were put into individual polyethene bag with proper marking and tagging and brought to the Department of Agricultural Chemistry, Sher- e- Bangla Agricultural University, Dhaka for chemical analyses.

3.3 Types of vegetables: Three types of winter vegetables such as (1) Leafy vegetables (red amaranth, spinach, radish leaves, fenugreek leaves, bottle gourd leaves) (2) Fruity vegetables (brinjal, tomato, bottle gourd) (3) Roots and tubers vegetables (radish, carrot, turnip) were used as sample materials.

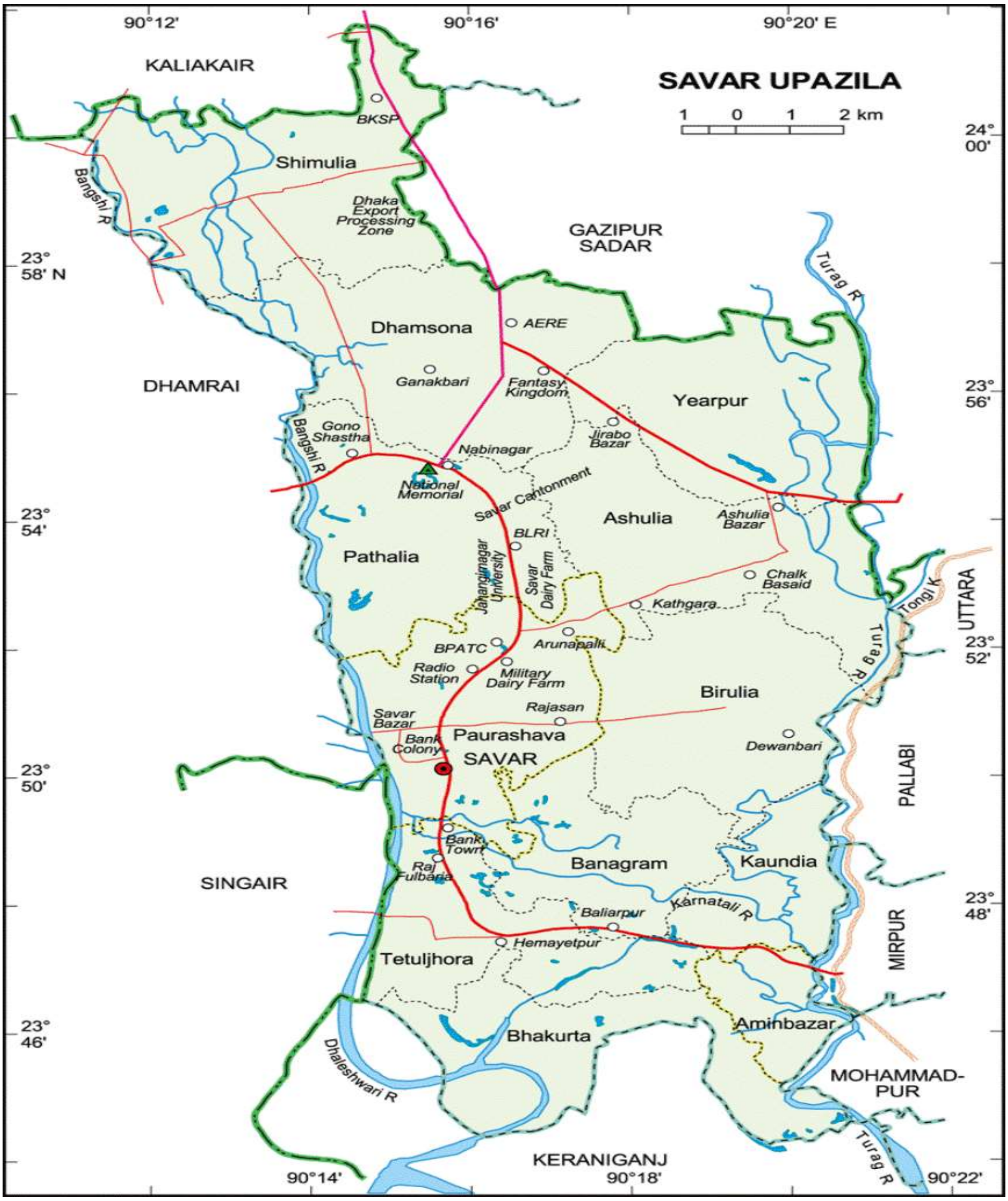

Figure 1. A map of Savar Thana

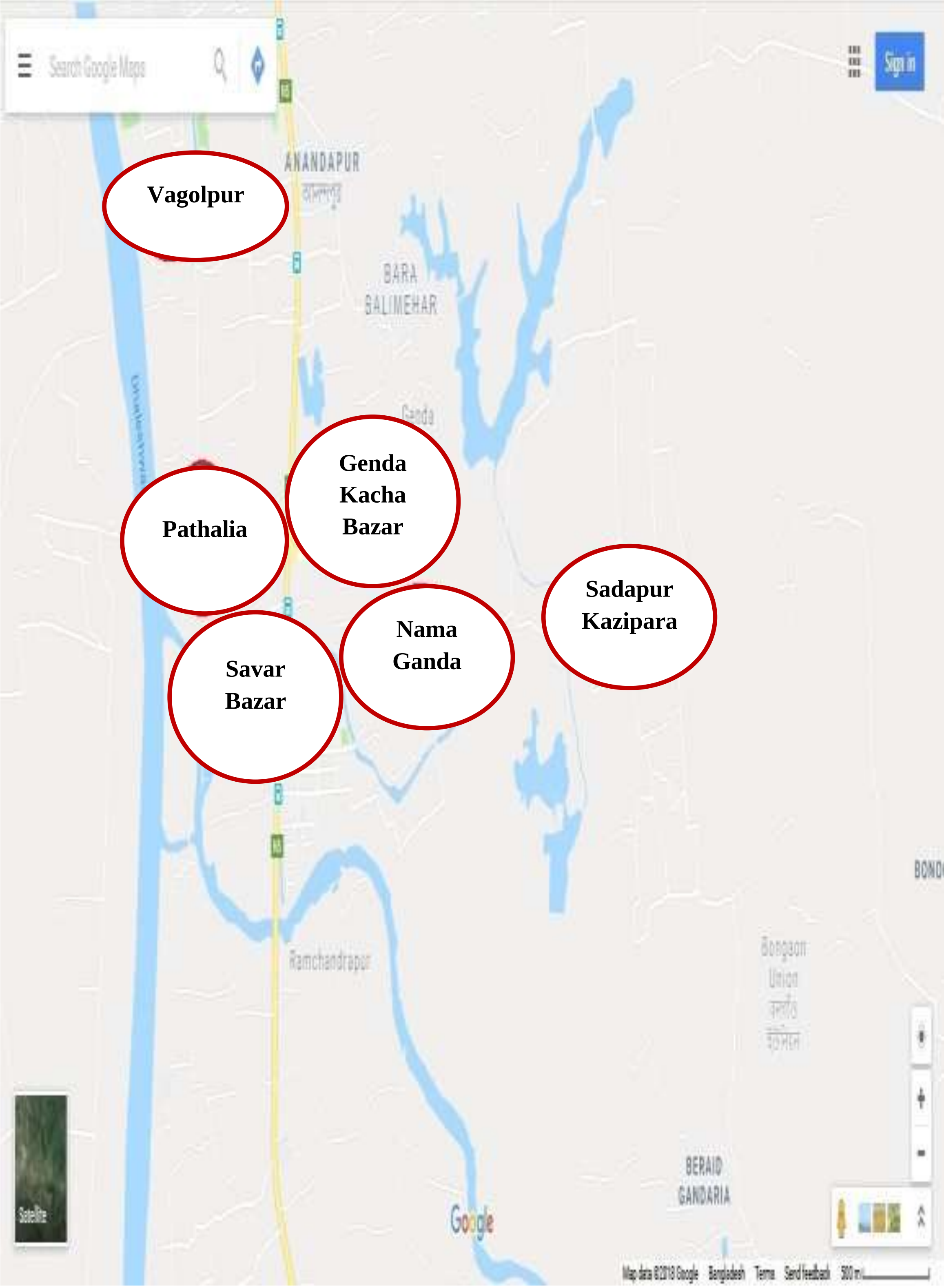

Figure 2. A map of Savar Thana showing the study area (Vagolpur, Pathalia, Savar Bazar, Genda Bazar, Nama Ganda and Sadapur kazipara)

3.4 Chemical Analysis

3.4.1 Preparation of plant extract:

Vegetable samples were separated into roots and shoots after uprooting and then dried in an oven at 70^0C to obtain constant weight.Oven-dried shoot samples, root samples and grain samples were ground in a Wiley Hammer Mill, passed through 40 mesh screens, mixed well and stored in plastic vials. Exactly 1g oven-dried samples of different vegetables were taken in digestion tube. About 10 mL diacid mixture ($HClO_4$and HNO_3= 2:1) was taken in a digestion tube and left to stand for 20 minutes and then transferred to a digestion block and continued heating at 180-200^0C. The temperature was increased to 365^0C gradually to prevent frothing (50^0C steps) and left to digest until yellowish color of the solution turned to whitish color. Then the digestion tubes were removed from the heating source and allowed to cool to room temperature. About 40 mL of de-ionised water was carefully added to the digestion tubes and the contents filtered through Whatman no. 40 filter paper into a 100 mL volumetric flask and the volume was made up to the mark with de-ionised water. The samples were stored at room temperature in clearly marked containers.

3.4.2 Determination of Cadmium

Total Cadmium concentration was determined from the digest by Analytik JenanovAA 400P Atomic Absorption Spectrophotometer (Analytik Jena, 2017, country of origin: Germany).

3.4.3 Determination of Chromium

Total Chromium concentration was determined from the digest by Analytik JenanovAA 400P Atomic Absorption Spectrophotometer (Analytik Jena, 2017, country of origin: Germany).

3.4.4 Determination of Lead

Total Lead concentration was determined from the digest by Analytic JenanovAA 400P Atomic Absorption Spectrophotometer (Analytik Jena, 2017, country of origin: Germany).

3.4.5 Determination of Zinc

Total Zinc concentration was determined from the digest by Analytik JenanovAA 400P Atomic Absorption Spectrophotometer (Analytik Jena, 2017, country of origin: Germany).

3.4.6 Determination of Copper

Total Copper concentration was determined from the digest by Analytik JenanovAA 400P Atomic Absorption Spectrophotometer (Analytik Jena, 2017, country of origin: Germany).

3.5 Statistical Analysis

The data were compiled and tabulated in proper form and were subjected to statistical analysis. Analysis of variance, Standard deviation, Mean and Range was done in this study. The software SPSS 15.0.has been used for statistical analysis.

CHAPTER IV

RESULTS AND DISCUSSION

Eleven species of vegetables (red amaranth, radish, radish spinach, carrot, tomato, brinjal, bottle gourd spinach, fenugreek leaves, bottle gourd, turnip and spinach) were collected from six different places of Savar thana (Vagolpur, Namagenda, Savar thana bazar, Genda bazar, Pathalia and Sadapur) of Dhaka city to detect and quantify metal residues. The results obtained from this study are presented and described in this chapter using figures and tables.

4.1 Heavy Metals in Vegetable Samples from Vagolpur

The mean ± SD of the five studied metals in 8 different vegetable species are listed in (Figure 3). The mean concentrations of Cr ranged from 0.00mg/kg (tomato, brinjal, bottle gourd spinach, fenugreek leaves, bottle gourd, and spinach) to 0.64 mg/kg (Red amaranth) (Figure 4). The maximum Cr content (0.64 mg/kg) was obtained from red amaranth, which was followed by radish (0.41mg/kg). Chromium concentrations in vegetable species were lower than the guideline value (2.3mg/kg) set by FAO/WHO (2011). An earlier study by Karim *et al*. (2008) reported much higher concentrations of Cr in Bangladeshi vegetables (mean: 27.1 ppm, range: 23.3–33.8 ppm). The results implied that the mean Cr concentrations in vegetables were considerably lower than the mean Cr concentrations detected in Bangladeshi vegetables in other studies (Ahmad and Gani 2010; Karim *et al*. 2008). In vegetables, mean concentrations of Cd ranged from 0.00 mg/kg (red amaranth, radish, tomato, and brinjal) to 0.27 mg/kg (bottle gourd spinach) (Figure 3). The maximum Cd content (0.27mg/kg) was obtained from bottle gourd spinach, which was followed by bottle gourd (0.25mg/kg), spinach and fenugreek leaves. In most of the vegetable species, Cd concentrations were higher than the MAC (0.05mg/kg) (Figure 3) indicating these species are contaminated by Cd. The results also showed a large variation among vegetable species in Cd concentration, which were in agreement with previous findings (Jinadasa*et al*. 1997), with *A. hybridus*, *A. Gangeticus* L and *Allium cepa* possessing a higher risk for Cd accumulation than other vegetables (Figure 3).

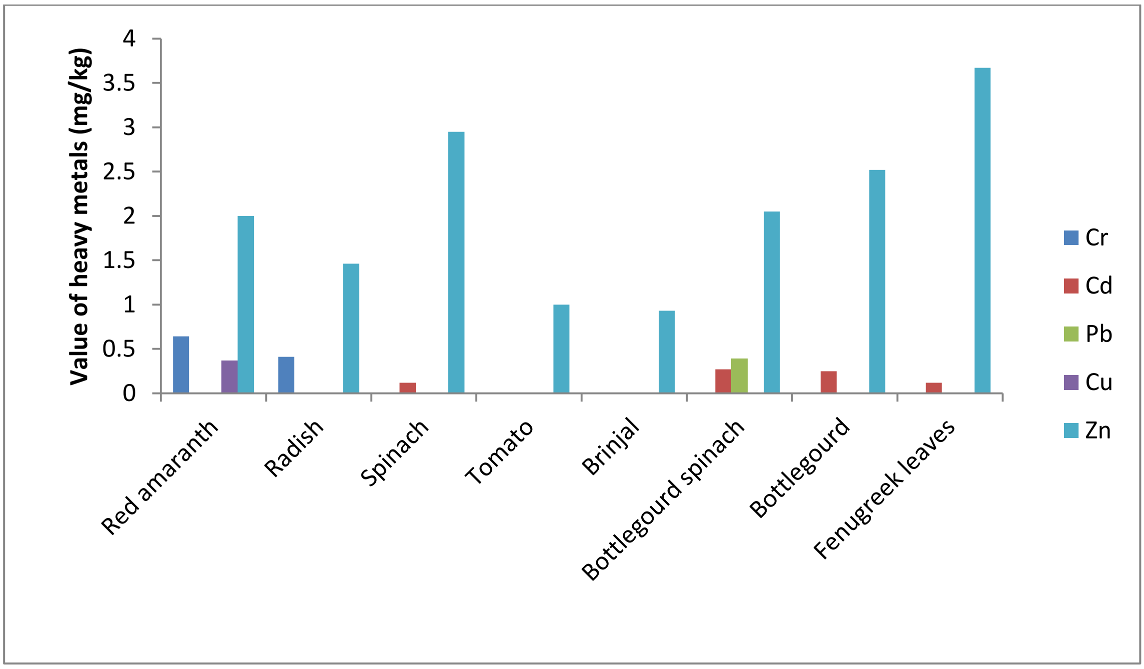

Figure 3. Amount of Cr, Cd, Pb, Zn and Cu in different vegetables collected from vagolpur in Savar Thana

The highest mean concentration of Pb was observed in bottle gourd spinach (0.39mg/kg) and the lowest Pb concentration (0 mg/kg) was in (red amaranth, radish tomato, brinjal, fenugreek leaves, bottle gourd, and spinach) (Figure 3). Lead concentrations in bottle gourd spinach was higher than the safe recommended limits by FAO/WHO (2011), indicting these vegetables species were contaminated by Pb and might pose risk due to consumption. Burning of industrial waste and coal in the brick fields were observed at the study area, which might result in the deposition of particulate matter (PM) on vegetables. Thus, the vegetables can be exposed to fine particles of Pb from $PbSO_4$, PbO, and $PbCO_3$. Uzu *et al*. (2011) showed that particulate matter (PM) containing Pb can be deposited on plant leaves and penetrate inside the tissues. The observed variation of heavy metals in vegetable species could be due to variable capabilities of metal absorption and accumulation (Pandey and Pandey 2009) and variations in growth period and rates (Saha and Zaman 2013) and soil properties such as soil pH, cation exchange capacity, organic content, and the interaction of soil–plant root–microbes (Gebrekidan *et al*. 2013).

The mean concentrations of Cu in vegetable species were obtained red amaranth (0.37mg/kg) and the lowest Cu concentration (0 mg/kg) was in (bottle gourd spinach, radish tomato, brinjal, fenugreek leaves, bottle gourd, and spinach) (Figure 3). Copper concentrations in vegetables were lower than the guideline value of 40 mg/kg set by FAO/WHO (2011). Copper concentrations in vegetables of our study was lower than the previous studies (Rahman *et al*. 2013; Sharma *et al*. 2007) indicating vegetables were not contaminated by Cu.

Mean Zn concentrations ranged from 0.93(mg/kg) in brinjal to 3.67 mg/kg (fenugreek leaves) (Figure 3). In the study area, the main sources of heavy metals in agricultural soils where the farmers grow vegetables are the repeated use of untreated or poorly treated waste water from industrial establishments and the application of chemical fertilizers and pesticides (Islam *et al*. 2009; Bhuiyan *et al*. 2011; Rahman *et al*. 2013).

4.2 Heavy Metals in Vegetable Samples from Nama Genda

The mean ± SD of the five studied metals in 8 different vegetable species are red amaranth, radish spinach, radish, carrot, spinach, tomato, brinjal, bottle gourd. The mean concentrations of Cr ranged from 0.00mg/kg (spinach, tomato, brinjal, bottle gourd) to 1.30 mg/kg (radish spinach) (Figure 4). The maximum Cr content (mg/kg) was obtained from radish spinach, which was followed by radish (1.04 mg/kg), carrot (0.66 mg/kg) and red amaranth (0.61 mg/kg). Chromium concentrations in vegetable species were lower than the guideline value (2.3 mg/kg) set by FAO/WHO (2011). An earlier study by Karim *et al*. (2008) reported much higher concentrations of Cr in Bangladeshi vegetables (mean: 27.1 ppm, range: 23.3–33.8 mg/kg). The results implied that the mean Cr concentrations in vegetables were considerably lower than the mean Cr concentrations detected in Bangladeshi vegetables in other studies (Ahmad and Gani 2010; Karim *et al*. 2008)..

Eight vegetable samples were collected from Nama genda. Among them, there was no contained residue of Cd (Figure 4). In all vegetable species, Cd concentrations were lower than the MAC (0.05 mg/kg) indicating these species are not contaminated by Cd. The results also showed a large variation among vegetable species in Cd concentration, which were in agreement with previous findings (Jinadasa *et al*. 1997), with *A. hybridus*, *A. Gangeticus*L and *Allium cepa* possessing a higher risk for Cd accumulation than other vegetables.

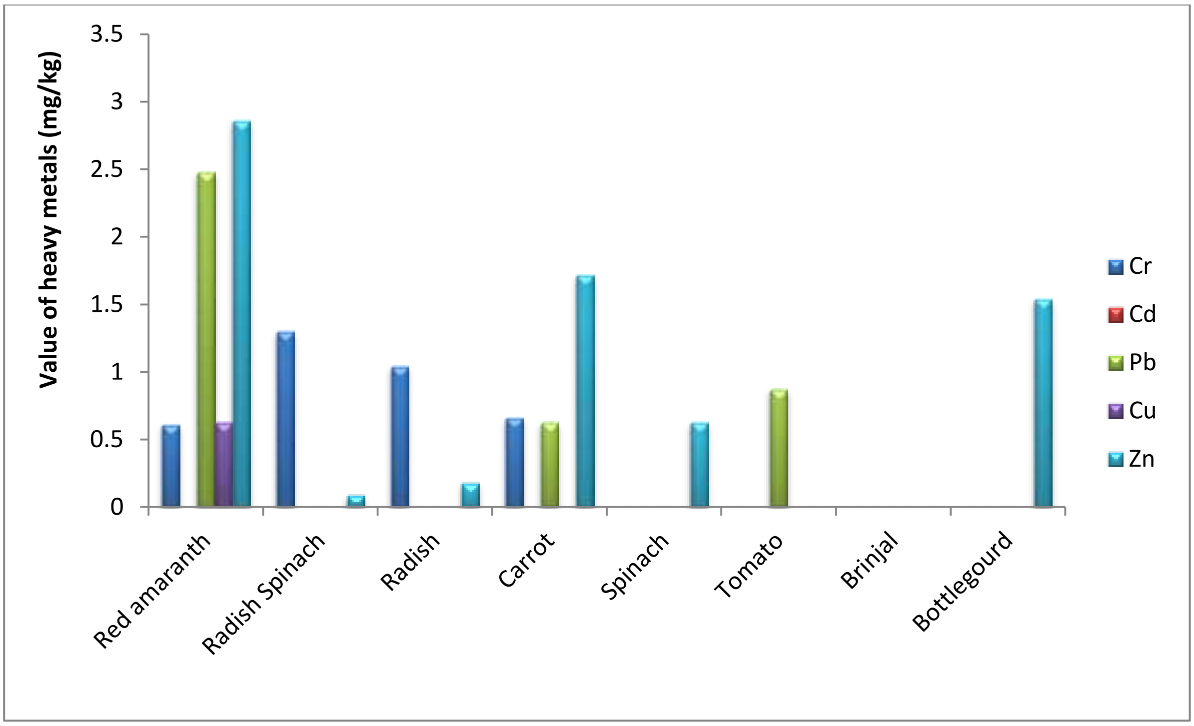

Figure 4. Amount of Cr, Cd, Pb, Zn and Cu in different vegetables collected from Nama genda in Savar thana

The highest mean concentration of Pb was observed in red amaranth(2.48 mg/kg), which was followed by tomato (0.87 mg/kg) and Carrot (0.63 mg/kg) and the lowest Pb concentration (0 mg/kg) was in (radish spinach, radish, spinach, brinjal, bottle gourd) (Figure 4). Lead concentrations in Bottle gourd spinach was higher than the safe recommended limits by FAO/WHO (2011), indicting these vegetables species were contaminated by Pb and might pose risk due to consumption. Burning of industrial waste and coal in the brick fields were observed at the study area, which might result in the deposition of particulate matter (vegetables. Thus, the vegetables can be exposed to fine particles of Pb from $PbSO_4$, PbO, and $PbCO_3$. Uzu *et al*. (2011) showed that particulate matter (PM) containing Pb can be deposited on plant leaves and penetrate inside the tissues. The observed variation of heavy metals in vegetable species could be due to variable capabilities of metal absorption and accumulation (Pandey and Pandey,

2009) and variations in growth period and rates (Saha and Zaman, 2013) and soil properties such as soil pH, cation exchange capacity, organic content, and the interaction of soil–plant root–microbes (Gebrekidan *et al*. 2013).

Out of 8 Vegetables from nama genda, only one (12.5% of the total number of vegetables) contained Cu residues and 7 vegetables (87.5% of the total number of vegetable) contained no detectable Cu residues of the vegetable. The highest amount Cu (0.63 ppm) was observed from red amaranth (Figure 4). Copper concentrations in vegetables were lower than the guideline value of 40 mg/kg set by FAO/WHO (2011). Copper concentrations in vegetables of our study was lower than the previous studies (Rahman *et al*. 2013; Sharma *et al*. 2007) indicating vegetables were not contaminated by Cu.

Out of 8 Vegetables, 6 (75% of the total number of vegetables) contained Zn residues and 2 vegetables (25% of the total number of vegetable) contained no detectable Zn residues of the vegetable. The highest amount Zn (2.86 mg/kg) was observed from red amaranth. In the study area, the main sources of heavy metals in agricultural soils where the farmers grow vegetables are the repeated use of untreated or poorly treated waste water from industrial establishments and the application of chemical fertilizers and pesticides (Islam *et al*. 2009; Bhuiyan *et al*. 2011; Rahman *et al*. 2013).

4.3 Heavy Metals in Vegetable Samples from Pathalia

The mean ± SD of the five studied metals in 9 different vegetable species are red amaranth, radish spinach, radish, carrot, spinach, tomato, brinjal, bottle gourd, fenugreek leaves and one water sample. The mean concentrations of Cr ranged from 0.00mg/kg (carrot, spinach, tomato, brinjal, bottle gourd, fenugreek leaves and one water sample) to 1.38 mg/kg (radish spinach) (Figure 5). The maximum Cr content (1.38 mg/kg) was obtained from radish spinach, which was followed by red amaranth

(1.34 ppm) and radish (0.34 mg/kg). Chromium concentrations in vegetable species were lower than the guideline value (2.3 ppm) set by FAO/WHO (2011). An earlier study by Karim *et al*. (2008) reported much higher concentrations of Cr in Bangladeshi vegetables (mean: 27.1 mg/kg, range: 23.3–33.8 mg/kg). The results implied that the mean Cr concentrations in vegetables were considerably lower than the mean Cr concentrations detected in Bangladeshi vegetables in other studies (Ahmad and Gani 2010; Karim *et al*. 2008).

Nine vegetable samples and one water sample were collected from Pathalia. Among them, four vegetables (44.44% of the total number of vegetables) contained Cd residues and 5 vegetables (55.56% of the total number of vegetable) contained no detectable Cd residues of the vegetable (Figure 6). In most of vegetable species, Cd concentrations were lower than the MAC (0.05 mg/kg) (Figure 5) indicating these species are not contaminated by Cd. The results also showed a large variation among vegetable species in Cd concentration, which were in agreement with previous findings (Jinadasa *et al*. 1997), with *A. hybridus*, *A. Gangeticus*L and *Allium cepa* possessing a higher risk for Cd accumulation than other vegetables (Figure 5s).

The highest mean concentration of Pb was observed in red amaranth(2.85mg/kg), which was followed by radish spinach (0.10mg/kg), bottle gourd spinach (0.08 mg/kg) and water sample (0.03mg/kg) and the lowest Pb concentration (0 mg/kg) was in (radish, carrot, spinach, brinjal and fenugreek leaves) (Figure 6). Lead concentrations in red amaranth was higher than the safe recommended limits by

FAO/WHO (2011), indicting these vegetables species were contaminated by Pb and might pose risk due to consumption. Burning of industrial waste and coal in the brick fields were observed at the study area, which might result in the deposition of particulate matter (PM) on vegetables. Thus, the vegetables can be exposed to fine particles of Pb from $PbSO_4$, PbO, and $PbCO_3$. Uzu *et al*. (2011) showed that particulate matter (PM) containing Pb can be deposited on plant leaves and penetrate inside the tissues. The observed variation of heavy metals in vegetable species could be due to variable capabilities of metal absorption and accumulation (Pandey and Pandey 2009) and variations in growth period and rates (Saha and Zaman 2013) and soil properties such as soil pH, cation exchange capacity, organic content, and the interaction of soil–plant root–microbes (Gebrekidan *et al*. 2013).

Out of 9 Vegetables collected from Pathalia, among them, there was no contained residue of Cu in vegetable samples (Figure 5). Copper concentrations in vegetables were lower than the guideline value of 40 mg/kg set by FAO/WHO (2011). Copper concentrations in vegetables of our study was lower than the previous studies (Rahman *et al*. 2013; Sharma *et al*. 2007) indicating vegetables were not contaminated by Cu.

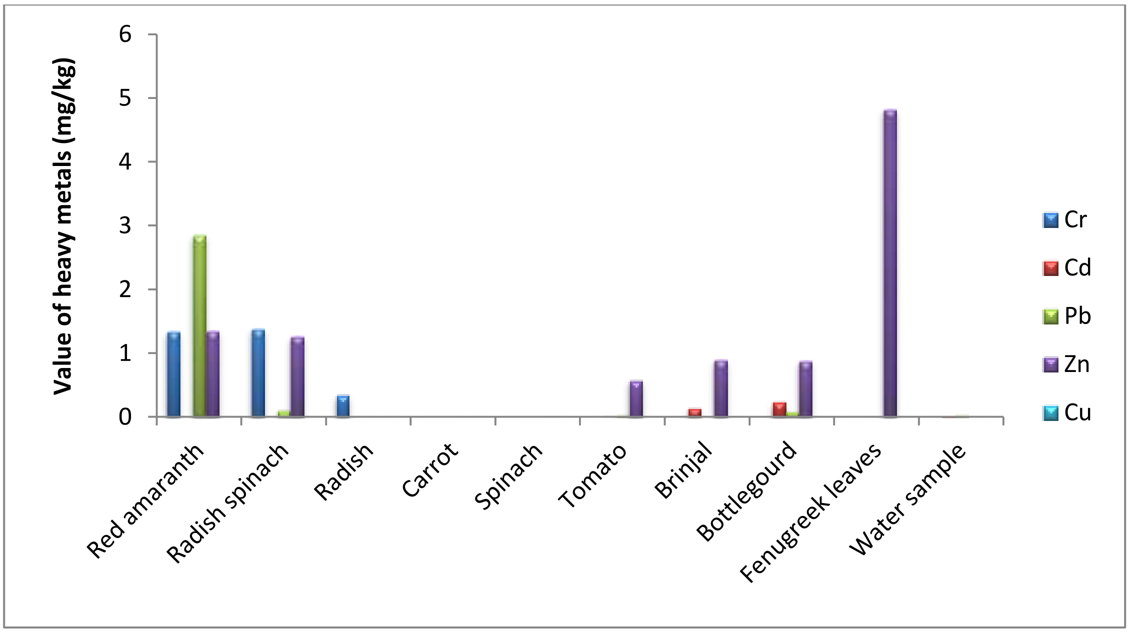

Figure 5. Amount of Cr, Cd, Pb, Zn and Cu in different vegetables and water collected from Pathalia in Savar thana

Out of 9 Vegetables and one water sample, 7 (70% of the total number of vegetables) contained Zn residues and 2 vegetables and one water sample (30% of the total number of vegetable) contained no detectable Zn residues of the vegetable (Figure 5). The highest amount Zn (4.82 mg/kg) was observed from fenugreek leaves. In the study area, the main sources of heavy metals in agricultural soils where the farmers grow vegetables are the repeated use of untreated or poorly treated waste water from industrial establishments and the application of chemical fertilizers and pesticides (Islam *et al*. 2009; Bhuiyan *et al*. 2011; Rahman *et al*. 2013).

4.4 Heavy Metals in Vegetable Samples from Genda bazar

The mean ± SD of the five studied metals in 9 different vegetable species are red amaranth, radish spinach, radish, carrot, spinach, tomato, brinjal, bottle gourd, and turnip. The mean concentrations of Cr ranged from 0.00mg/kg (carrot, tomato, brinjal, bottle gourd, and turnip) to 2.12 mg/kg (red amaranth) (Table 1). The maximum Cr content (2.12 mg/kg) was obtained from red amaranth, which was followed by radish (0.57 mg/kg) and radish spinach (0.51 mg/kg). Chromium concentrations in vegetable species were lower than the guideline value (2.3 mg/kg) set by FAO/WHO (2011). An earlier study by Karim *et al*. (2008) reported much higher concentrations of Cr in Bangladeshi vegetables (mean: 27.1 mg/kg, range: 23.3–33.8 mg/kg). The results implied that the mean Cr concentrations in vegetables were considerably lower than the mean Cr concentrations detected in Bangladeshi vegetables in other studies (Ahmad and Gani 2010; Karim *et al*. 2008).

Nine vegetable samples were collected from Genda bazar. Among them, only one (11.11% of the total number of vegetables) contained Cd residues and 8 vegetables (88.89% of the total number of vegetable) contained no detectable Cd residues of the vegetable (Table 1). The highest amount of Cd concentration (0.18 mg/kg) was contented from bottlegourd. In most of vegetable species, Cd concentrations were lower than the MAC (0.05 mg/kg) indicating these species are not contaminated by Cd but bottlegourd, Cd concentrations were higher than the MAC (0.05mg/kg) indicating the vegetable are contaminated by Cd. The results also showed a large variation among vegetable species in Cd concentration, which were in agreement with previous findings (Jinadasa *et al*. 1997), with *A. hybridus, A. Gangeticus* L and *Allium cepa* possessing a higher risk for Cd accumulation than other vegetables.

The highest mean concentration of Pb was observed in radish spinach (3.89mg/kg), which was followed by red amaranth (3.71mg/kg), brinjal (0.51mg/kg) and the lowest Pb concentration (0 mg/kg) was in (radish, carrot, spinach, tomato, bottle gourd and turnip). Lead concentrations in radish spinach and red amaranth was higher than the safe recommended limits by FAO/WHO (2011), indicting these vegetables species were contaminated by Pb and might pose risk due to consumption. Burning of industrial waste and coal in the brick fields were observed at the study area, which might result in the deposition of particulate matter (PM) on vegetables. Thus, the vegetables can be exposed to fine particles of Pb from $PbSO_4$, PbO, and $PbCO_3$. Uzu *et al*. (2011) showed that particulate matter (PM) containing Pb can be deposited on plant leaves and penetrate inside the tissues. The observed variation of heavy metals in vegetable species could be due to variable capabilities of metal absorption and accumulation (Pandey and Pandey 2009) and variations in growth period and rates (Saha and Zaman 2013) and soil properties such as soil pH, cation exchange capacity, organic content, and the interaction of soil–plant root–microbes (Gebrekidan *et al*. 2013).

Out of 9 Vegetables collected from Genda bazar, Among them, only one vegetable was contained residue of Cu in red amaranth (Table 1). Copper concentrations in vegetables were lower than the guideline value of 40 mg/kg set by FAO/WHO (2011). Copper concentrations in vegetables of our study was lower than the previous studies (Rahman *et al*. 2013; Sharma *et al*. 2007) indicating vegetables were not contaminated by Cu. Out of 9 Vegetables, 8 (88.89% of the total number of vegetables) contained Zn residues and 1 vegetables (11.11% of the total number of vegetable) contained no detectable Zn residues of the vegetable (Table1). The highest amount Zn (3.45mg/kg) was observed from spinach. In the study area, the main sources of heavy metals in agricultural soils where the farmers grow vegetables are the repeated use of untreated or poorly treated waste water from industrial establishments and the application of chemical fertilizers and pesticides (Islam *et al*. 2009; Bhuiyan *et al*. 2011; Rahman *et al*. 2013).

4.5 Heavy Metals in Vegetable Samples from Sadapur

The mean ± SD of the five studied metals in 6 different vegetable species are red amaranth, radish spinach, radish, spinach, brinjal, bottle gourd and one water sample. The mean concentrations of Cr ranged from 0.00mg/kg (radish, spinach, brinjal, bottle gourd and one water sample) to 1.98 mg/kg (radish spinach) (Table 2). The maximum Cr content (1.98 mg/kg) was obtained from radish spinach, which was followed by red amaranth (1.01mg/kg). Chromium concentrations in vegetable species were lower than the guideline value (2.3 mg/kg) set by FAO/WHO (2011). An earlier study by Karim *et al*. (2008) reported much higher concentrations of Cr in Bangladeshi vegetables (mean: 27.1 mg/kg, range: 23.3–33.8 mg/kg).

Table 1. Amount of Cr, Cd, Pb, Zn and Cu in different vegetables collected from Genda Bazar in Savar thana

Name of vegetables		Cr (mg/kg fw)	Cd (mg/kg fw)	Pb (mg/kg fw)	Cu (mg/kg fw)	Zn (mg/kg fw)
Red amaranth	Mean±SD	2.12±0.02	0	3.71±0.03	1.29±0.01	1.57±0.07
	Range	2.10-2.14	0	3.68-3.74	1.28-1.30	1.51-1.65
Radish Spinach	Mean±SD	0.51±0.01	0	3.89±0.04	0	1.12±0.04
	Range	0.50-0.52	0	3.85-3.93	0	1.08-1.16
Radish	Mean±SD	0.57±0.02	0	0	0	0.45±0.05
	Range	0.55-0.59	0	0	0	0.41-0.51
Carrot	Mean±SD	0	0	0	0	0
	Range	0	0	0	0	0
Spinach	Mean±SD	0.06±0.02	0	0	0	3.45±0.03
	Range	0.04-0.08	0	0	0	3.41-3.48
Tomato	Mean±SD	0	0	0	0	0.56±0.02
	Range	0	0	0	0	0.54-0.58
Brinjal	Mean±SD	0	0	0.51±0.03	0	0.75±0.04
	Range	0	0	0.48-0.54	0	0.71-0.79
Bottle gourd	Mean±SD	0	0.18±0.02	0	0	1.51±0.02
	Range	0	0.16-0.20	0	0	1.49-1.53
Turnip	Mean±SD	0	0	0	0	3.05±0.04
	Range	0	0	0	0	3.01-3.09

The results implied that the mean Cr concentrations in vegetables were considerably lower than the mean Cr concentrations detected in Bangladeshi vegetables in other studies (Ahmad and Gani 2010; Karim *et al*. 2008).

Six vegetable samples and one water sample were collected from Sadapur. Among them, three (50% of the total number of vegetables) contained Cd residues and 3 vegetables (50% of the total number of vegetable) and one water sample contained no detectable Cd residues of the vegetable and water. (Table 2). The highest amount of Cd concentration (0.42mg/kg) was contented from Bottle gourd. In most of vegetable species, Cd concentrations were lower than the MAC (0.05 mg/kg) indicating these species are not contaminated by Cd but Bottle gourd, Cd concentrations were higher than the MAC (0.05mg/kg) indicating the vegetable are contaminated by Cd. The results also showed a large variation among vegetable species in Cd concentration, which were in agreement with previous findings (Jinadasa *et al*. 1997), with *A. hybridus*, *A. Gangeticus* L and *Allium cepa* possessing a higher risk for Cd accumulation than other vegetables.

The highest mean concentration of Pb was observed in red amaranth (1.74mg/kg), which was followed by radish spinach (0.48mg/kg) and water sample (0.03mg/kg) and the lowest Pb concentration (0 mg/kg) was in (radish, spinach, brinjal, bottle gourd) (Table 2). Lead concentrations in radish spinach and red amaranth was higher than the safe recommended limits by FAO/WHO (2011), indicting these vegetables species were contaminated by Pb and might pose risk due to consumption. Burning of industrial waste and coal in the brick fields were observed at the study area, which might result in the deposition of particulate matter (PM) on vegetables. Thus, the vegetables can be exposed to fine particles of Pb from $PbSO_4$, PbO, and $PbCO_3$. Uzu *et* *al*. (2011) showed that particulate matter (PM) containing Pb can be deposited on plant leaves and penetrate inside the tissues. The observed variation of heavy metals in vegetable species could be due to variable capabilities of metal absorption and accumulation (Pandey and Pandey 2009) and variations in growth period and rates (Saha and Zaman 2013) and soil properties such as soil pH, cation exchange capacity, organic content, and the interaction of soil–plant root–microbes (Gebrekidan *et al*. 2013).

Out of 6 Vegetables collected from Genda bazar, among them, only one vegetable was contained residue of Cu (0.42 mg/kg) in Red amaranth (Table 2). Copper concentrations in vegetables were lower than the guideline value of 40mg/kg set by FAO/WHO (2011). Copper concentrations in vegetables of our study was lower than the previous studies (Rahman *et al*. 2013; Sharma *et al*. 2007) indicating vegetables were not contaminated by Cu.

Out of 6 Vegetables, 6 (100% of the total number of vegetables) contained Zn residues and 1 one water sample) contained no detectable Zn residues of the vegetable (Table 2). The highest amount Zn (3.26 mg/kg) was observed from spinach. In the study area, the main sources of heavy metals in agricultural soils where the farmers grow vegetables are the repeated use of untreated or poorly treated waste water from industrial establishments and the application of chemical fertilizers and pesticides (Islam *et al*. 2009; Bhuiyan *et al*. 2011; Rahman *et al*. 2013).

4.6 Heavy Metals in Vegetable Samples from Savar thana bazar

The mean ± SD of the five studied metals in 9 different vegetable species are red amaranth, radish spinach, radish, carrot, spinach, tomato, brinjal, bottle gourd and turnip.

Table 2. Amount of Cr, Cd,Pb, Zn and Cu in different vegetables collected from Sadapur in Savar Thana

Name of vegetables		Cr (mg/kg fw)	Cd (mg/kg fw)	Pb (mg/kg fw)	Cu (mg/kg fw)	Zn (mg/kg fw)
Red amaranth	Mean± SD	1.01±0.02	0	1.74±0.07	0.42±0.02	1.23±0,1
	Range	1.0-1.04	0	1.66-1.80	0.40-0.45	1.13-1.33
Radish spinach	Mean± SD	1.98±0.01	0	0.48±0.02	0.00	1.19±0.02
	Range	1.97-2.0	0	0.46-0.50	0.00	1.17-1.21
Radish	Mean± SD	0	0	0	0	0.26±0.02
	Range	0	0	0	0	0.24-0.28
Spinach	Mean± SD	0	0.04±0.01	0	0	3.26±0.01
	Range	0	0.03-0.06	0	0	3.16-3.36
Brinjal	Mean± SD	0	0.07±0.01	0	0	1.06±0.01
	Range	0	0.06-0.08	0	0	1.04-1.08
Bottle gourd	Mean± SD	0	0.42±0.01	0	0	1.90±0.20
	Range	0	0.41-0.49	0	0	1.7-2.1
Water sample	Mean± SD	0	0	0.03±0.02	0	0.00
	Range	0	0	0.01-0.05	0	0.00

The mean concentrations of Cr ranged from 0.00mg/kg (spinach, tomato, brinjal, bottlegourd and turnip) to 2.24mg/kg (radish spinach) (Table 4). The maximum Cr content (2.24mg/kg) was obtained from radish spinach, which was followed by red amaranth (1.77mg/kg). Chromium concentrations in vegetable species were lower than the guideline value (2.3 mg/kg) set by FAO/WHO (2011). An earlier study by Karim *et al*. (2008) reported much higher concentrations of Cr in Bangladeshi vegetables (mean: 27.1 mg/kg, range: 23.3–33.8 mg/kg). The results implied that the mean Cr concentrations in vegetables were considerably lower than the mean Cr concentrations detected in Bangladeshi vegetables in other studies (Ahmad and Gani 2010; Karim *et al*. 2008).

Nine vegetable samples were collected from Savar thana bazar. Among them, two vegetables (22.22% of the total number of vegetables) contained Cd residues and 7 vegetables (77.78% of the total number of vegetable) contained no detectable Cd residues of the vegetable (Table 4). The highest amount of Cd concentration (0.33mg/kg) was contented from bottlegourd. In most of vegetable species, Cd concentrations were lower than the MAC (0.05mg/kg) indicating these species are not contaminated by Cd but bottlegourd, Cd concentrations were higher than the MAC (0.05 mg/kg) indicating the vegetable are contaminated by Cd. The results also showed a large variation among vegetable species in Cd concentration, which were in agreement with previous findings (Jinadasa *et al*. 1997), with *A. hybridus, A. Gangeticus* L and *Allium cepa* possessing a higher risk for Cd accumulation than other vegetables.

The highest mean concentration of Pb was observed in Carrot (3.17mg/kg), which was followed by brinjal (2.98mg/kg) and radish spinach (1.75 mg/kg) and the lowest Pb concentration (0 mg/kg) was in (red amaranth, radish, spinach, tomato, and turnip) (Table 4). Lead concentrations in most of vegetable was higher than the safe recommended limits by FAO/WHO (2011), indicting these vegetables species were contaminated by Pb and might pose risk due to consumption. Burning of industrial waste and coal in the brick fields were observed at the study area, which might result in the deposition of particulate matter (PM) on vegetables. Thus, the vegetables can be exposed to fine particles of Pb from $PbSO_4$, PbO, and $PbCO_3$. Uzu *et al*. (2011) showed that particulate matter (PM) containing Pb can be deposited on plant leaves and penetrate inside the tissues. The observed variation of heavy metals in vegetable species could be due to variable capabilities of metal absorption and accumulation (Pandey and Pandey 2009) and variations in growth period and rates (Saha and Zaman 2013) and soil properties such as soil pH, cation exchange capacity, organic content, and the interaction of soil–plant root–microbes (Gebrekidan *et al*. 2013).

Out of 9 Vegetables collected from Genda bazar, among them, only one vegetable was contained residue of Cu (1.299 mg/kg) in red amaranth (Table 4).Copper concentrations in vegetables were lower than the guideline value of 40 mg/kg set by FAO/WHO (2011). Copper concentrations in vegetables of our study was lower than the previous studies (Rahman *et al*. 2013; Sharma *et al*. 2007) indicating vegetables were not contaminated by Cu.

Out of 9 Vegetables, 9 (100% of the total number of vegetables) contained Zn residues (Table 4). The highest amount Zn (4.37 mg/kg) was observed from Spinach. In the study area, the main sources of heavy metals in agricultural soils where the farmers grow vegetables are the repeated use of untreated or poorly treated waste water from industrial establishments and the application of chemical fertilizers and pesticides (Islam *et al*. 2009; Bhuiyan *et al*. 2011; Rahman *et al*. 2013).

In this study, the mean concentration of Cr is 0.85 mg/kg and it ranged from 0.81-1.37 mg/kg (Table 3). The mean concentration of Cr (0.85 mg/kg) is higher than the reported value found in Noakhali (0.6 mg/kg) in Bangladesh and pearl river, China (0.2 mg/kg) estimated by Rahman *et al.* (2013) and Li *et al.* (2012) respectively and lower than the reported value found in Dhaka, Bangladesh (1.7 mg/kg) estimated by Ahmed and Goni (2010) (Table 3).

In this study, the mean concentration of Cd was found 0.16 mg/kg and it ranged from (0.10-0.20) mg/kg (Table 3). The mean concentration of Cd (0.16 mg/kg) is higher than the reported value found in Noakhali (0.06mg/kg) in Bangladesh and pearl river, China (0.06 mg/kg) estimated by Rahman *et al.* (2013) and Li *et al.* (2012) respectively and lower than the reported value found in Dhaka, Bangladesh (0.6mg/kg) and New South Wales, Australia(0.2mg/kg) estimated by Ahmed and Goni (2010) and Kachenko and Singh (2006) respectively (Table 3).

The mean concentration of Pb was observed 1.23 mg/kg and it ranged from (0.39-2.70) mg/kg in this experiment (Table 3). The mean concentration of Pb (1.23 mg/kg) is higher than the reported value found in pearl river, China (0.06 mg/kg) estimated by Li *et al*. (2012) respectively and lower than the reported value found in Dhaka, Bangladesh (3.7 mg/kg),New South Wales, Australia(3.1mg/kg) and Varanasi, India (36 mg/kg) estimated by Ahmed and Goni (2010), Kachenko and Singh (2006) and Sharma *et al.* (2007) respectively (Table 3).

The mean concentration of Cu was found 0.79 mg/kg and it ranged from (0.36-1.29) mg/kg in this study (Table 3). The mean concentration of Pb (0.79 mg/kg) is higher than the reported value found in pearl river, China (0.70 mg/kg) estimated by Li *et al.*

(2012) and lower than the reported value found in Dhaka, Bangladesh (3.9 mg/kg),New South Wales, Australia(1.9 mg/kg) and Varanasi, India (36 mg/kg) estimated by Ahmed and Goni (2010), Kachenko and Singh (2006) and Sharma *et al.* (2007) respectively (Table 3).

Table 3. Comparison of metal concentrations (mg/kg fw) in vegetables with the reported values in the literatures

Study area	Cr	Cd	Pb	Cu	References
Savar, Dhaka	0.85 (0.81-1.37)	0.16 (0.10–0.20)	1.23 (0.39–2.70)	0.79 (0.36–1.29)	This study
Noakhali, Bangladesh	0.6 (0.2–1.9)	0.06 (0.006–0.3)	3.7 (0.7–17)	2.1 (2.1–86)	Rahman et al. 2013
Dhaka, Bangladesh	1.7	0.6	3.9	3.9	Ahmad and Gani 2010
Varanasi, India	NA	2.1 (1.1–4.5)	1.4 (0.9–2.2)	36 (21–71)	Sharma et al. 2007
New South Wales, Australia	NA	0.2	3.1	1.9	Kachenko and Singh 2006
Pearl River, China	0.2	0.06	0.06	0.7	Li et al. 2012

Note: Data in parentheses indicates minimum and maximum value; NA = Data not available

Table 4. Amount of Cr, Cd, Pb, Zn and Cu in different vegetables collected from Savar thana bazar

Name of vegetables		Cr (mg/kg fw)	Cd (mg/kg fw)	Pb (mg/kg fw)	Cu (mg/kg fw)	Zn (mg/kg fw)
Red amaranth	Mean±SD	1.77±0.02	0.00	0.00	1.299±0.03	1.79±0.01
	Range	1.75-1.79	0.00	0.00	1.296-1.30	1.78-1.80
Radish spinach	Mean±SD	2.24±0.04	0.00	1.75±0.50	0.00	0.33±0.03
	Range	2.20-2.28	0.00	1.70-1.80	0.00	0.30-0.36
Radish	Mean±SD	0.40±0.20	0.00	0.00	0.00	0.80±0.05
	Range	0.20-0.60	0.00	0.00	0.00	0.75-0.85
Carrot	Mean±SD	1.10±0.0.1	0.00	3.17±0.02	0.00	0.16±0.04
	Range	1.00-1.20	0.00	3.15-3.19	0.00	0.14-0.20
Spinach	Mean±SD	0.00	0.00	0.00	0.00	4.37±0.03
	Range	0.00	0.00	0.00	0.00	4.34-4.40
Tomato	Mean±SD	0.00	0.00	0.00	0.00	0.34±0.01
	Range	0.00	0.00	0.00	0.00	0.33-0.35
Brinjal	Mean±SD	0.00	0.00	2.98±0.01	0.00	0.94±0.03
	Range	0.00	0.00	2.97-2.99	0.00	0.91-0.97
Bottlegourd	Mean±SD	0.00	0.33±0.3	0.32±0.02	0.00	1.23±0.02
	Range	0.00	0.30-0.36	0.30-0.34	0.00	1.21-1.25
Turnip	Mean±SD	0.00	0.07±0.02	0.00	0.00	1.06±0.02
	Range	0.00	0.05-0.09	0.00	0.00	1.04-1.08

CHAPTER V

SUMMARY& CONCLUSION

The experiment was conducted in the Agro- Environmental Chemistry laboratory of the Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University,Dhaka-1207 during the period from December 2016 to May 2017 to assess different heavy metals of winter vegetables grown at different places of Savar Thana under Dhaka district. Different vegetables samples were collected from intensively growing areas of Savar Thana such as Sadapur kazipara, Nama Genda, Pathalia and Vagolpur and nearest local market ie. Savar Thana Bazar and Genda Bazar under Dhaka district. Different types (red amaranth, radish, radish spinach, carrot, tomato, brinjal, bottle gourd spinach, fenugreek leaves, bottle gourd, turnip and spinach) of vegetables samples were collected randomly from each selected location. Vegetables were collected at the stage of harvesting from farmers field and nearest local markets.

Nine vegetable samples were collected from Vagolpur. The maximum Cr concentration (0.64mg/kg) was obtained from red amaranth. The highest mean concentration of Pb was observed in bottle gourd spinach (0.39mg/kg). The mean concentrations of Cu in vegetable species were obtained red amaranth (0.37mg/kg). The maximum Zn concentration 3.67(mg/kg) was obtained in fenugreek leaves.

Eight vegetable samples were collected from Nama genda. The maximum Cr content (1.30 mg/kg) was obtained from radish spinach. The highest mean concentration of Pb was observed in red amaranth (2.48 mg/kg). The highest amount Cu (0.63mg/kg) was observed from red amaranth. The highest amount Zn (2.86 mg/kg) was observed from red amaranth.

Nine vegetable samples were collected from Pathalia. The maximum Cr content (1.38 mg/kg) was obtained from radish spinach. Four vegetables (44.44% of the total number of vegetables) contained Cd residues. The highest mean concentration of Pb was observed in red amaranth (2.85 mg/kg). The highest amount Zn (4.82 mg/kg) was observed from fenugreek leaves.

Nine vegetable samples were collected from Genda bazar. The maximum Cr content (2.12 mg/kg) was obtained from red amaranth. The highest amount of Cd concentration (0.18 mg/kg) was contented from bottle gourd. The highest mean concentration of Pb was observed in radish spinach (3.89 mg/kg). Only one vegetable was contained residue of Cu in red amaranth. The highest amount Zn (3.45 mg/kg) was observed from spinach.

Six vegetable samples were collected from Sadapur. The maximum Cr content (1.98mg/kg) was obtained from radish spinach. The highest amount of Cd concentration (0.42 mg/kg) was contented from bottle gourd. The highest mean concentration of Pb was observed in red amaranth (1.74 mg/kg). Only one vegetable was contained residue of Cu (0.42 mg/kg) in red amaranth. The highest amount Zn (3.26 mg/kg) was observed from spinach.

Nine vegetable samples were collected from Savar thana bazar. The maximum Cr content (2.24 mg/kg) was obtained from radish spinach. The highest amount of Cd concentration (0.33 mg/kg) was contented from bottle gourd. The highest mean concentration of Pb was observed in carrot (3.17 mg/kg). Only one vegetable was contained residue of Cu (1.299 mg/kg) in red amaranth. The highest amount Zn (4.37 mg/kg) was observed from spinach.

Vegetables play a significant role in human nutrition. Levels of essential minerals, trace elements and heavy metals of some wild, waste water irrigated and commonly edible vegetables available in Savar thana were studied. The findings of the present study concluded that from the analysis in various constituents it showed that vegetable is a contaminated by heavy metal. Common edible vegetable available in six places in Savar area contained heavy metals that might be incorporated via contaminated soil, irrigated waste water or others. Heavy metals found in some vegetables that were above the WHO/FAO recommended safe permissible level. Awareness of people and regular monitoring of levels of these metals in vegetables is essential to prevent the incorporation in the food chain. Consumers are purchasing these heavy metals contaminated vegetables, which is a great concern of our health risk.

RECOMMENDATIONS

There is a need for assessment of different heavy metals from rest of the villages of Savar Thana. Further research is needed to obtain more specific information about the plant accumulation of different heavy metals and their distribution in the different plant parts. There is a great concern on potential health risk of the people of these areas exposed to different heavy metals contaminated vegetables

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APPENDIX

Appendix I. Amount of Cr, Cd, Pb, Zn and Cu in different vegetables collected from Vagolpur in Savar thana

Name of vegetables		Cr (mg/kg fw)	Cd (mg/kg fw)	Pb (mg/kg fw)	Cu (mg/kg fw)	Zn (mg/kg fw)
Red amaranth	Mean±SD	0.64±0.06	0.00	0.00	0.37±0.02	2.0±o.10
	Range	0.58-0.70	0.00	0.00	0.36-0.38	1.9-2.1
Radish	Mean±SD	0.41±0.03	0.00	0.00	0.00	1.46±0.01
	Range	0.38-0.45	0.00	0.00	0.00	1.45-1.48
Spinach	Mean±SD	0.00	0.12±0.02	0.00	0.00	2.95±0.17
	Range	0.00	0.10-0.14	0.00	0.00	2.95-3.10
Tomato	Mean±SD	0.00	0.00	0.00	0.00	1.0±0.10
	Range	0.00	0.00	0.00	0.00	0.90-1.10
Brinjal	Mean±SD	0.00	0.00	0.00	0.00	0.93±0.12
	Range	0.00	0.00	0.00	0.00	0.80-1.05
Bottlegourd spinach	Mean±SD	0.00	0.27±0.02	0.39±0.01	0.00	2.05±0.04
	Range	0.00	0.25-0.30	0.38-0.40	0.00	2.01-2.10
Bottlegourd	Mean±SD	0.00	0.25±0.02	0.00	0.00	2.52±0.08
	Range	0.00	0.23-0.27	0.00	0.00	2.44-2.60
Fenugreek leaves	Mean±SD	0.00	0.12±0.02	0.00	0.00	3.67±0.08
	Range	0.00	0.10-0.15	0.00	0.00	3.65-3.77

Appendix II. Amount of Cr, Cd, Pb, Zn and Cu in different vegetables collected from Pathalia in Savar thana

Name of vegetables		Cr (mg/kg fw)	Cd (mg/kg fw)	Pb (mg/kg fw)	Zn (mg/kg fw)	Cu (mg/kg fw)
Red amaranth	Mean ± SD	1.34±0.05	0.00	2.85±0.05	1.35±0.05	0.00
	Range	1.30-1.40	0.00	2.80-2.90	1.30-1.40	0.00
Radish spinach	Mean ± SD	1.38±0.10	0.00	0.10±0.05	1.26±0.2	0.00
	Range	1.27-1.48	0.00	0.05-0.11	1.1-1.5	0.00
Radish	Mean ± SD	0.34±0.05	0.00	0.00	0.00	0.00
	Range	0.30-0.40	0.00	0.00	0.00	0.00
Carrot	Mean ± SD	0.00	0.00	0.00	0.00	0.00
	Range	0.00	0.00	0.00	0.00	0.00
Spinach	Mean ± SD	0.00	0.00	0.00	0.01±0.02	0.00
	Range	0.00	0.00	0.00	0.0-0.04	0.00
Tomato	Mean ± SD	0.00	0.006±0.002	0.03±0.02	0.57±0.03	0.00
	Range	0.00	0.004-0.009	0.0-0.05	0.54-0.60	0.00
Brinjal	Mean ± SD	0.00	0.14±0.004	0.00	0.89±0.05	0.00
	Range	0.00	0.10-0.18	0.00	0.84-0.94	0.00
Bottle gourd spinach	Mean ± SD	0.00	0.24±0.04	0.08±0.03	0.88±0.05	0.00
	Range	0.00	0.20-0.29	0.04-0.11	0.82-0.92	0.00
Fenugreek leaves	Mean ± SD	0.00	0.00	0.00	4.82±0.3	0.00
	Range	0.00	0.00	0.00	4.87-5.0	0.00
Water sample	Mean ± SD	0.00	0.02±0.01	0.03±0.02	0.00	0.00
	Range	0.00	0.00-0.04	0.01-0.05	0.00	0.00

Appendix III. Amount of Cr, Cd, Pb, Zn and Cu in different vegetables collected from Nama Genda

Name of vegetables		Cr (mg/kg fw)	Cd (mg/kg fw)	Pb (mg/kg fw)	Cu (mg/kg fw)	Zn (mg/kg fw)
Red amaranth	Mean ± SD	0.61±0.02	0.00	2.48±0.02	0.63±0.04	2.86±0.04
	Range	0.59-0.63	0.0	2.46-2.50	0.59-0.67	2.82-2.90
Radish Spinach	Mean ± SD	1.30±0.02	0.00	0.00	0.00	0.09±0.02
	Range	1.28-1.32	0.00	0.00	0.00	0.07-0.11
Radish	Mean± SD	1.04±0.02	0.00	0.00	0.00	0.18±0.2
	Range	1.02-1.06	0.00	0.00	0.00	0.16-0.20
Carrot	Mean ± SD	0.66±0.02	0.00	0.63±0.02	0.00	1.72±0.02
	Range	0.64-0.68	0.00	0.61-0.65	0.00	1.70-1.74
Spinach	Mean ± SD	0.00	0.00	0.00	0.00	0.63±0.01
	Range	0.00	0.00	0.00	0.00	0.62-0.64
Tomato	Mean ± SD	0.00	0.00	0.87± 0.02	0.00	0.00
	Range	0.00	0.00	0.85-0.89	0.00	0.00
Brinjal	Mean ± SD	0.00	0.00	0.00	0.00	0.00
	Range	0.00	0.00	0.00	0.00	0.00
Bottle gourd	Mean ± SD	0.00	0.00	0.00	0.00	1.54±0.03
	Range	0.00	0.00	0.00	0.00	1.51-1.57

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