Studies on Arsenic and Lead Contamination in Crops and Vegetables of Harischandrapur Village of Jessore District in Bangladesh

by

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Declaration

This is to certify that the thesis work entitled **"Studies on Arsenic and Lead contamination in Crops and Vegetables of Harischandrapur Village of Jessore District in Bangladesh**" has been carried out by Nusrat Sultana in the Department of Chemistry, Khulna University of Engineering & Technology, Khulna, Bangladesh. The above thesis work or any part of this work has not been submitted anywhere for the award of any degree or diploma.

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Abstract

Various fruits and vegetables such as Mango (*Mangifera indica* L.), Jackfruit (*Artocarpus heterophyllus* L.), Guava (*Psidiun guajava* L.), Pummelo (*Citrus grandis* L.), Lime *(Citrus aurantifollia),* Papaya (*Carica papaya* L.), Coconut (*Cocos nucifera* L.), Sapodilla *(Manilkara zapota),*Yard long bean *(Vigna sesquipedalis)*, Okra(*Abelmoschus esculentus),* Ribbed gourd *(Luffa acutangula),* Plantain (*Musa paradisiacal),* Cucumber (*Cucumis sativus),* Green hot chili (*Capsicum frutescens*), Stem Amaranth leaf (*Amaranthus lividus*), Red Amaranth (*Amaranthus gangeticus*), Indian Spinach (*Basella rubra),* Brinjal (*Solanum melongena*), Pumpkin (*Cucurbita moschata*), Pea seed (*Pisum sativum*), Rice (*Oryza sativa L*), Leaf of Taro (*Colocasia esculenta*) and Corm of elephant yam (*Amorphophallus paeoniifolius)* were collected from Harischandrapur village of Jessore district of Bangladesh and screened for arsenic, lead, iron, manganese, copper and zinc by Atomic Absorption Spectrophotometer (AAS).

The average moisture contents in soil, fruits, fruity vegetables, root-stem vegetables, leafy vegetables and seed vegetables were found 19.91%, 82.25%, 87.67%, 88.65%, 83.36% and 45.00% respectively. The mean concentrations of arsenic, iron and manganese in irrigation water were 0.11 mg/L, 4.28 mg/L and 0.48 mg/L respectively which are higher than Bangladesh drinking water standard. The average concentration of arsenic in irrigation water is higher than FAO standard (<0.100 mg/L for irrigation water).

The average concentrations of arsenic, iron, manganese, copper and zinc were found 8.63 mg/Kg, 12162.78 mg/Kg, 256.07 mg/Kg, 21.91 mg/Kg and 57.40 mg/Kg respectively in soils which are lower than FAO, USEPA & EU standard for agricultural soil.

The average concentrations of arsenic in fruits, fruity vegetables, root-stem vegetables, leafy vegetables and seed vegetables were detected 0.17 mg/Kg, 0.14 mg/Kg, 0.23 mg/Kg, 0.51 mg/Kg and 0.15 mg/Kg respectively which are lower than that of standard value recommended by WHO and FAO (<1.00 mg/Kg) for food.

The average concentrations of iron in fruits, fruity vegetables, leafy vegetables and seed vegetables were monitored 31.13 mg/Kg, 60.38 mg/Kg, 338.68 mg/Kg and 42.83 mg/Kg respectively that are lower than WHO/FAO standard (<1.00mg/Kg) for food.

The mean concentrations of manganese in fruits, fruity vegetables, leafy vegetables and seed vegetables were detected 2.86 mg/Kg, 12.90 mg/Kg, 24.26 mg/Kg and 8.48 mg/Kg respectively which are lower than EU standard (<500mg/Kg).

The mean concentrations of copper were found 3.40 mg/Kg, 9.36 mg/Kg, 4.76 mg/Kg, 9.70 mg/Kg respectively in fruits, fruity vegetables, leafy vegetables and seed vegetables which are lower than EU standard (<20.00 mg/Kg) for food.

The average concentrations of zinc in fruits, fruity vegetables, leafy vegetables and seed vegetables were detected 14.72 mg/Kg, 28.48 mg/Kg, 23.37 mg/Kg and 27.15 mg/Kg respectively which are lower than EU standard (<50.00 mg/Kg). The concentration of lead in all selected soil, water, fruits and vegetables were lower than detection level.

Maximum average concentration of arsenic, iron and manganese was found in leafy vegetables. On the other hand maximum mean concentration of copper and zinc were measured in fruity and seed vegetables.

In our research, 40 peoples were monitored for calculating the consuming of arsenic, iron, manganese, copper and zinc through daily intake of food (fruits and vegetables), water and their health risk factors were also analyzed. In this study area, the people's average age, body weight and daily intake of water, rice, vegetables and fruits were 28.48 years, 46.60Kg, 2.80L, 0.39Kg, 0.12Kg and 0.14Kg respectively. The order of daily intake and health risk index of metals from food and water was Iron>Manganese>Arsenic>Zinc>Copper. The fruits and vegetables of the study area are safe for human health according to WHO oral dose reference data (R_{fd}) for metals and health risk index.

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CHAPTER I

Introduction

1.1 Overview

Fruits and Vegetables are essential parts of human diet which are containing carbohydrates, proteins, vitamins, minerals and trace elements. Heavy metals (As, Fe, Mn, Pb, Cd, Cr, Cu and Zn) are toxic and it may be contaminated in our food chain (fruits and vegetables) through irrigation water, soil, fertilizers, industrial emission and transportation sources. Heavy metals are easily accumulated by plants from contaminated soil and irrigation water and it can deposit in human vital organs which may be affected on human health [1]. Arsenic pollution has been reported from more than 70 countries on six continents [2]. The contamination of arsenic in ground water poses a risk to the health of millions of people, especially in the densely populated river deltas of south-east Asia (Bangladesh, China, Cambodia, Laos, India, Nepal, Myanmar, Pakistan and Vietnam). However, the scale of the problem is much larger in Bangladesh than in any other country in the world [3]. The world health organization (WHO) has described the situation of arsenic contamination in Bangladesh as the largest poisoning of a population in the history [4]. Peoples were changing their habits to use ground water instead of surface water for reducing the water borne diseases (Diarrhea, Dysentery, Typhoid & Cholera) in 1980 [5]. Bangladesh is heavily dependent on ground water for drinking, cooking and irrigation purposes. Handtube wells were considered as reliable means for extracting contaminants free ground water at low cost [6]. In Bangladesh approximately 97% peoples were using ground water for drinking, cooking and irrigation purposes since 1990s [7]. Peoples were using ground water from 4-5 million of hand tube wells that have been sunk over the 30 years [8]. In 1993 arsenic contamination was detected in ground water at Barogharia union of Nawabgong district in Bangladesh [9]. About 80 million people in 61 districts out of 64 districts pose a serious health threat due to using arsenic contaminated ground water [10-11]. Numerous recent studies have been indicated that arsenic constitutes a serious health risk via arsenic contaminated water and food. Arsenic is a cumulative substance, which is slowly passes out of the body through the urine, hair, finger/toe nails and skin. It takes around 8-14 years after starting to drink arsenic contaminated water for symptoms to appear [12]. This period depends on the amount of arsenic ingested, the length of exposure and immunity level of the person. Symptoms of the initial stage of the disease are skin pigmentation, eye infections, trachea and cancer [13]. Due to the illness of people the nation is losing millions and millions of manpower as well as impoverishes strength, knowledge, economy, development and finally it begins to kill slowly and painfully.

Arsenic contaminated water is not safe for drinking , cooking and irrigation. According to DGHS (Directorate General of Health Services) data 38412 arsenicosis patients have been suspected in Bangladesh due to consume arsenic contaminated water for drinking and cooking [14]. Arsenic safe water and food is the first priority for arsenicosis patients. Many studies have been conducted on arsenic levels in ground water, soils and crops of arsenic contaminated zone in Bangladesh [15].Very few studies have been focused on the relationship between ground water-soil and soil-rice in paddy fields. Environmental arsenic enters into food in two ways [16-18]. Water-soil-plant transfer is the first way of arsenic contamination in food chain. Arsenic, iron and manganese contaminated water is responsible for soil contamination. Plants uptake metals from these contaminated soils which are the main sources of arsenic, iron, manganese contamination in vegetables, rice and fruits. Another way is arsenic contaminated water is using for food processing. Arsenic uptake by crop plants grown in soils contaminated with high concentrations of arsenic, and irrigated with arsenic-contaminated groundwater has also been reported [19]. Soil acts as a major sink of arsenic flow into agro ecosystems, thereby increase the availability of the toxicant to the cropped species [20].

Adequate data on the carcinogenicity of organic arsenic have not been generated. The joint FAO/WHO Expert Committee on Food Additives (JECFA) set a provisional maximum tolerable daily intake (PMTDI) of inorganic arsenic as 0.002 mg/kg of body weight for humans in 1983 and confirmed a provisional tolerable weekly intake (PTWI) as 0.015 mg/kg of body weight in 1988 [21-22]. Generally higher contents of arsenic, manganese, copper, zinc, lead, cadmium, chromium and nickel related heavy metals are toxic and they are called urgency pollutants. In urban and rural areas agricultural land contamination with toxic metals is common as a result of industrial and municipal activity. Soil contaminated with metals is a primary route of toxic exposure to humans. Toxic metals can enter the human body by consumption of contaminated food, crops, water and fruits [23].Vegetables grown on contaminated land may accumulate toxic metals. Heavy metal contaminated vegetables and fruits have toxic effects on human health through disturbances of biochemical processes, such as liver, kidney, cardiovascular, nervous system and bone disorders [24-25]. Health risk assessment of heavy metals in contaminated vegetables is being carried out in development countries [26]. In Bangladesh very few research studies and published data are available on heavy metals contamination on vegetables and fruits [27-30].

1.2 Fruits and Vegetables

Fruits and vegetables are the basic components of food which provide nutritional support for the human body. It is usually of plant or animal origin and contains essential nutrients, such as fats, proteins, vitamins or minerals. The substance is ingested by an organism and assimilated by the organism's cells to provide energy, maintain life or stimulate growth [31]. Many plants and plant parts are eaten as food and around 2,000 plant species are cultivated for food. Many of these plant species have several distinct cultivars [32]. Seeds of plants are a good source of food for animals and humans. They contain the nutrients necessary for the plant's initial growth. In fact, the majority of food consumed by human beings is seed-based foods. Edible seeds include cereals (corn, wheat, rice, et cetera), legumes (beans, peas, lentils etc.) and nuts. Oilseeds are often pressed to produce rich oils - sunflower, flaxseed, rapeseed (including canola oil) and sesame etc. [33]. Fruits, therefore, make up a significant part of the diets of most cultures. Some botanical fruits, such as tomatoes, pumpkins and eggplants are eaten as vegetables [34]. Vegetables are a second type of plant matter that is commonly eaten as food. These include root vegetables (potatoes and carrots), bulbs (onion family), leafy vegetables (spinach and lettuce), stem vegetables (bamboo shoots and asparagus), inflorescence vegetables (globe artichokes, broccoli and other vegetables such as cabbage or cauliflower) [35]. More than 90 vegetables and 60 fruits are being grown in Bangladesh [36]. Major vegetable crops include brinjal (eggplant), chili, lady’s finger, potato, tomato, bottle gourd and red amaranth etc. In an average Bengali home, the main meal would consist of boiled rice served with some sort of vegetables [37]. The most widely cultivated fruits are mango, jackfruit, black berry, jujube, pineapple, litchi, guava, papaya, coconut, custard apple, wood apple, elephant apple, Indian blackberry, tamarind, cashew nut, pomegranate, Palmyra palm, rose apple, and Indian olive. There are many minor edible fruits too, which are locally available such as Burmese grape (latkan), monkey jack, rattan, river ebony, velvet apple, cowa, wild date palm etc. [38]. Bangladeshi eats a total of 126 g of fruit and vegetables daily. This is far below the minimum consumption of 400 g of vegetables and fruit recommended by FAO and the World Health Organization (WHO) [39]. Food safety is a major concern worldwide. The heavy metals pollution is one of the problems that arise due to the increased uses of fertilisers and other chemicals to meet the higher demands of food production for human consumption. Heavy metals are the major contaminants of food supply and may be considered the most important problem to our environment [40]. A heavy metal is any one of a number of elements that exhibit metallic properties, which includes transition metals lanthanides actinides as well as the metalloids arsenic and antimony. Many heavy metals have considerable toxicity, others are considered not deemed to possess significant toxic properties, and in fact, several of these elements including zinc, iron, copper, chromium and cobalt are necessary for metabolic function for a large class of organisms [41]. Heavy metals such as Cd, Cu, Pb, Cr and Hg are important environmental pollutants, particularly in areas with high anthropogenic pressure. Their presence in the atmosphere, soil, water, even in traces, can cause serious problems to all organisms [42].

1.3 Sources of heavy metal contamination

Sources of food contamination include environmental and industrial pollution, agricultural practices, food processing and packaging. Absorption of heavy metals through food has been shown to have serious consequences on health – such as kidney disease, damage to the nervous system, diminished intellectual capacity, heart disease, gastrointestinal diseases, bone fracture, cancer and death [25]. Preliminary studies in different parts of Bangladesh indicate that the food chain is exposed to contaminate by heavy metals and trace elements [43]. It is found that industrial sludge, often used as a soil fertilizer has high concentrations of heavy metals. Similarly, high levels of heavy metals were found in soils in the Sundarbans [44]. When these metals are absorbed by crops and animals they enter the food chain and constitute a serious health hazard. An analysis of heavy metal concentrations in vegetables in Jessore shows that all of the vegetables commonly consumed in diets contain dangerously high concentrations of heavy metals [36].

Table 1.1: Important trace elements in natural waters [45]

Element	Source	Effects and significance
Arsenic	Mining byproduct, chemical waste	Toxic, possibly carcinogenic
Chromium	Metal plating	Essential as Cr(III), toxic
Copper	Metal plating, mining to industrial wastes	Essential trace elements, toxic plants and algae at higher levels
Iron	Industrial wastes, corrosion, Acid mine water, microbial action	Essential nutrient, damages fixtures by staining
Lead	Industrial wastes, mining, Fuels	Toxic, harmful to wildlife damages fixtures by staining
Manganese	Industrial wastes, acid mine water, microbial action	Toxic to plants, damages fixtures by staining

1.4 Heavy metals in Soil

Soil consists of a solid phase of minerals and organic matter, as well as a porous phase that holds gases and water. Accordingly, soils are often treated as a three-state system of solids, liquids, and gas [46]. Most soils have a density between 1 and 2 g/cm^3 [47]. It is called the "Skin of the Earth" [48].

An agricultural definition of soil is "a dynamic natural body on the surface of the earth in which plants grow, composed of mineral, organic materials and living forms" [49].

An engineering definition of soil is "all the fragmented mineral material at or near the surface of the earth, the moon or other planetary body plus the air, water, organic matter and other substances which may be included therein" [50].

Soils may become contaminated by the accumulation of heavy metals and metalloids through emissions from the rapidly expanding industrial areas, mine tailings, disposal of high metal wastes, leaded gasoline and paints, land application of fertilizers, animal manures, sewage sludge, pesticides, wastewater irrigation, coal combustion residues, spillage of petrochemicals and atmospheric deposition [51]. Soils are the major sink for heavy metals released into the environment by aforementioned anthropogenic activities and unlike organic contaminants which are oxidized to carbon (IV) oxide by microbial action, most metals do not undergo microbial or chemical degradation and their total concentration in soils persists for a long time after their introduction [52]. The presence of toxic metals in soil can severely inhibit the biodegradation of organic contaminants [53]. Heavy metal contamination of soil may pose risks and hazards to humans and the ecosystem. Due to direct ingestion or contact with contaminated soil, the food chain (soil-plant-human or soil-plant-animal-human), drinking of contaminated ground water, reduction in food quality (safety and marketability) via phytotoxicity, reduction in land usability for agricultural production causing food insecurity and land tenure problems [54].

1.5 Health Risk From Metal Contaminated Fruits and Vegetables

Intake of heavy metals contaminated vegetables may pose a risk to the human health. Heavy metal contamination of the food items is one of the most important aspects of food quality assurance [51]. The prolonged consumption of unsafe concentrations of heavy metals through food stuffs may lead to the chronic accumulation of heavy metals in the kidney and liver of humans causing disruption of numerous biochemical processes, leading to cardiovascular, nervous, kidney and bone diseases [25]. 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 act as carcinogens [55]. The contamination of vegetables with heavy metals due to soil and atmospheric contamination poses a threat to its quality and safety. Dietary intake of heavy metals also poses risk to animals and human health. Heavy metals such as Cd and Pb have been shown to have carcinogenic effects [55]. High concentrations of heavy metals (Cu, Cd and Pb) in fruits and vegetables were related to high prevalence of upper gastrointestinal cancer. Regular monitoring of these metals in food materials is essential for preventing excessive build up of the metals in the food chain [56].

Table 1.2: Effects of heavy metals on plants [45]

Element	Symptoms
Ni	Gray-green leaves, brown and stunted roots and plant growth
As	Red-brown necrotic spots, yellowing or browning of roots
Zn	Chlorotic and necrotic leaf tips, retarded growth, injured roots
Cd	Brown margin of leaves, chlorosis, reddish veins and petioles
Cr	Chlorosis, necrotic spots and purpling tissues, injured root growth
Cu	Dark green leaves, thick, short, or barbed-wire roots
Pb	Dark green leaves, wilting, stunted foliage and brown short roots

For humans, typical presentations associated with exposure to any of the classical toxic heavy metals, such as arsenic (a metalloid) and lead are shown below.

1

2

3

4

5

6

Figure 1.1: Some picture about toxic effects of arsenic [57]

7

8

9

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Figure 1.2: toxic effects of lead [57]

Bangladesh is a land of agriculture. Agriculture production depends on irrigation water. Before, 1980 surface water was main source of irrigation water for agriculture production but now ground water is the main source of irrigation. Sharsha upazila is the highly arsenic contaminated zone in Jessore district. According to JICA-AAN (Japan International Cooperation Agency-Asia Arsenic Network) tube well screening survey data 23.2% drinking tube well water and 15.0% irrigation tube wells water arsenic concentrations are exceeding than drinking (>0.05mg/L) and irrigation (>0.100) water quality standard in Bangladesh. At Goga union drinking tube wells and Irrigation tube wells arsenic contamination is higher than others union in Sharsha upazila [58-59].

The concentration of arsenic in drinking tube wells and irrigation tube wells were 80% & 75% respectively in Harischandrapur village, the depths of tube wells range 50ft to 400ft [58, 59]. The area is located on the high Ganges river flood plain in the agro ecological zone in Bangladesh [58]. The soil type in this area is calcareous dark soil with low fertility [59]. Arsenic calamity in Bangladesh is causing serious health damage among rural residents. While drinking water is undoubtedly the major source of arsenic entering the human body, food is also major contributor of arsenic into the human body. Environmental arsenic enters into food in two ways [60-61]. Water-soil-plant transfer is the first way of arsenic contamination. Arsenic contaminated water used in irrigation also contaminates soils, and uptake by plants causes arsenic contamination in vegetables, rice and fruits. Another way is the use of arsenic contaminated water for food processing. The purpose of the research study to assess the significance of arsenic intake from food compared with that from drinking water using data from a rural area in Jessore district in Bangladesh.

Jessore district is situated in southern part of Bangladesh. Farmers and growers are cultivating various seasonal fruits and vegetables. This research work was conducted at Harischandrapur village under Sharsha upazila in Jessore district. The soil of jessore district is fertile and climate is suitable for fruits and vegetables growing. For crops cultivation farmer are using chemical fertilizer, pesticide, herbicide, hormones and other chemical materials and which is responsible to reduce the soil fertility and increase chemical contamination. The study area was selected on the basis of irrigation water quality and heavy metals (arsenic, lead, iron, manganese, copper and zinc) contamination profile.

1.6 Aim of the present study

The objectives of the research work are to estimate the arsenic, lead and other essential heavy metals (Iron, Manganese, Copper and Zinc) in foods of Harischandrapur village. The specific aims are:

1. to analyze the concentration of Arsenic (III) in Crops and vegetables of Harischandrapur village in Jessore district,
2. to find out the concentration of Arsenic in soil and water of this village,
3. to analyze the concentration of other heavy metals (Lead, Iron, Manganese, Copper and Zinc) in food of Harischandrapur village,
4. to predict about the quality of foods and vegetables of this village.

The aim of this study is to provide an overview of the latest findings of As, Pb and other heavy metals (iron, manganese, copper and zinc) contamination in food materials through metals-contaminated irrigation-water and the subsequent transfer of metals via water/soil to crops. These findings would likely help the researchers and policy makers to conduct more research on this issue and formulate proper agricultural strategies to produce As and other heavy metals free food products and to reduce the metals causing disease risk in human being.

CHAPTER II

Literature Review

Previous studies were measured arsenic contamination in varrious kinds of leafy vegetables (Taro,amaranth and indian spinach) which vegetables arsenic contents were 0.44mg/Kg to 1.20 mg/Kg (Table-2.1).

Table 2.1: Conc. of arsenic in various leafy vegetables

Name of Leafy Vegetable	Scientific Name	Conc. Of Arsenic in vegetables (mg/Kg)	Location	Reference
Taro leaf	*Colocasia esculenta*	0.44	Jessore, Bangladesh	[62]
Taro leaf	*Colocasia esculenta*	0.63	Chapai Nawabgang, Bangladesh	[63]
Amaranth Leaf	*Amaranthus lividus*	0.70	Jessore, Bangladesh	[64]
Indian spinach	*Basella rubra*	0.80	Jessore, Bangladesh	[64]
Subuj shak	*Amaranthus lividus*	1.20	Jessore, Bangladesh	[64]

On the other hand some studies were detected arsenic in fruity vegetables (Pumpkin, eggplant, okra, green banana, green papaya, green chilli, red chilli and tomato) which concentration's range was 0.11mg/Kg to 0.80mg/Kg (Table-2.2).

Table 2.2: Conc. of arsenic in various fruity vegetables

Fruity Vegetables	Scientific Name	Conc. Of Arsenic in vegetables (mg/Kg)	Location	Reference
Pumpkin	*Cucurbita moschata*	0.40	Jessore, Bangladesh	[64]
Eggplant	*Solanum melongena*	0.20	Jessore, Bangladesh	[64]
Okra	*Abelmoschus esculentus*	0.80	Jessore, Bangladesh	[64]
Green banana	*Musa paradisiacal*	0.40	Jessore, Bangladesh	[64]
Green chili	*Capsicum frutescens*	0.11	West Bengal, India	[65]
Red chili	*Capsicum frutescens*	0.20	Jessore, Bangladesh	[64]
Tomato	-	0.20	Jessore, Bangladesh	[64]

Existing studies were showed the arsenic contamination in stem and root vegetables which concentration was 0.10mg/Kg to 2.00mg/Kg (Table-2.3).

Table 2.3: Conc. of arsenic in various root and stem vegetables

Root and stem Vegetable	Conc. Of Arsenic in vegetables (mg/Kg)	Location	Reference
Ghatkol	0.45	Jessore, Bangladesh	[62]
Ghatkol	0.50	Jessore, Bangladesh	[66]
Olkachu	0.34	Jessore, Bangladesh	[62]
Olkachu	0.30	Jessore, Bangladesh	[64]
Olkachu steam	0.10	Jessore, Bangladesh	[64]
Stem amaranth leaf	1.90	Jessore, Bangladesh	[64]
Potato	0.30	Jessore, Bangladesh	[64]
Mukhi kachu (root)	1.00	Jessore, Bangladesh	[64]
Pani kachu (stem)	0.90	Jessore, Bangladesh	[64]
Black Kachu	0.90	Jessore, Bangladesh	[64]
Kata Kachu	0.50	Jessore, Bangladesh	[64]
Dosta Kachu	2.00	Jessore, Bangladesh	[64]
Man Kachu	0.50	Jessore, Bangladesh	[66]

Meragh *et al.* & Biswas *et al.* were studied arsenic contamination on seed crops system (rice and pea seed) which was showed 0.31 mg/kg to 1.83 mg/Kg (Table-2.4).

Table 2.4: Conc. of arsenic in seed vegetables

Seed Vegetables	Conc. Of Arsenic (mg/kg)	Location	References
Rice	1.75-1.83	West Bengal, India	[67]
Pea seed	0.314	West Bengal, India	[65]

Many researchers were monitored arsenic contamination in irrigation water and soil which values were listed in following tables.

Table 2.5: Conc. of arsenic in irrigation soil samples

Soil Sample (Site)	Conc. Of Arsenic (mg/kg)	References
Open space of Marua bazar	2.15	[66]
Open area beside the pond	4.89	
Path leading to Marua bazar near the pond	3.44	
Around the tube well	4.05 5.14 7.95	
Centre of the yard	3.75 5.29 5.34	
Kachu field in the yard	5.34	
Top soil layer of paddy field in Srinagar thana, Bangladesh	7-27.5	[68]
Top soil layer of paddy field in Sonargaon area, Bangladesh	3.2-19	
Surface soil (Daudkandi and Begumgang) in Bangladesh	15.68	[69]
Surface soil in Faridpur of Bangladesh	33.15	[70]
Top soil in Dhamrai region of Bangladesh	6.1	

Table 2.6: Arsenic in water and corresponding arsenic in soils in some parts of Bangladesh

Location	Water Arsenic (mg/L)	Soil arsenic (mg/kg)	References
Chapainawabgaj Sadar	0.01-0.056	1.27-31.84	[71-73]
Kustia Sadar	0.01-0.07	7.01-24.20	
Bera	0.01-0.056	16.56-22.29	
Ishurdi	0.01-0.41	1.27-24.20	
Sarishabari	0.025-0.071	3.18-10.83	
Gopalganj Sadar	0.015-0.079	0.26-7.03	
Mukshidpur	0.012-0.05	0.30-8.62	
Monirampur	0.024-0.076	0.69-4.96	
Pirghacha	0.013-0.066	1.2-8.1	
Rajarhat	0.01-0.049	0.20-5.5	
Chapainawabgaj Sadar	0.05-0.079	1.9-7.4	
Charghat	0.015-0.068	0.20-40.08	
Sharsha	0.041	13.67	
Sirajdikhan	0.544	10.655	
Alamdanga	0.058	10.675	
Meherpur	0.016	28.22	
Laksham	0.145	10.791	
Sonargaon	0.86	14.00	
Bancharampur	0.092	17.147	
Nagarkanda	0.064	26.559	

Table 2.7: Arsenic content of irrigation water, soil and different parts of rice plants in Bangladesh

Arsenic in water (mg/L)	Arsenic in soil (mg/kg)	Rice variety	As in rice grain (mg/kg)	References
0.156	7.52	BR-14	0.00	[74]
0.364	2.07	BR-14	0.00	
0.277	12.0	BR-14	0.00	
0.199	3.76	BR-28	0.00	
0.131	3.98	BR-28	0.032	
0.188	3.30	BR-28	0.00	
0.255	2.42	BR-28	0.063	
0.62	2.01	BR-29	0.016	
0.208	3.63	BR-29	0.00	
0.278	9.93	IR-50	0.00	
0.105	3.37	Purbachi	0.022	
0.222	2.24	Purbachi	0.026	
0.177	3.02	Purbachi	0.094	

Table 2.8: Arsenic concentration of soil in different locations of Bangladesh

Location	Arsenic content (mg/kg)	References
Barisal	26.1	[67]
Ramgati	16.8	
Burichang	18.4	
Chandina	6.8	
Dhamrai	6.1	[70]
Faridpur	33.15	
Mirsharai	6.5	
Pahartali	7	[67]
Rawjan	8.6	
Belabo	14.6	
Sirajdikhan	4.93	
Chandina	3.321	[73]
Sonargoan	9.915	
Ghatail	16.5	
Sonatala	13.4	
Kendua	9	[67]
Tarakanda	9.3	
Melandaha	9.6	
Dumuria	21	
Ishurdi	33.3	
Bhabanipur	1.783	
Kalapur	0.594	
Bhabanipur	1.783	[65]
Sherpur	2.576	
Srimongal	1.981	
Khulna	5.13	
Meherpur	4.68	[76]
Pabna	7.6	
Polashbari	7.6	
Pirgacha	12.4	[67]
Bhabanipur	24.3	
Atwari	8.1	
Khulna	5.13	
Meherpur	4.68	
Pabna	7.6	
Laksam	2.68	[76]
Gazipur	3.13	
Rajshahi	3.8	
Comilla	5.64	[69]
Chapainabganj	56.68	[71]

Akter, M., *et al*. 2012, also detected different types of heavy metal and organic matter contents in soil samples that has showed in following table.

Table 2.9: Heavy metals status of some selected Regions of Bangladesh [77]

Soil type	Location	Organic matter (%)	Cu	Zn	Fe	Mn	As	Cd	Pb
Non calcareous	BAU farm Mymensingh	1.51	6.69	1.22	74.23	48.48	1.07	2.09	23.86
	Sutiakhali, Mymensingh	1.31	5.66	1.63	68.02	43.25	3.93	2.25	28.20
Calcareous	Ishardi, Pabna	1.10	0.56	1.22	7.62	2.67	5.53	2.58	43.67
	Lalpur, Natore	1.06	0.53	1.50	11.12	2.39	5.77	2.39	26.19
Peat	Dumuria, Khulna	28.24	0.20	6.43	164.29	7.68	19.53	2.46	60.90
	Kotalipara, Gopalgonj	24.72	0.89	4.50	173.14	7.51	21.28	1.94	42.25
Saline	Asasuni, Satkhira	2.29	1.10	2.61	14.12	12.76	10.81	2.43	38.41
	Chorfasion, Bhola	4.31	2.84	2.05	30.25	9.42	11.82	3.15	54.09
Alkaline	Kaligonj, Sathkhira	1.63	1.85	1.78	97.00	27.85	10.55	2.89	48.22
	Botiaghata, Khulna	2.63	1.71	1.22	101.05	27.61	6.23	1.51	51.82
Acid	Madhupur, Tangail	0.65	2.94	2.32	346.12	83.58	3.76	1.64	40.68
	Tangail sadar, Tangail	1.61	3.29	1.77	315.09	77.47	3.63	1.38	28.82
Acid sulphate	Chakaria, Cox'bazar	2.28	8.06	1.88	81.53	32.16	13.23	1.81	36.88
	Moheskhali, Cox'bazar	4.57	7.70	1.75	135.00	37.34	6.16	2.08	43.37

Habib Mohammad Naser *et al*. also studied heavy metals (lead, cadmium, nickel, cobalt, chromium) accumulation in crop system (spinach & amaranth) and in soil which was showed in following table-2.10.

Table 2.10: Heavy metals status in crop system [78]

Vegetable	Pb	Cd	Ni	Co	Cr
Spinach	1.52	0.583	5.07	1.03	6.20
Red Amaranth	1.58	0.337	4.93	1.33	5.70
Amaranth	1.95	0.478	4.92	1.57	4.81

Table 2.11: Heavy metals status in soil [78]

Soil	Pb	Cd	Ni	Co	Cr
Spinach (soil)	4.77	0.7	14.7	12.6	22.90
Red Amaranth(soil)	5.00	0.71	14.4	12.4	22.40
Amaranth(soil)	5.16	0.68	14.8	12.9	21.9

Farid *et al*. (2003) conducted a study on level of arsenic in different types of vegetables cultivated with Arsenic free and Arsenic contaminated ground-water in Bangladesh. They found that the level of arsenic was higher in vegetables which were irrigated with arsenic contaminated water [72].

Table 2.12: Arsenic content in different vegetables grown under varied locations

Crop	Location	Arsenic content (mg/kg)			
		Contaminated		Non contaminated	
		Range	Mean	Range	Mean
Tomato	Nawabgonj	0.016-0.049	0.030	0.001-0.025	0.011
Potato	Monirampur	0.013-0.021	0.017	0.001-0.014	0.007
	Gopalgonj Sadar	0.211-0.390	0.301	0.083-0.0284	0.184
	Pirgachha	0.042-0.107	0.068	0.024-0.068	0.041
	Rajarhat	0.000-0.080	0.024	0.000-0.055	0.021
Brinjal	Nawabgonj	0.042	0.049	0.028-0.063	0.045
Red Amaranth	Monirampur	0.132-0.606	0.321	0.072-0.240	0.163
Bitter gourd	Gopalgonj		0.091		0.039
Stem Amaranth	Nawabgonj	0.093-0.201	0.161	0.099-0.109	0.103
	Pirgachha	0.182-2.791	0.935	0.060-0.370	0.241
	Monirampur	-	0.620	-	0.074
Kachur data	Charghat	0.060-0.333	0.168	0.092-0.163	0.125
	Monirampur	-	0.400	-	0.103
China shak	Pirgachha		0.539		0.278
Cabbage	Muksedpur	0.031-0.042	0.037	0.000-0.059	0.030
	Monirampur	-	0.106	-	0.080
Indian spinach	Monirampur	0.134-0.387	0.267	0.092-0.228	0.154
	Muksedpur	0.096-0.126	0.111	0.000-0.091	0.046
Cauliflower	Muksedpur		0.011		0.001
Chili	Gopalgonj		0.112		0.103
Okra	Charghat	0.034-0.046	0.04	0.016-0.046	0.031

Table2.13: Arsenic content in different soil samples under varied locations [72]

Place	Range of As (ppm) in soil
Gopalganj Sadar	0.261-7.035
Mukshidpur	0.303-8.628
Monirampur	0.690-4.960
Pirghacha	1.200-8.100
Rajarhat	0.200-5.500
Chapi Nawabganj	1.980-7.480
Charghat	0.200-40.080

Bangladesh Agricultural Research Institute also measured Arsenic contamination in irrigation water, soil and food crops which also showed in table-2.13.

Table 2.14: Information of Sampling location and arsenic concentration of samples [79]

Village	Thana	Crop name	As Conc. in soil	As Conc. in Crop
Khatra	Dhamrai	Amaranth	13.31	0.42
Khatra	Dhamrai	Bottle gourd	13.90	0.3
Khatra	Dhamrai	Chili	14.60	0.23
Sreerampur	Dhamrai	Chili	10.80	0.27
Sreerampur	Dhamrai	Cabbage	8.16	0.23
Pucoria	Ghior	Cabbage	31.62	0.45
Pucoria	Ghior	Cabbage	23.54	0.11
Doulatdia (south)	Rajbari	Cabbage	15.83	0.3
Doulatdia (south)	Rajbari	Sweet gourd	31.16	0.57
Doulatdia (south)	Rajbari	Country bean	9.15	0.22
Doulatdia (south)	Rajbari	Raddish	13.80	0.56
Nimtoli	Rajbari	Coriander leaf	10.81	1.93
Nimtoli	Rajbari	Tomato	17.24	0.76
Nimtoli	Rajbari	Cauliflower	13.36	0.24
Nimtoli	Rajbari	Radish	12.74	0.42
Nimtoli	Rajbari	Country bean	11.42	0.26
Moharajpur	Rajbari	Potato	5.83	0.27
Mojlishpur	Rajbari	Potato	16.66	0.19
Keshobnagar	Faridpur	Potato	9.16	0.64
Keshobnagar	Faridpur	Brinjal	11.33	0.49
Keshobnagar	Faridpur	Red Amaranth	7.26	0.45
Shonkor Pasha	Nogorkanda	Red Amaranth	9.16	1.17
Shonkor Pasha	Nogorkanda	Potato	11.88	0.34
Naopara	Vanga	Country bean	14.98	0.15
Pulse Research Sub Centre, Madaripur	Madaripur	Country bean	16.64	0.18
Noya Khandi	Madaripur	Country bean	17.49	0.34
Noya Khandi	Madaripur	Red Amaranth	14.6	1.85
Noya Khandi	Madaripur	Indian spinach	11.44	1.54
Chagoldia	Madaripur	Sponge gourd	14.99	0.64
Chagoldia	Madaripur	Indian spinach	10.66	1.13
Choudhuri Kanda	Vanga	Kachu	14.14	1.66
Choudhuri Kanda	Vanga	Indian spinach	12.18	2.03
Choudhuri Kanda	Vanga	Bottle gourd	16.32	1.06
BRRI station, Vanga	Vanga	Radish	22.13	1.74

CHAPTER III

Study Area and Experimental Method

3.1 Study area

The weather and soil characters of Jessore district are suitable for agriculture. This study area is located at Goga union in Jessore district which stands on the Ichamoti boundary river of Bangladesh-India Border area in the south-western part of Bangladesh. Jessore district has eight upazilas and Sharsha upazila is one of them which have been affected by arsenic contamination problem. Sharsha upazila has 11 unions and one pouroshova. Goga union has 9 villages, 6287 house hold , 24174 population, drinking shallow tube wells were 1860 and irrigation tube wells were 100 [80-82]. At Goga union average 58% drinking shallow tube wells and 52% irrigation tube wells were arsenic contaminated [80-82]. This survey was conducted at Harischandrapur village at Goga union. This village’s arsenic contamination status, no. of arsenicosis patients and no. of safe water devices are shown in the table [Table-3.1]. This survey was conducted in May to October, 2016 for monitoring the heavy metals contamination in drinking water, irrigation water, irrigation soil, vegetables and fruits which were growing at Horishchandrapur village.

Table-3.1: Arsenic contamination information at Goga union [80-82]

Village Name	No of Households	No. of male	No. of female	Total Population	No. of arsenicosis patients	Drinking tubewell arsenic contamination rate (%)	Irrigation tubewell arsenic contamination rate (%)
Panchbhulat	771	1539	1387	2926	0	84	88
Agrovulat	732	1021	872	1893	0	38	75
Harischandrapur	**340**	**637**	**637**	**1274**	**1**	**80**	**75**
Goga-West	704	1003	1180	2183	0	69	70
Goga-East	706	1289	1422	2711	1	70	33
Amlai	703	1386	1339	2725	0	26	0
Kaliani	931	1563	1565	3128	5	99	86
Ichapur-Gopalpur	990	2945	2755	5700	1	45	38
Setai	410	861	773	1634	0	15	21
Total	6287	12244	11930	24174	8	58	52

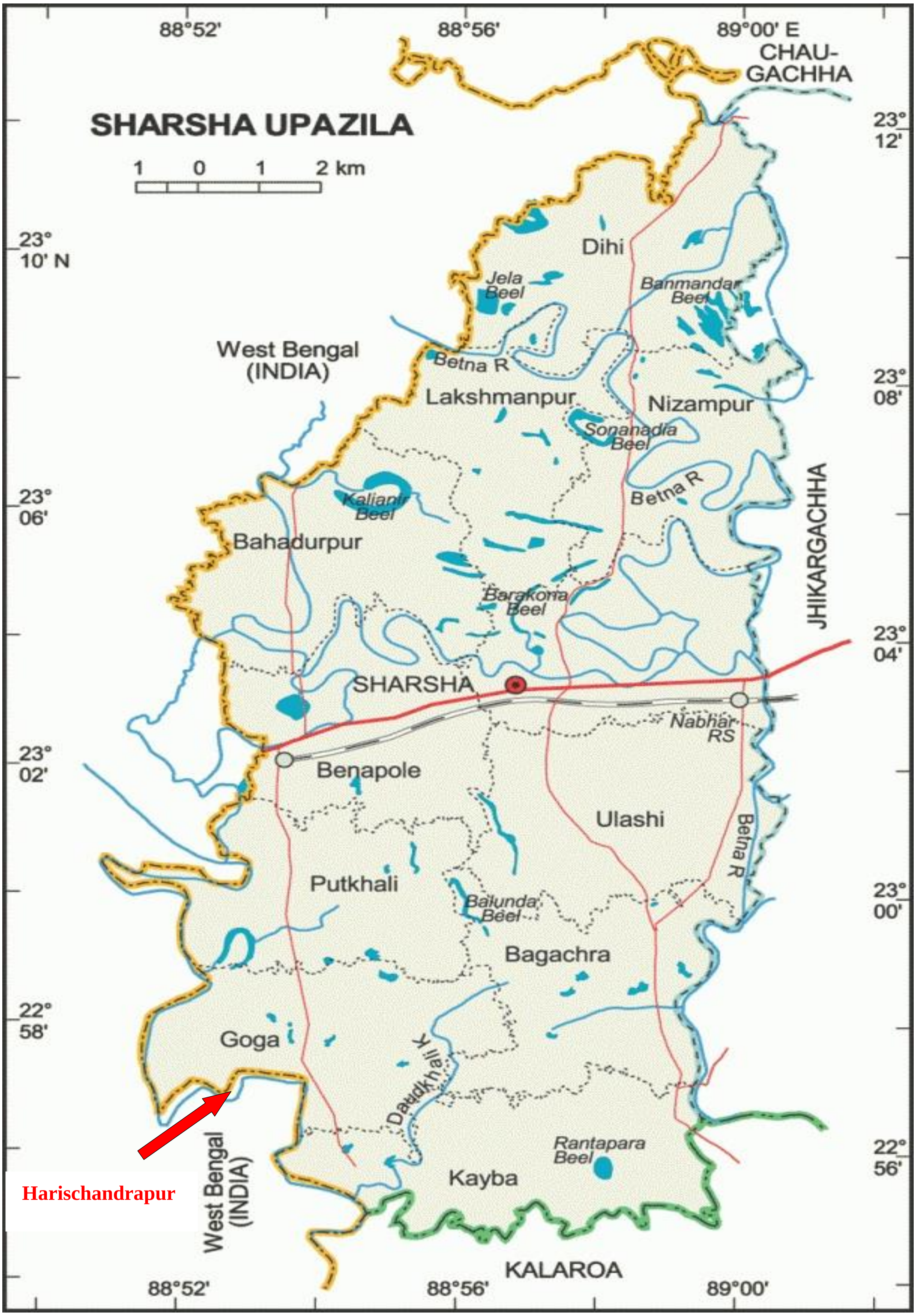

Figure 3.1: Map of the study area (Banglapedia 2011) [83]

3.2 Methodology

This study was conducted in May to July, 2016 at Harischandrapur village which village arsenic contamination in ground water has been reported [58-61]. This study was monitored the heavy metals contamination in irrigation water, soil, fruits and vegetables which were grown at this study area. Daily intake of water, fruits and vegetables quantity data was collected from each household members who were taking contaminated water, fruits and vegetables. In this survey period, i was collected data about age, body weight and daily intake of food from this study area. The following procedures were used for sample collection, sample processing, sample analysis and health risk index calculation purposes.

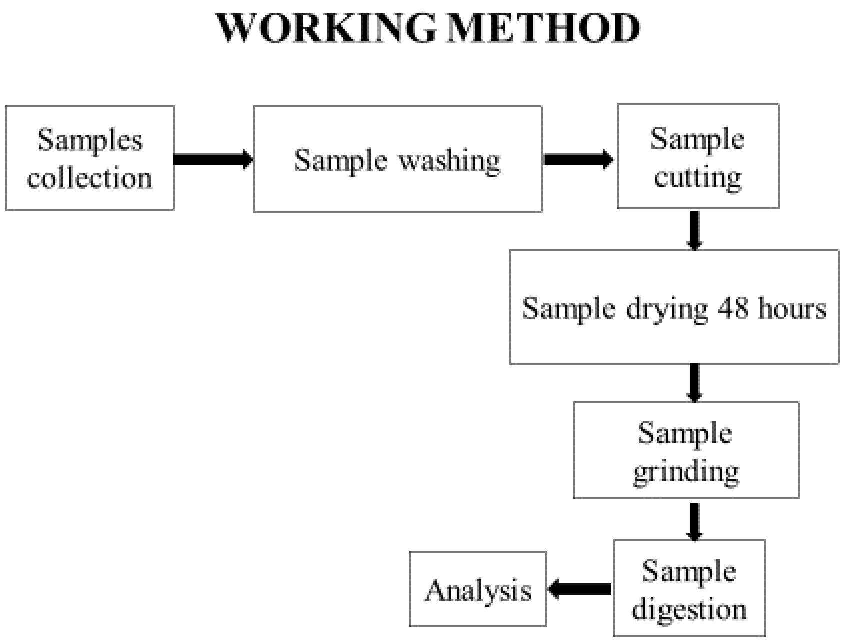

Figure 3.2: Working method

3.2.1 Sample collection

Water samples were collected in 100ml plastic bottles and preserved by using 2ml of 6N nitric acid for metals analysis. Soil, fruit's and vegetable's samples were collected in polyethylene bag. All of samples were quickly transported to laboratory for sample preparation and metal analysis.

Figure 3.3: Sample collection

1 2

3 4

Figure 3.4: Collected samples: (1) Jackfruit (2) Green mango (3) Green papaya (4) Sapodilla

5 6

7 8

Figure 3.5: Collected samples: (5) Guava (6) Lime (7) Green coconut (8) Pummelo

9 10

11 12

Figure 3.6: Collected samples: (9) Stem Amaranth Leaf (10) Indian Spinach (11) Red Amaranth (12) Green hot chili

13

14

15

16

Figure 3.7: Collected samples: (13) Coconut (14) Okra (15) Cucumber (16) Yard Long bean

17

18

19

20

Figure 3.8: Collected samples: (17) Brinjal (18) Pea Seed (19) Ribbed gourd (20) Plantain

21

22

23

24

Figure 3.9: Collected samples: (21) Rice (22) stem of taro (23) kachur loti (24) Leaf of taro

25

26

27

28

Figure 3.10: Collected samples: (25) Wild aroid (26) Corm of elephant yam (27) Stem of elephant yam (28) Pumpkin

Figure 3.11: Collected samples: Soil and water

3.2.2 Sample preparation (Washing and cutting)

The collected fruit and vegetable samples were washed with distilled water to remove dust particles. The samples were then cut to separate the roots, stems and leaves using a knife.

Figure 3.12: Cutting and preparation of samples for drying

3.2.3 Drying of samples

Soil sample was dried at room temperature for pH and organic matter analysis. On the other hand for metal and moisture contents analysis all of soil, fruits and vegetable samples were dried in an electric oven at 105°C for 24 to 48 hours and then cooled in desiccators.

Figure 3.13: Drying and grinding of samples

3.2.4 Grinding of samples

Dried soil, fruit and vegetable samples were ground into a fine powder (80 mesh) using a commercial blender (TSK- West Point, France) and stored in polyethylene bags, until used for acid digestion.

3.2.5 Sample digestion

Soil, water, fruit and vegetable samples were digested separately by using USEPA (United State Environment Protection Agency) method [84]. About 0.50 gm to 5.00 gm of soil, fruit and vegetable samples were separately taken in to clean and dried 100 ml borosilicate glass beaker and 15ml of concentrated nitric acid (HNO_3) was added to it. The beaker was covered by watch glass and the mixture was preserved through overnight under fume hood. The beakers were placed on hot plate and heated the acid mixed sample at 95 ± 5^0C for 2-4 hours under fume hood. The acid digestion was repeated for completing the reaction (addition of 5 ml of conc. HNO_3) until no brown fumes given off by the sample. The beakers were cooled at room temperature and then 2ml of di-ionized water and 3 ml of 30% hydrogen peroxide (H_2O_2) was added and covered the beaker with a watch glass. Heated the beaker at 95 ± 5^0C on hot plate to start the peroxide reaction until the effervescence subsided and allowed the beaker to be cooled. After cooling the beaker was rinsed by de-ionized water and filtered through Whatman-41 filter paper. The filtered sample was transferred into 100ml of volumetric flask and diluted to 100ml by adding de-ionized water. Finally the digested sample was stored in 100ml plastic bottles and kept at 4^0C in refrigerator. Acid digested sample's metal (arsenic) analysis was conducted by HG-AAS method and lead, iron, manganese, copper and zinc analysis was conducted by Flame-AAS method [85].

Figure 3.14: Digestion and filtration of samples

3.3 Sampling protocol

The standard protocol for sampling was followed during the sampling period. The important steps are included:

- Location of the sampling point and identified it on the location map
- Numbering of the liquid samples
- Temperature of the samples at degree Celsius
- Time and date of sample collection
- The sampling point was marked on the locations map on the containers by a permanent marker pen
- The collected samples were stored at 4ºC in the freeze for analysis

3.4 Sample information and coding

Table 3.2: Soil and water sample information data

Sample ID	Local name	English name
S-4,7,10,13,31	Mati	Soil
S-3	Daber pani	Green coconut water
S-1,2,5,8,17,18	Pani	Water
S-23	Narkeler pani	Coconut water

Table 3.3: Fruit and vegetable samples information data

Sample ID	Local name	English name	Scientific name
S-6	Kacha Aam	Green mango	*Mangifera indica L.*
S-11	Barbati	Yard Long bean	*Vigna sesquipedalis*
S-12	Derosh	Okra	*Abelmoschus esculentus*
S-14	Jinga	Ribbed gourd	*Luffa acutangula*
S-15	Kacha kola	Plantain	*Musa paradisiacal*
S-16	Shosha	Cucumber	*Cucumis sativus*
S-19	Marich	Green hot chili	*Capsicum frutescens*
S-20	Batabi lebu	Pummelo	*Citrus grandis*
S-21	Peyara	Guava	*Psidium guajava*
S-22	Sofeda	Sapodilla	*Manilkara zapota*
S-23	Narikel	Coconut	*Cocos nucifera*
S-24	Kagozi lebu	Lime	*Citrus aurantifollia*
S-25	Kacha papya	Green papaya	*Carica papaya*
S-26	Data shak	Stem Amaranth leaf	*Amaranthus lividus*
S-27	Lal shak	Red Amaranth	*Amaranthus gangeticus*
S-28	Sabuj Pui shak	Indian Spinach	*Basella rubra*
S-29	Begun	Brinjal	*Solanum melongena*
S-30	Misti kumra	Pumpkin	*Cucurbita moschata*
S-32	Kacha kathal	Jackfruit	*Artocarpus integrifolia*
S-33	Motorshuti	Pea seed	*Pisum sativum*
S-35	Dhan	Rice	*Oryza sativa L*
S-36	Kochu shak	Leaf of Taro	*Colocasia esculenta*
S-37	Kochu data	Stem of Taro	*Colocasia esculenta*
S-38	Kochu loti	Stem of Taro	*Colocasia esculenta*
S-39	Ghatcol	Wild aroid	*Syngonium podophyllum*
S-40	Oal	Corm of elephant yam	*Amorphophallus paeoniifolius*
S-41	Oaler data	Stem of elephant yam	*Amorphophallus paeoniifolius*

3.5 Sample analysis

3.5.1 Moisture contents analysis

Soil, fruits and vegetables sample's moisture determination is a major significance for sample preparation, digestion and analysis. Soil moisture influences crop growth not only by affecting nutrient availability, but also nutrients transformation and biological behavior. All analysis in the laboratory is related to an oven-dry basis and therefore must consider the actual soil moisture content [86].

Apparatus:

1. Electric Oven
2. Desiccator
3. Glass Petridis
4. Electronic Balance

Procedure:

Glass Petri dishes were cleaned by 10% nitric acid and dried in electric oven at 120 ˚C. After drying then Petri dishes were kept in desiccator for cooling. After cooling then dried empty Petri dishes weight were taken and data were recorded. 100gm of Soil, fruit's and vegetable's samples were taken in Petridis and dried in electric oven for 24 hours at 105˚C until constant weight were obtained on cooling in a desiccators. The weights of raw samples with empty Petri dishes and dried samples with Petri dishes data were taken and recorded in table [86]. The percentage of moisture contents and solid contents in soil fruit and vegetable samples were calculated by using the following equation:

$$(W1-W2)\times 100/W1$$

Where,

W1=Weight of raw sample in gm

W2=Weight of dried sample in gm (oven dry that 105ºC)

3.5.2 Soil pH analysis

The pH is defined as the negative logarithm of hydrogen ion activity. Since pH is logarithmic, the hydrogen ion concentration in solution increases ten times when its pH is lowered by one unit. The pH range normally found in soil is 3 to 9. Significance of pH lies in its influence on availability of soil nutrients, solubility of toxic nutrients elements in the soil, physical breakdown of root cells, cation exchange capacity in soils and biological activities in soil are pH dependent. At high pH, availability of phosphorus (P) and most of micronutrients except Boron (B) and Molybdenum (Mo) trends to decreases. Soil pH is measure of the acidic, or neutral or alkaline properties of soil. Soil pH is measured in 1:5 soil and water suspension solution.

Apparatus:

1. pH meter with Glass membrane electrode
2. Magnetic Starrier
3. Glass beaker (100ml)
4. Measuring cylinder (100ml)

Reagents:

1. De-ionized water
2. pH 4.00 & 7.00 standard buffer solution

Procedure:

1. At first 25gm of air dried soil sample was taken in cleaned 100 ml glass beaker.

2. 125ml of de-ionized water was added in to beaker and mixed well by using glass rod.

3. This suspension mixture was stirred for 5 minutes and then allowed to stand for 30 minutes.

4. The pH meter was calibrated by using pH 4.00 & 7.00 buffer standard solution.

5. The pH of Soil and water (1:5) suspension solution was measured by calibrated pH meter.

6. Data was recorded in to the table.

3.5.3 Soil organic matter analysis

The organic matter represents the remains of roots, plants materials and soil organisms in various stages of decomposition and synthesis and is variable in composition. Soil organic matter has a major influence on soil aggregation, nutrients reserve and its availability, moisture retention and biological activity. Soil organic matter was measured by spectrophotometric method in acidic potassium dichromate reduction solution. Soil containing organic carbon is oxidized to carbon dioxide in presence of dichromate ion in acidic medium. In this method reduction of hexavalent chromium (Cr^{6+}) to trivalent chromium (Cr^{3+}) and color change from orange to green. The intensity of green color is proportional to the trivalent chromium (Cr3+) concentration which is related to the organic contents in the soil.

Apparatus:

1. Sintered Glass filter
2. Volumetric flask (100 ml)
3. Measuring cylinder (100 ml)
4. Filtration unit
5. Erlenmeyer flask (250 ml)
6. UV-VIS Spectrophotometer
7. Cooling pad

Reagents:

1. Organic free De-ionized water
2. Potassium dichromate (1N)
3. Conc. Sulfuric acid (98%)
4. Potassium Hydrogen phthalate (4.4%)

Preparation of potassium dichromate (1N): 4.90 gm of potassium dichromate was dissolved in de-ionized water and marked up to 100 ml in volumetric flask.

Preparation of standard solution (4.4%): 4.64 gm of potassium hydrogen phthalate was taken in 100ml volumetric flask and dissolved it by 100 ml de-ionized water

Procedure:

1. 1.0 gm soil sample was taken in 250 ml Erlenmeyer flask and another conical flask was prepared for blank sample.

2. 10 ml of 1N potassium dichromate solution was added into the sample and blank and mixed well.

3. 20 ml of concentrated sulfuric acid was added into the sample and blank, mixed well and allowed to stand for 10 minutes.

4. The each flask was covered with 50 ml Erlenmeyer flask, swirled gently to mix and kept it on cooling pads.

5 After 10 minutes, 100 ml of distilled water was added, mixed well and allowed to stand for 10 minutes.

6. 25 ml of soil mixer (except blank sample) was filtered by sintered glass filter.

7. DR/2010 UV-VIS Spectrophotometer was started and programme was entered (420) for organic matter analysis at 610 nm wavelength.

8. The concentration of organic matter in blank and soil sample was measured by HACH DR/2010 Spectrophotometer at 610 nm.

Figure 3.15: Organic matter analysis by UV-VIS Spectrophotometer

3.5.4 Heavy metal analysis

The metal concentrations (As, Cu, Zn, Fe, Pb and Mn) were determined at environmental laboratory, AAN (Asia Arsenic Network) in Jessore by using Atomic Absorption Spectrophotometer (AAS). During analysis the instrument was calibrated by using reference standard solution for each metal concentration analysis. Calibration curve relation coefficients were 0.995 to 0.999 and laboratory control standard recovery was 99 % to 105%.

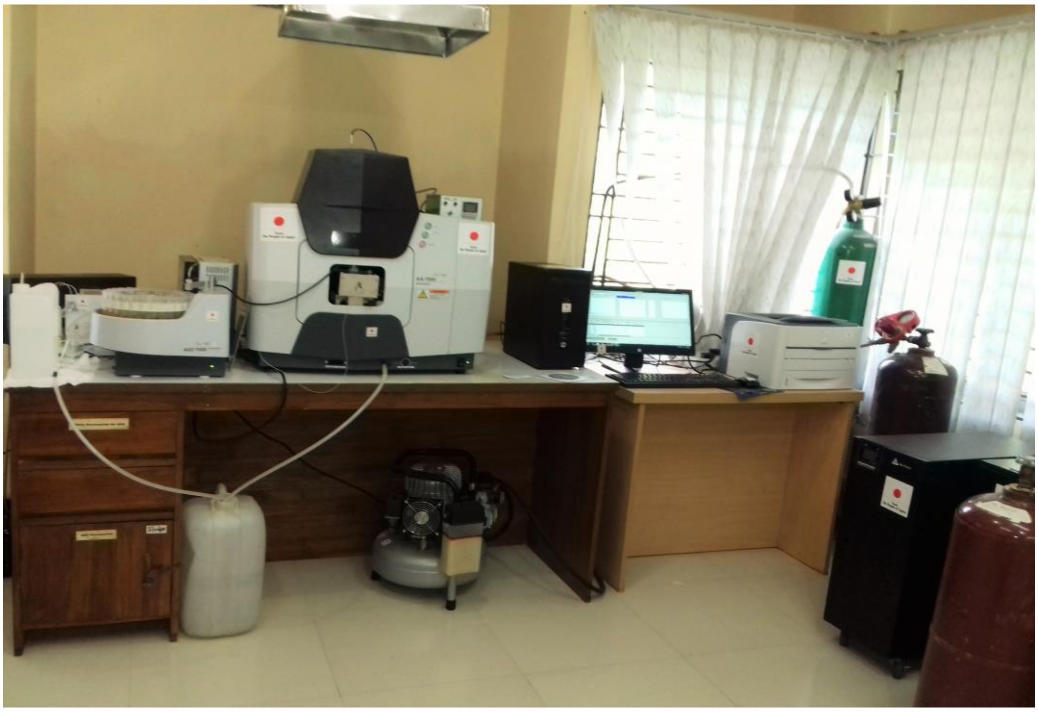

Figure 3.16: Atomic Absorption Spectrophotometer

3.6 Theory of Measurement

3.6.1 Beer's law

The amount of monochromatic radiation absorbed by a sample is described by the Beer-Bougure-Lambart law, commonly called Beer's law. Let us consider the absorption of monochromatic radiation of radiant power, P_o which passes through a solution of an absorbing species at concentration C and path length b; the emergent (transmitted) radiation has radiant power, P. Bouguer and Lambart recognized that when electromagnetic radiation is absorbed, the power of the transmitted energy decreases in exponential manner as:

$$P = P_o 10^{-kb}$$

$$\text{or } \frac{P}{P_o} = 10^{-kb} = T \qquad \ldots \qquad \ldots \qquad \ldots \qquad (1)$$

Where k is a constant and T is called the transmittance, the fraction of radiant energy transmitted. Logarithmic form of the equation is

$$\log T = \log \frac{P}{P_o} = -kb \qquad \ldots \qquad \ldots \qquad \ldots \qquad (2)$$

Beer stated that a similar law holds for the dependence of T on the concentration, C of an absorbing species;

$$T = \frac{P}{P_o} = 10^{-k'C} \qquad \ldots \qquad \ldots \qquad \ldots \qquad (3)$$

$$\text{or} \qquad \log T = \log \frac{P}{P_o} = -k'C \qquad \ldots \qquad \ldots \qquad \ldots \qquad (4)$$

Where, k' is a new constant. Combining these two laws is obtained what is known as Beer-Bouguer-Lambart law, commonly known as Beer's Law. It describes the dependence of T on both the path-length and the concentration of the absorbing species:

$$T = \frac{P}{P_o} = 10^{-abC} \qquad \ldots \qquad \ldots \qquad \ldots \qquad (5)$$

where 'a' is a combined constant of k & k'. The logarithmic form of (5) is

$$\log T = \log \frac{P}{P_o} = -abC \qquad \ldots \qquad \ldots \qquad \ldots \qquad (6)$$

It is more convenient to omit the negative sign on the right hand side of the equation and to define a new term, absorbance, A:

$$A = -\log T = \log \frac{P}{P_o} = abC \quad ... \quad ... \quad (7)$$

Where 'A' is the absorbance. This is the common form of Beer's law. It is the absorbance that is directly proportional to the concentration. The constant 'a' is then called the absorptivity or extinction coefficient. When 'C' is expressed in moles/liter, 'b' in cm, the constant 'a' is replaced by ε and the Beer's law is written as:

$$A = \varepsilon bC \quad ... \quad ... \quad ... \quad ... \quad (8)$$

This new quantity ε is known as molar absorptivity. Since A is unitless, ε has the unit of liter $mole^{-1}\ cm^{-1}$. Molar absorptivity is dependent on the nature of the absorbing material and the wavelength of radiation. Beer's law holds strictly for monochromatic radiation, since the absorptivity varies with wavelength.

3.7 Atomic absorption spectroscopy

Atomic absorption (AA) spectroscopy in analytical chemistry is a technique for determining the concentration of a particular metal element within a sample. Atomic absorption spectroscopy can be used to analyze the concentration of over 62 different metals in a solution. It is based on the absorption of radiation by free atoms. Each chemical element in the atomic states absorbs only radiation of well-defined wavelengths characteristics of the particular element involved. It is the reversed physical to that involved in flame photometry and emission spectroscopy. Atomic absorption takes place when unexcited atoms absorb energy and become excited atoms. Electrons can exist in one of two states:

Ground State: In this state, the electron contains the least energy possible, orbiting as close as it can to the nucleus.

Excited State: In this state, the electron contains more energy than in its ground state, orbiting further from the nucleus of the atom.

Absorption therefore is carried out by unexcited atoms, whereas emission arises from excited atoms.

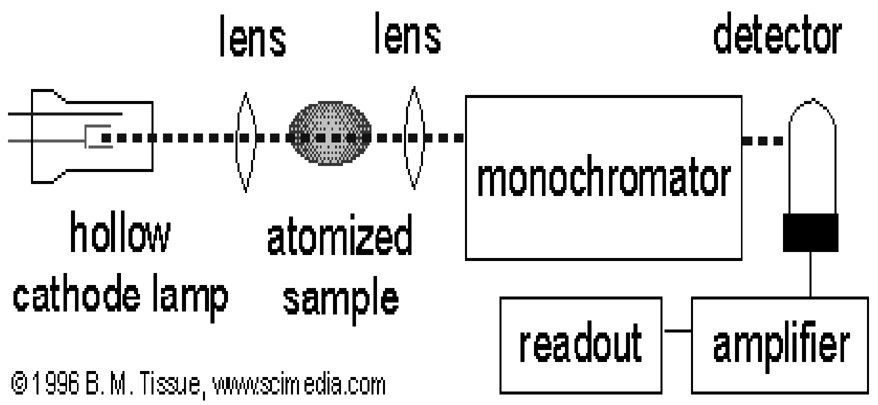

Figure 3.17: Equipments used in AAS

The equipment used in AAS is basically the same as for other spectroscopic absorption methods. It consists of;

Radiation source:

The light source is usually a hollow-cathode lamp of the element that is being measured. Lasers are also used in research instruments. Since lasers are intense enough to excite atoms to higher energy levels, they allow atomic absorption and atomic fluorescence measurements in a single instrument. The disadvantage of these narrow-band light sources is that only one element is measurable at a time.

Monochromator:

The function of the monochromator is to select radiation of the correct wavelength and eliminate other radiation from the light path. For many elements such as sodium, potassium and copper the spectrum is simple and only low resolution monochromator is required. However, for certain other elements, particularly the transition elements, high resolution is necessary to prevent unabsorbable emission lines.

Detectors:

Photomultipliers are used exclusively on commercial equipment. In practice, it is the function of the detector to measure the intensity of radiation before and after absorption by the sample. From this one can calculate how much radiation has been absorbed from the intense beam.

Optical slit system:

Two slits are included in the optical system, an entrance slit and an exit slit. The entrance slit serves to obtain a narrow, parallel beam of light from the source. The exit slit is used to select radiation of the correct wavelength after it emerges from the monochromator.

Atomizer:

The function of the atomizer is to convert the combined atoms of the liquid sample into free atoms. The most common atomizer is the flame. In practice the liquid sample is introduced into the flame in the form of a droplet. The droplets evaporate and leave a solid residue. The residue, which contains the same atoms, is decomposed by the flame and free atoms are liberated. These free atoms absorb the radiation which is measured in this procedure. The metal concentrations (Cu, Zn, Fe, Pb, Cd, Mo and Ni) are determined by atomic absorption spectrometry using a Shimadzu model AA7000 (Japan) Atomic Absorption Spectrophotometer (AAS). During analysis the instrument are calibrated by using reference standard solution for each metal concentration analysis. Calibration curve relation coefficients are 0.995 to 0.999 and laboratory control standard recovery are 99 % to 105%. According to blank sample analysis data this instrument detection level are 0.002 mg/L.

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3.8 Transfer factor (TF)

Soil to plant metal transfer was computed as transfer factor (TF), which was calculated by using the equation.

$$TF = C_{Fruit/vegetables} / C_{Soil}$$

Where, $C_{Fruit/vegetables}$ is the concentration of heavy metals in fruits and vegetables and C_{Soil} is the concentration of heavy metals in soil.

3.9. Daily intake of metals (DIM)

Daily intake of food (fruits, vegetables and water) in adult was calculated by data obtained during the survey though a questionnaire. DIM was calculated by the following equation.

$$DIM = C_{metal} \times C_{factor} \times D_{food\ intake} / B_{average\ weight} \quad [87]$$

where, C_{metal} represents the heavy metal concentrations in food (fruits, vegetables and water) in mg kg^{-1}, C_{factor} represents conversion factor (0.085), $D_{food\ intake}$ represents daily intake of food and $B_{average\ weight}$ represents average body weight respectively. The average food intake was calculated by conducting a survey where about 40 peoples having an average body weight of 46.60 kg were asked for their daily intake of particular food (fruits, vegetables and water) from sampling sites.

3.10 Health risk index (HRI)

To assess the human health risk of heavy metals, it is necessary to calculate the level of human exposure to that metal by tracing the route of exposure of pollutant to human body. There subsist many exposures routes for heavy metals that depend upon a contaminated media of soil, fruits and vegetables on the recipients. Receptor population use the food enriched with higher concentration of heavy metals which enters the human body leading to health risks [88]. In the present research work, fruits and vegetables were collected from the study area and their metals concentrations were used to calculate the health risk index (HRI). The health risk index of the present research work was compared with the one reported by Khan et al. [88] and Jan et al. [89]. Results of HRI were found to be lower than those of Khan et al. [88] and Jan et al. [89]. Value of HRI depends upon the daily intake of metals (DIM) and oral reference dose (Rf_D). Rf_D is an estimated per day exposure of metal to the human body that has no hazardous effect during life time. The health risk index for As, Pb, Fe, Mn, Cu and Zn by consumption of contaminated foods was calculated by following equation

$$HRI = DIM / R_{fd} \quad [89].$$

where DIM represents the daily intake of metals and R_{fd} represents reference oral dose. R_{fd} value for As, Cr, Pb, Cd and Mn is 0.002, 1.5, 0.004, 0.001 and 0.033 (mg/kg bw/day) respectively [90].

CHAPTER IV

Results and Discussion

Fruits and vegetables are essential food for recovery of vitamins and minerals in human body. Foods quality and safety depend on irrigation water and soil quality. This study was conducted for 6 water samples, 5 soil samples, 6 fruits samples, 10 fruity vegetables, 6 roots and stem vegetables, 3 leafy vegetables and 3 seed vegetables sample to analyze arsenic, iron, manganese, copper and zinc by HG-AAS (hydride generation atomic absorption spectrophotometric) and flame-AAS method.

4.1. Features of the fruits, soil and water samples

4.1.1 Moisture contents in soil samples

Moisture and solid contents of soil samples are shown in figure 4.1 and table 4.1. Average moisture and solid content in soil samples is 19.91% & 80.09% respectively. Maximum moisture content is found 23.34% in soil-7 (under mango tree) and minimum moisture content is detected15.54% in soil-4 (under coconut tree). On the other hand a maximum solid content is measured 84.46% in soil-4 (under coconut tree) sample and minimum solid content is obtained 76.66% in soil-7 (under mango tree) sample.

Table 4.1: Moisture contents and solid contents in soil samples

Sample ID.	Sources of Sample	Solid Content (%)	Moisture Content (%)
S-4	Soil	84.46	15.54
S-7	Soil	76.66	23.34
S-10	Soil	79.56	20.44
S-13	Soil	78.14	21.86
S-31	Soil	81.61	18.39
Maximum		84.46	23.34
Minimum		76.66	15.54
Average		80.09	19.91

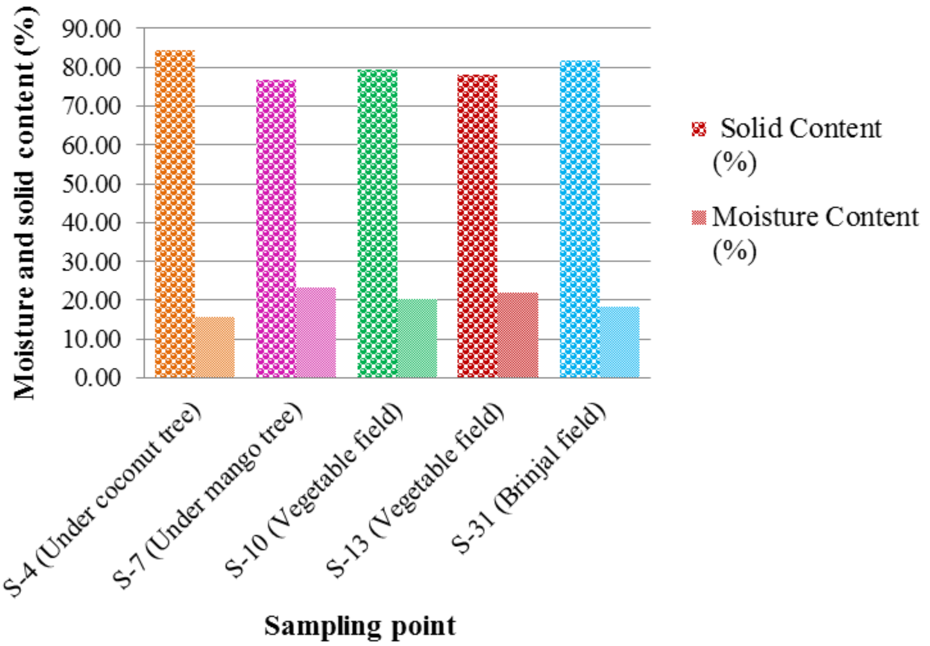

Figure 4.1: Moisture and solid contents in soil samples

Table 4.2: pH & organic matter (%) in soil samples

Sample ID & Sources	pH	Organic matter (%)
Soil-4 (Under coconut tree)	7.76	1.89
Soil-7 (Under mango tree)	7.71	2.91
Soil-10 (Vegetable field)	8.16	1.61
Soil-13 (Vegetable field)	7.7	2.89
Soil-31 (Brinjal field)	7.53	2.28

4.1.2 pH of soil samples

pH is the most important factor in agriculture soil for nutrients availability and specific crops cultivation. Soil pH significantly influences heavy metal concentrations in both soil and plant tissues. The pH value indicates whether or not the soil is acidic or alkaline and to what degree. A value between 6.5 and 7.5 is considered as neutral, whereas values below 6.5 are acidic and values above 7.5 are alkaline. Acidic soil will increase metal availability in soil. Soil pH should be maintained with in neutral range [91]. In the study area, soil pH is found in the range of 7.50 to 8.50.

4.1.3 Organic matter in soil samples

Organic matter is an essential nutrient for crops growth in agricultural fields. Soil organic matter should be maintaining at least 5% for soil fertility [91]. In this study area, the soil organic matter concentration is ranged from 1.60 % to 2.91 %. All of soil's organic matter concentration is lower than 5%. Soil fertility and crops production capacity are decreasing due to lack of organic matter in soil. For increasing soil fertility and sustainable crops production farmers should be used organic fertilizer for crop production.

Table 4.3: Moisture and solid contents in fruit samples

Sample ID.	Sources of Sample	Solid Content (%)	Moisture Content (%)
S-6	Mango(Himsagar)	16.34	83.66
S-9	Mango(Langra)	14.54	85.46
S-20	Pummelo	11.64	88.36
S-21	Guava	28.83	71.17
S-22	Sapodilla	22.02	77.98
S-24	Lime	13.16	86.84
Maximum		28.83	88.36
Minimum		11.64	71.17
Average		17.75	82.25

4.1.4 Moisture contents in fruits sample

Moisture content is the most important factor for fruits sample quality analysis. Moisture contents in fruits are shown in figure 4.2 and table 4.3. Average moisture and solid content in fruits sample is 82.25% & 17.75% respectively. Maximum moisture content is detected 88.36% in pummelo and minimum moisture content is monitored 71.17% in guava. On the other hand the maximum solid content is found 28.83% in guava and minimum solid content is ascertained 11.64% in pummelo.

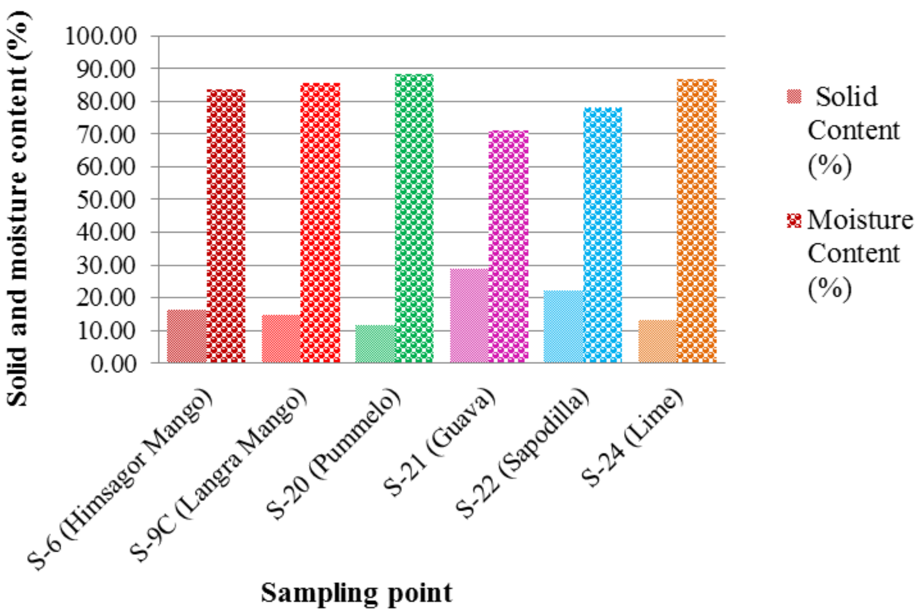

Figure 4.2: Moisture contents and solid contents in fruit's samples

4.1.5 Moisture contents in fruity vegetable samples

Moisture contents in fruity vegetables are shown in figure 4.3 and table 4.4. Average moisture and solid content in fruity vegetable samples is 87.67±9.76% & 12.33±9.76% respectively. Maximum moisture content is found 96.60% in cucumber and minimum moisture content is detected 63.02% in jackfruit. On the other hand the maximum solid content is observed 36.98% in Jackfruit and minimum solid content is measured 3.40% in cucumber.

4.1.6 Moisture contents in root and stem vegetable samples

Moisture contents in stem and root vegetables are shown in figure 4.4 and table 4.5. Average moisture and solid content in vegetable samples is 88.65% & 11.35% respectively. Maximum moisture content is found 94.51% in stem of taro and minimum moisture content is measured 70.87% in corm of elephant yam. On the other hand the maximum solid content is detected 29.13% in corm of elephant yam and minimum solid content is measured 5.49% in stem of taro.

Table 4.4: Moisture and solid contents in fruity vegetable samples

Sample ID.	Sources of Sample	Solid Content (%)	Moisture Content (%)
S-11	Yard long bean	11.46	88.54
S-12	Okra	9.21	90.79
S-14	Ribbed gourd	5.17	94.83
S-15	Plantain	16.61	83.39
S-16	Cucumber	3.40	96.60
S-19	Green Chili	17.28	82.72
S-25	Green papaya	6.69	93.31
S-29	Eggplant	8.18	91.82
S-30	Pumpkin	8.35	91.65
S-32	Jackfruit	36.98	63.02
Maximum		36.98	96.60
Minimum		3.40	63.02
Average		12.33	87.67

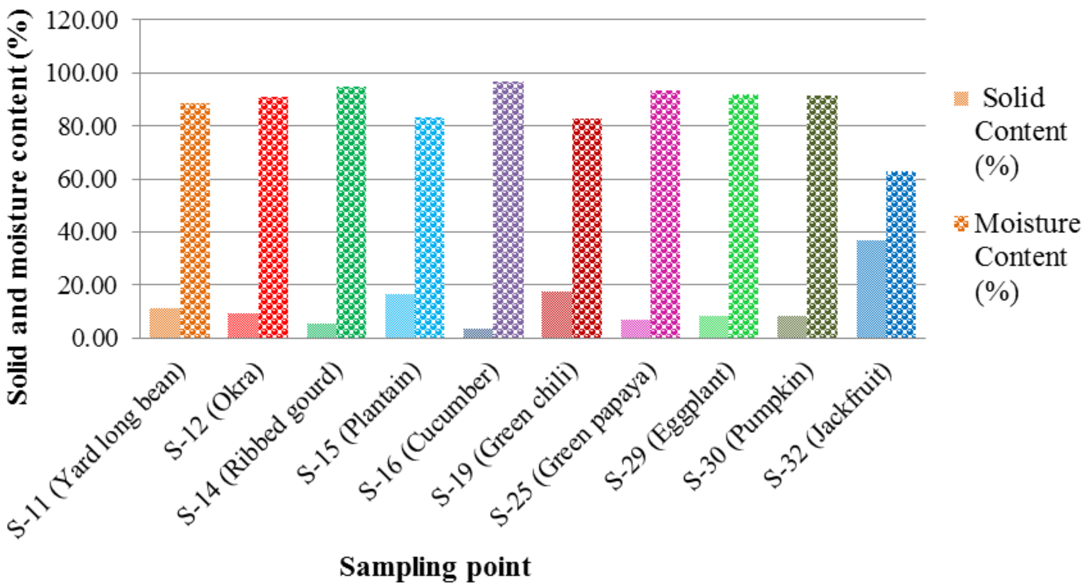

Figure 4.3: Moisture and solid contents in fruity vegetable sample

Table 4.5: Moisture and solid contents in stem and root vegetable samples

Sample ID.	Sources of Sample	Solid Content (%)	Moisture Content (%)
S-26	Stem Amaranth Leaf	8.49	91.51
S-37	Stem of taro	5.49	94.51
S-38	Kachur loti	7.62	92.38
S-39	Wild aroid	9.05	90.95
S-40	Corm of elephant yam	29.13	70.87
S-41	Stem of elephant yam	8.30	91.70
Maximum		29.13	94.51
Minimum		5.49	70.87
Average		11.35	88.65

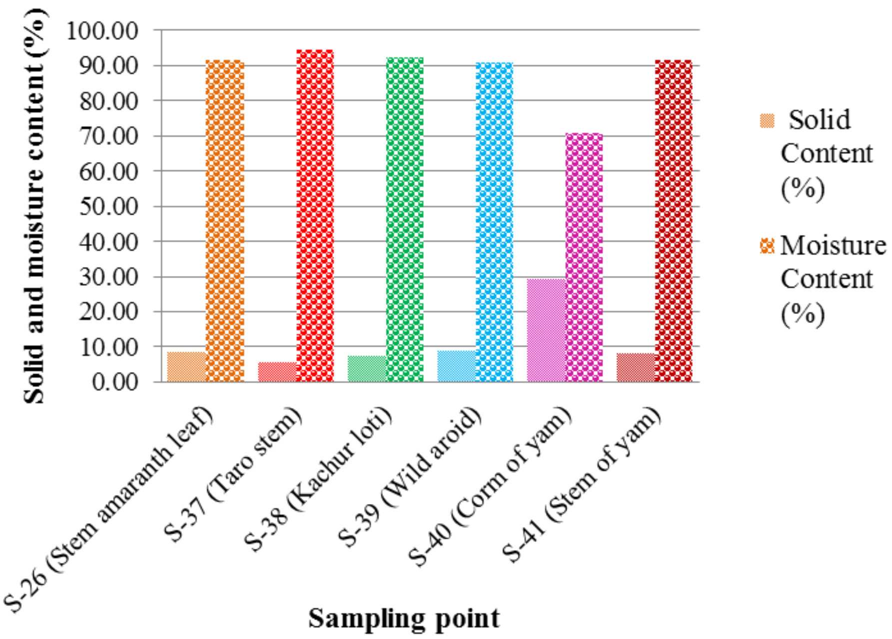

Figure 4.4: Moisture and solid contents in stem and root vegetable samples

4.1.7 Moisture contents in leafy vegetable samples

Moisture contents in leafy vegetables are shown in figure 4.5 and table 4.6. Average moisture and solid content in leafy vegetables is 83.36% & 16.64% respectively. Maximum moisture content is found 88.60% in indian spinach and minimum moisture content is measured 80.11% in red amaranth.

On the other hand a maximum solid content is found 19.89% in S-27 (red amaranth) and minimum solid content is observed 11.40% in S-28 (indian spinach).

Table 4.6: Moisture and solid contents in leafy vegetable samples

Sample ID.	Sources of Sample	Solid Content (%)	Moisture Content (%)
S-27	Red Amaranth	19.89	80.11
S-28	Indian spinach	11.40	88.60
S-36	Leaf of taro	18.63	81.37
Maximum		19.89	88.60
Minimum		11.40	80.11
Average		16.64	83.36

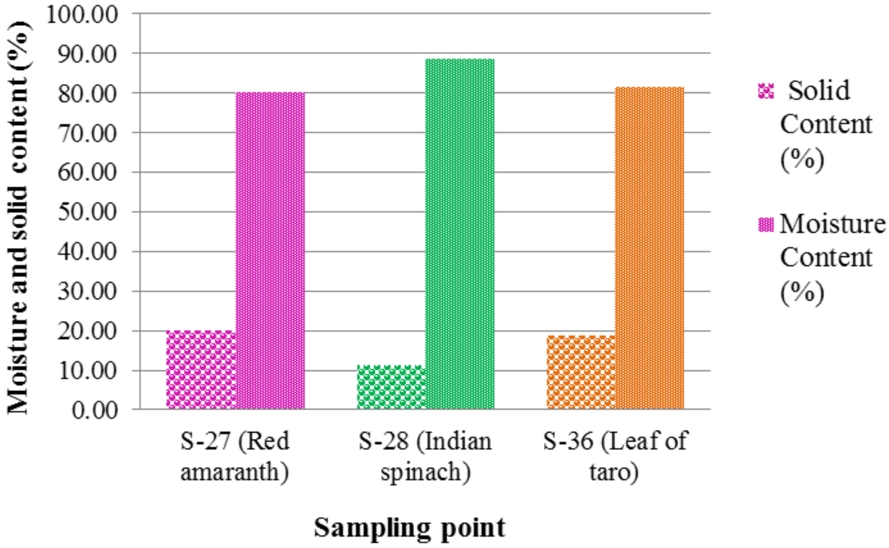

Figure 4.5: Moisture and solid contents in leafy vegetable samples

4.1.8 Moisture contents in seed vegetable samples

Moisture contents in seed vegetables are shown in figure 4.6 and table 4.6. Average moisture and solid content in these vegetable samples is 45.00% & 55.00% respectively. Maximum moisture content is found 58.80% in S-34 (coconut kernel) and minimum moisture content is detected 27.03% in S-33 (pea seed).

On the other hand the maximum solid content is observed 72.97% in S-33 (pea seed) and minimum solid content is obtained 41.20% in S-34 (coconut kernel).

Table 4.7: Moisture and solid contents in seed vegetable samples

Sample ID.	Sources of Sample	Solid Content (%)	Moisture Content (%)
S-33	Pea seed	72.97	27.03
S-34	Coconut kernel	41.20	58.80
S-35	Rice	50.84	49.16
Maximum		72.97	58.80
Minimum		41.20	27.03
Average		55.00	45.00

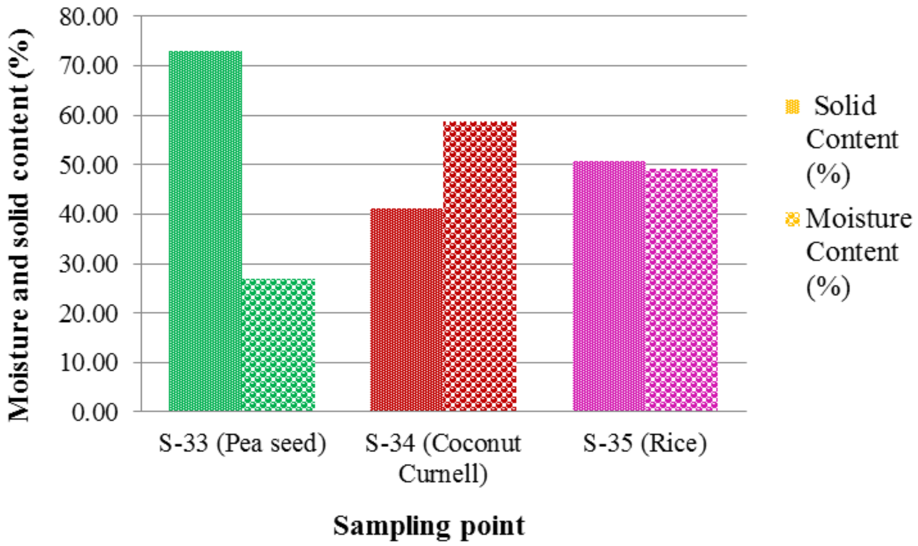

Figure 4.6: Moisture and solid contents in seed vegetable samples

4.1.9 Average moisture and solid contents in fruit and vegetable samples

Average moisture and solid contents in selected fruit and vegetable samples are shown in table-4.8 and figure 4.7. From figure 4.7, it is found that, average moisture contents in all collected samples are followed the order:

Root & stem vegetables > Fruity vegetables > Leafy vegetables > Fruits > Seed vegetables. On the other hand, average solid contents in all collected samples are followed the order: Seed vegetables > Fruits > Leafy vegetables > Fruity vegetables > Root & stem vegetables.

Table 4.8: Average moisture and solid contents in fruit and vegetable samples

Category Of Sample	Average Moisture content (%)	Average Solid content (%)
Fruits	82.25	17.75
Fruity vegetables	87.67	12.33
Root and stem vegetables	88.65	11.35
Leafy vegetables	83.36	16.64
Seed vegetables	45	55

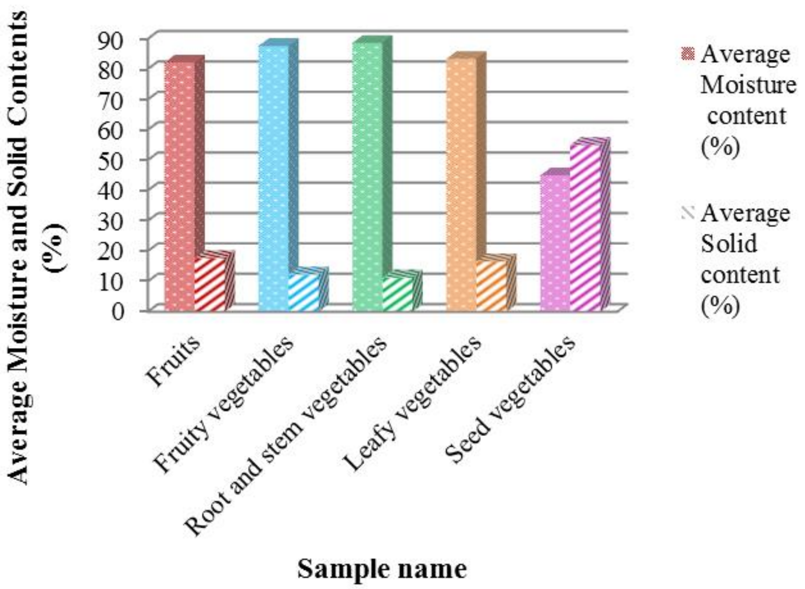

Figure 4.7: Average moisture and solid contents in fruit and vegetable samples

4.2 Metal concentrations in fruits pulp, soil and water

4.2.1 Arsenic concentrations in water, soil, fruits pulp and vegetables

Trace level of arsenic in food is threat for human health. This study was conducted to detect arsenic in irrigation water, soil, fruits and vegetables sample by using HG-AAS method. Arsenic detection level is 0.001mg/L and calibration curve relation coefficients was >0.995 which is calibrated by using 1ppb, 5ppb, 10ppb, 20ppb, 40ppb arsenic standard solution. Average concentration of arsenic in irrigation water was 0.11mg/L which is higher than Bangladesh irrigation water standard [92,93]. Maximum concentration of arsenic in irrigation water is monitored 0.340±0.001 mg/L in S-8 (STW, 202ft) and minimum concentration of arsenic is detected 0.001±0.000 mg/L in S-3 (green coconut water) which concentration is lower than WHO, USEPA and DoE standard for drinking water [92,94,95]. It is observed that all of irrigation tube wells water arsenic concentration is exceeded than DoE drinking water and BADC irrigation water standard [96]. Concentrations of arsenic in coconut, green coconut, pond, river and treated water were monitored 0.003±0.000, 0.001±0.000, 0.04±0.001, 0.02±0.001 & 0.012±0.001 mg/L respectively which values are lower than DoE standard for drinking and surface water [95].

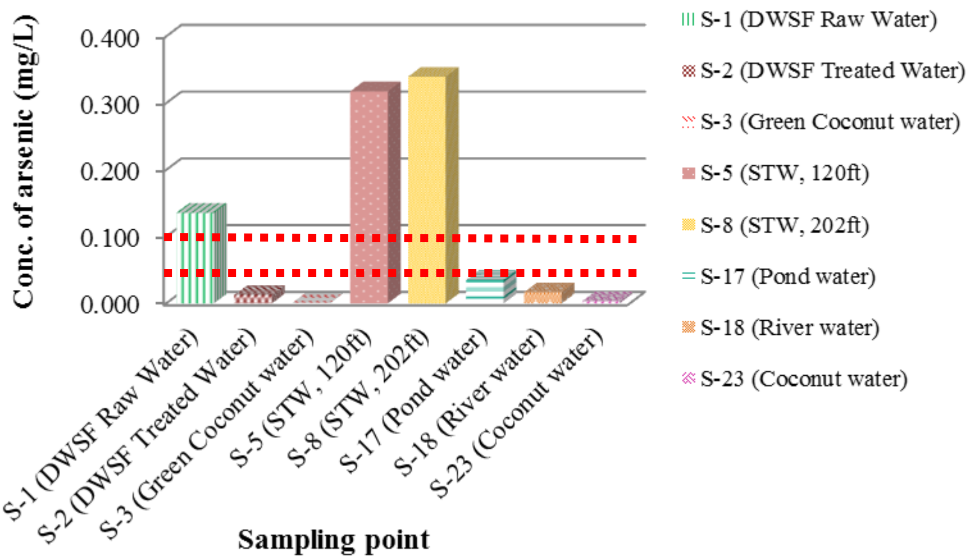

Figure 4.8: Concentration of arsenic in water samples

In soil sample, average concentration of arsenic was measured 8.63 mg/Kg which is lower than Bangladesh soil standard (20 mg/Kg) [94]. Maximum concentration of arsenic in soil sample is detected 11.47±0.11 mg/Kg in soil-31 (brinjal field). On the other hand the minimum concentration of arsenic is found 5.01±0.05 mg/kg in soil-4 (under coconut tree).

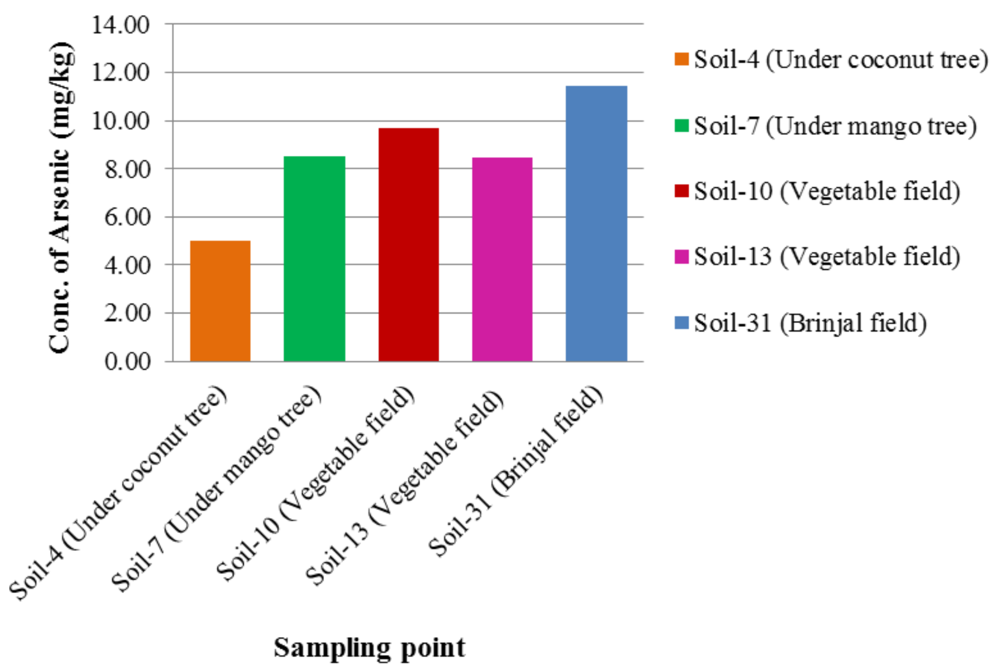

Figure 4.9: Concentration of arsenic in soil samples

In fruits sample, average concentration of arsenic is 0.17 mg/Kg. Maximum concentration of arsenic in fruits sample is monitored 0.24±0.02 mg/Kg in guava. On the other hand the minimum concentration of arsenic is found 0.12±0.00 mg/kg in mango. Average concentration of arsenic in fruits is bellow than the EU and WHO standard (1.00 mg/kg) which was recommended by Bangladesh ministry of agriculture and WHO [92,97].

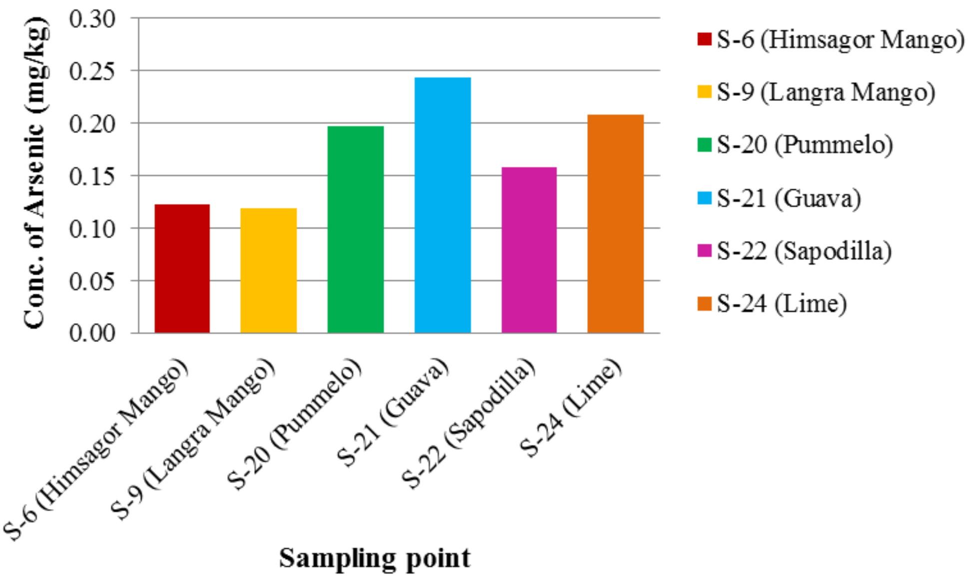

Figure 4.10: Concentration of arsenic in fruit samples

Average concentration of arsenic in fruity vegetables was 0.14 mg/Kg which value is lower than WHO/FAO standard. Maximum concentration of arsenic in fruity vegetable samples is measured 0.27±0.03 mg/Kg in cucumber. On the other hand the concentration of arsenic in pumpkins' samples is lower than detection level. It is observed that fruity vegetables arsenic contents are higher than fruits but lowers than leafy and root vegetables. This study is indicating that fruity vegetables arsenic accumulation tendency is lower than other vegetables.

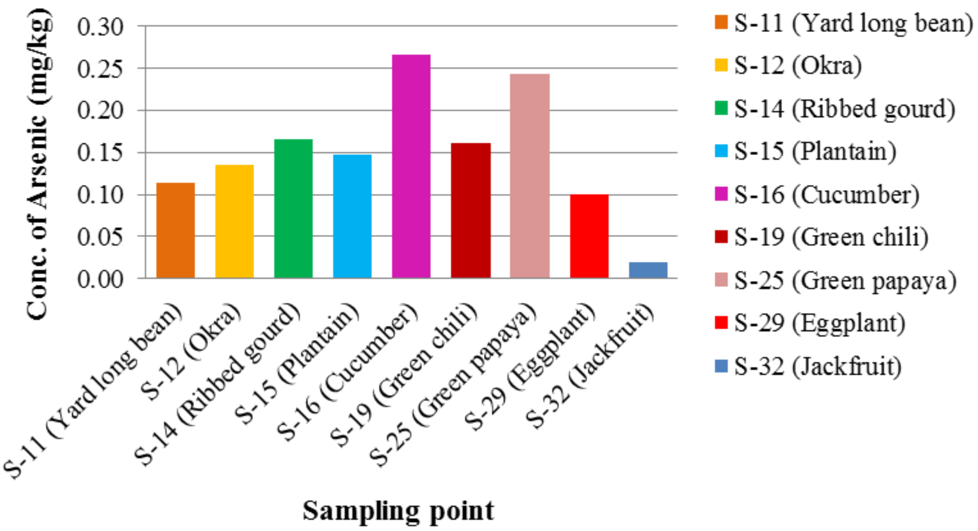

Figure 4.11: Concentration of arsenic in fruity vegetable samples

Average concentration of arsenic in stem and root vegetable samples is 0.23±0.19 mg/Kg. This concentration is lower than WHO/FAO food standard. Maximum concentration of arsenic in vegetable sample is detected 0.49±0.04 mg/Kg in stem of tato (kachur loti). Minimum concentration of arsenic is found 0.06±0.00 mg/kg in corm of yam. It is observed that accumulation of arsenic in root and stem vegetables is higher than fruits and fruity vegetables but lower than leafy and seed vegetables.

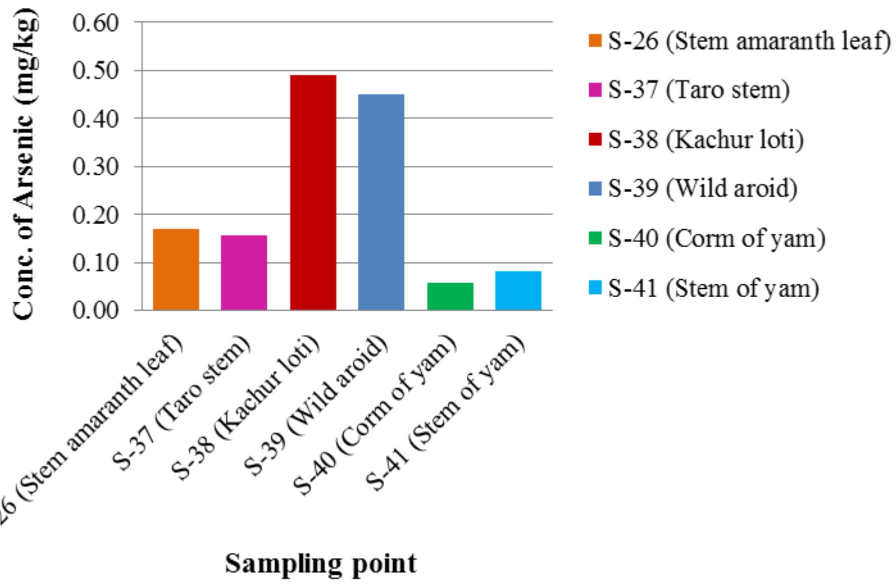

Figure 4.12: Concentration of arsenic in stems and root vegetable samples

Average concentration of arsenic is monitored 0.51 mg/Kg in leafy vegetables. This value is lower than WHO/FAO standard [92, 93]. Maximum concentration of arsenic in leafy vegetable sample was detected 0.85±0.05 mg/Kg in red amaranth which concentration is higher than other vegetables. On the other hand the minimum concentration of arsenic is found 0.07±0.00 mg/kg in indian spinach. It is observed that leafy vegetables arsenic accumulation is higher than fruits, fruity vegetables, seed vegetables, root and stem vegetables which value is lower than FAO/WHO standard [92, 93]. It is indicated that arsenic accumulation tendency in red amaranth is very high and its cultivation process by using arsenic contaminated irrigation water and soil should be avoided, because these sources may be increased the arsenic safety level in vegetables.

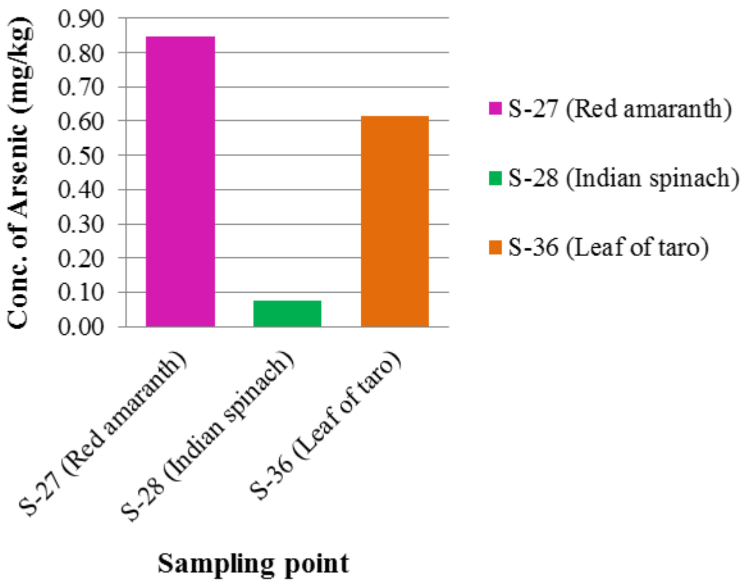

Figure 4.13: Concentration of arsenic in leafy vegetable samples

Average concentration of arsenic was detected 0.15 mg/Kg in seed vegetables which value is lower than FAO/WHO standard [92, 93]. Maximum concentration of arsenic in vegetable samples is measured 0.37±0.02 mg/Kg in rice. On the other hand the minimum concentration of arsenic is found 0.03±0.00 mg/kg in pea seed. In rice sample arsenic accumulation tendency is higher than other seed vegetables.

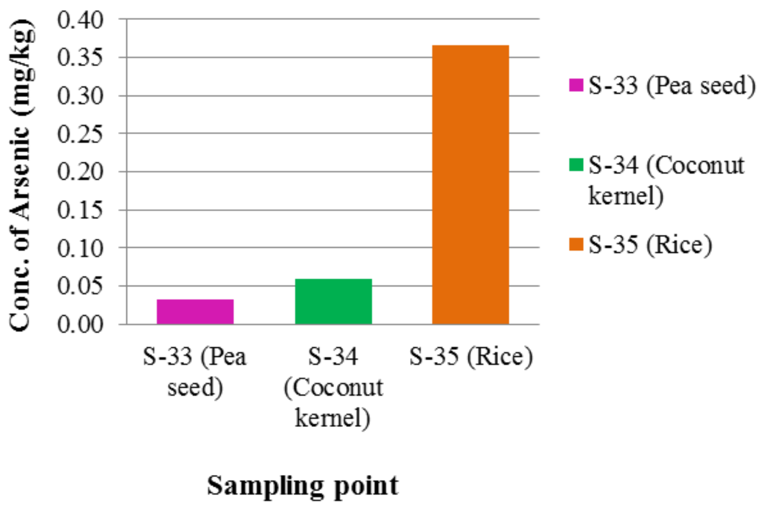

Figure 4.14: Concentration of arsenic in seed vegetable samples

4.2.2 Manganese concentrations in water, soil, fruits pulp and vegetable

Manganese concentration is measured in irrigation water, drinking water, coconut water, soil, fruits and vegetable samples which are collected from study area. Average concentration of manganese in water sample was 0.48±0.54 mg/L which is higher than Bangladesh drinking water standard (<0.1mg/L) [96]. Maximum concentration of manganese is detected 1.430±0.110 mg/L in S-3 (green coconut water) and minimum concentration of manganese is measured 0.02±0.001 mg/L in S-5 (STW, 120ft).

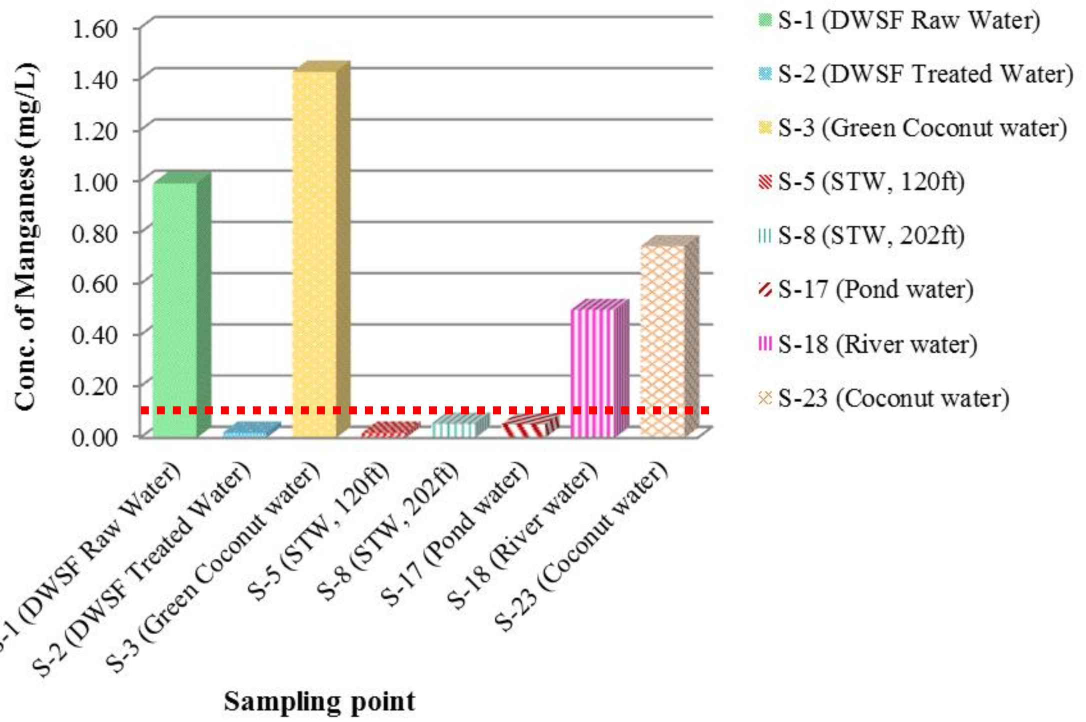

Figure 4.15: Concentration of manganese in water samples

In soil sample, average concentration of manganese was 256.07 mg/Kg which value is lower than USEPA & EU standard for soil. Maximum concentration of manganese in soil sample is detected 299.95 mg/Kg in S-7 (under mango tree). On the other hand minimum concentration of manganese is found 192.15±1.98 mg/kg in S-4 (under coconut tree). This study is showing that, the concentration of manganese is lower than USEPA & EU soil standard in all of soil samples (<1830 & <2000 mg/Kg) [94, 97].

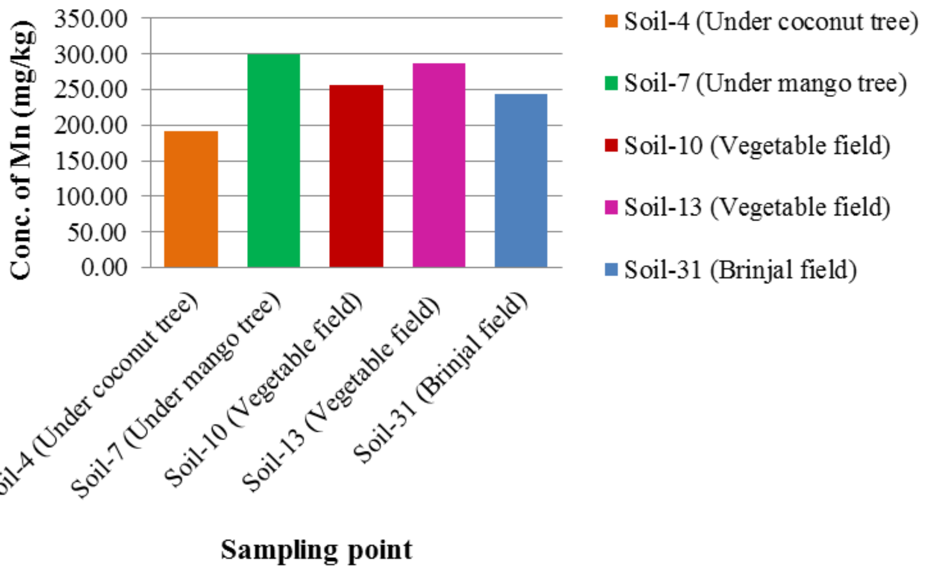

Figure 4.16: Concentration of manganese in soil samples

Average concentration of manganese was monitored 2.86mg/Kg in fruits sample which value is lower than food standard (500mg/Kg) which was recommended by WHO & USEPA [92, 94]. Maximum concentration of manganese is ascertained 8.45±0.08 mg/kg in S-21 (guava) and minimum concentration of manganese is measured 0.50±0.00 mg/kg in S-6 (himsagor mango). So, manganese accumulation tendency is shown higher in guava sample.

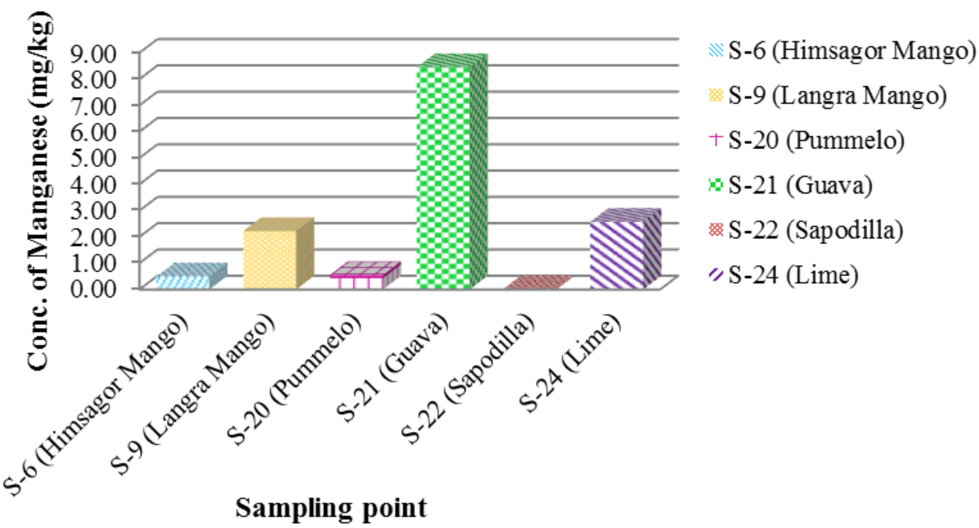

Figure 4.17: Concentration of manganese in fruit samples

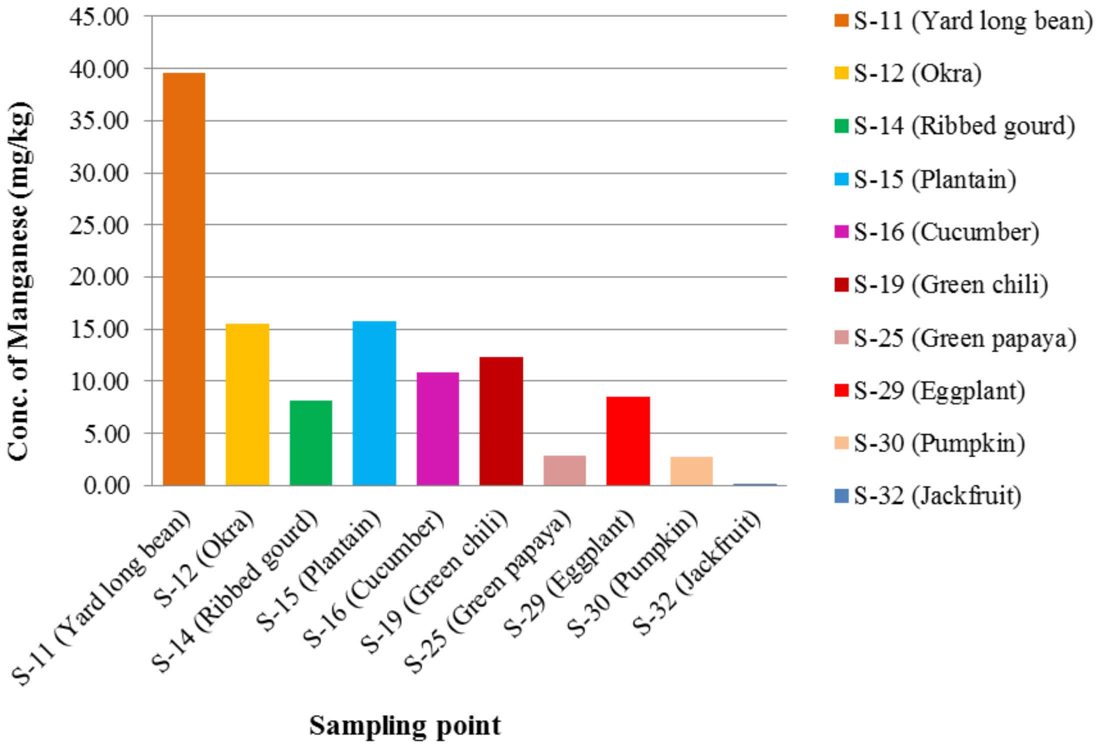

Figure 4.18: Concentration of manganese in fruity vegetable samples

Average concentration of manganese was monitored 12.90 mg/Kg in fruity vegetables which is lower than USEPA & EU standard for food sample. Maximum concentration of manganese is detected 39.55±1.01 mg/kg in S-11 (yard long bean) and minimum concentration of manganese is measured 2.72±0.02 mg/kg in S-30 (pumpkin). Yard long bean sample's manganese accumulation tendency is higher than others fruity vegetables.

Average concentration of manganese is monitored 9.06 mg/kg in S-26 (stem amaranth leaf). This concentration of manganese is lower than European Union food standard (<500mg/Kg) [98]. Manganese concentration of other samples was not analyzed. In leafy vegetable samples, concentration of manganese is 28.08±0.45 mg/kg in S-27 (red amaranth) and 20.44±0.31 mg/kg in S-28 (indian spinach) that is lower than European Union food standard (<500mg/Kg) [97].

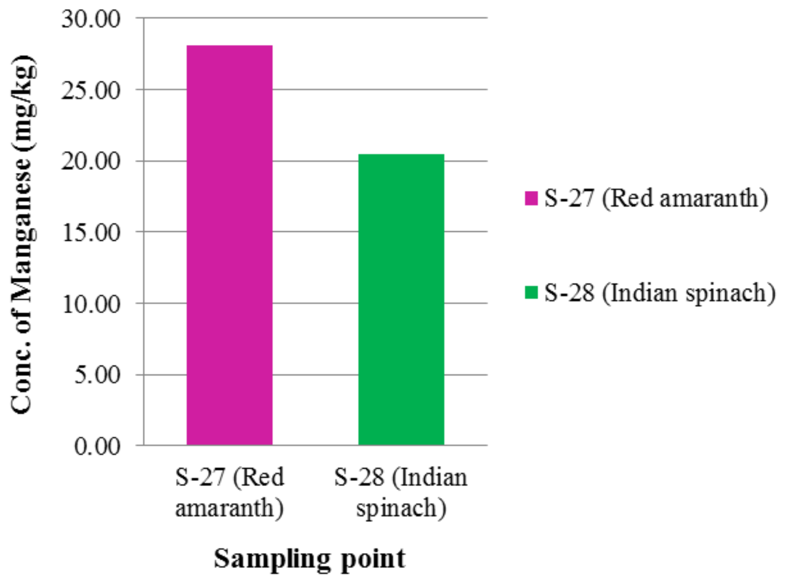

Figure 4.19: Concentration of manganese in leafy vegetable samples

Among seed vegetable samples, concentration of manganese is 9.12±0.09 mg/kg in S-33 (pea seed) and 7.85±0.06 mg/kg in S-34 (coconut kernel). This concentration of manganese is lower than European Union food standard (<500mg/Kg) [97].

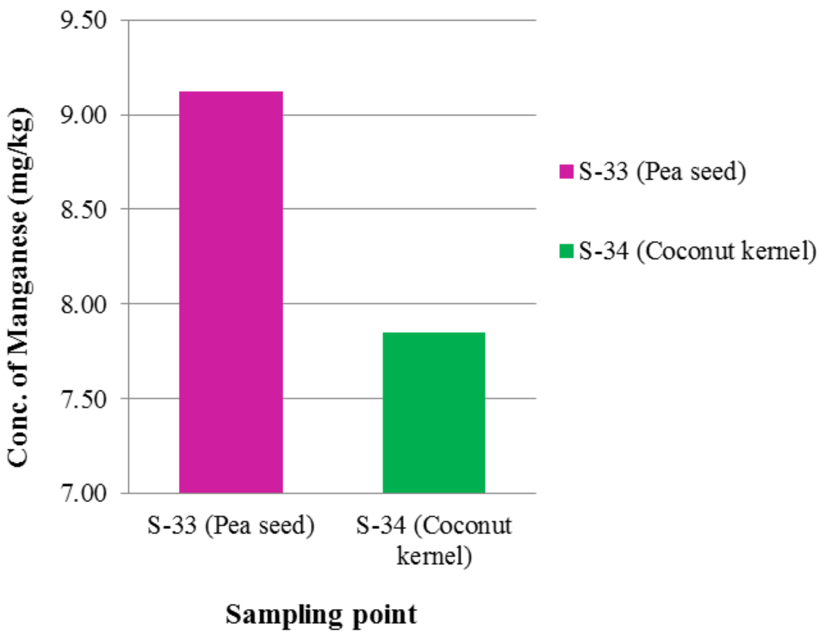

Figure 4.20: Concentration of manganese in seed vegetable samples

4.2.3 Iron concentrations in water, soil, fruits pulp and vegetable

Iron concentration is measured in irrigation water, drinking water, coconut water, soil, fruits and vegetables samples which are also collected from study area.

Average concentration of iron was monitored 4.28 mg/L which is higher than EQS, DoE & Bangladesh drinking water standard (0.3-1.00 mg/L) [95,98].

Maximum concentration of iron is observed 9.59±0.10 mg/L in S-1 (DWSF raw water) and minimum concentration of iron is detected 0.15±0.04 mg/L in S-2 (DWSF treated water).

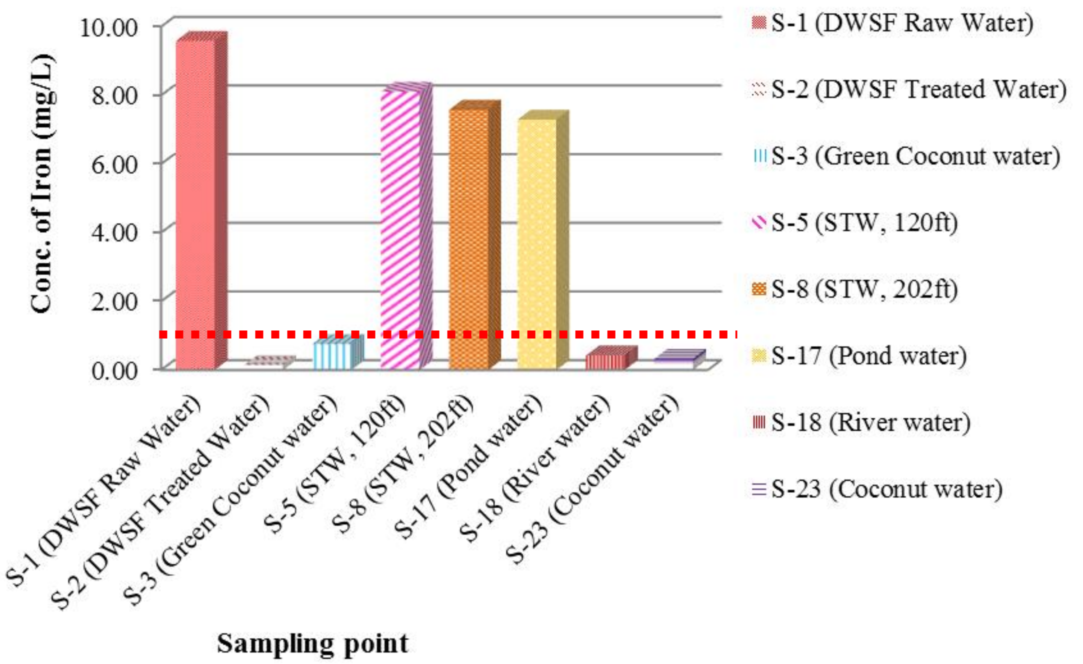

Figure 4.21: Concentration of iron in water samples

In soil samples, average concentration of iron is 12162.78 mg/Kg. Maximum concentration of iron in soil sample is found 25223.55±2.50 mg/Kg in S-7 (under mango tree). On the other hand the minimum concentration of iron is found 1665.51±0.89 mg/kg in soil-31 (brinjal field).

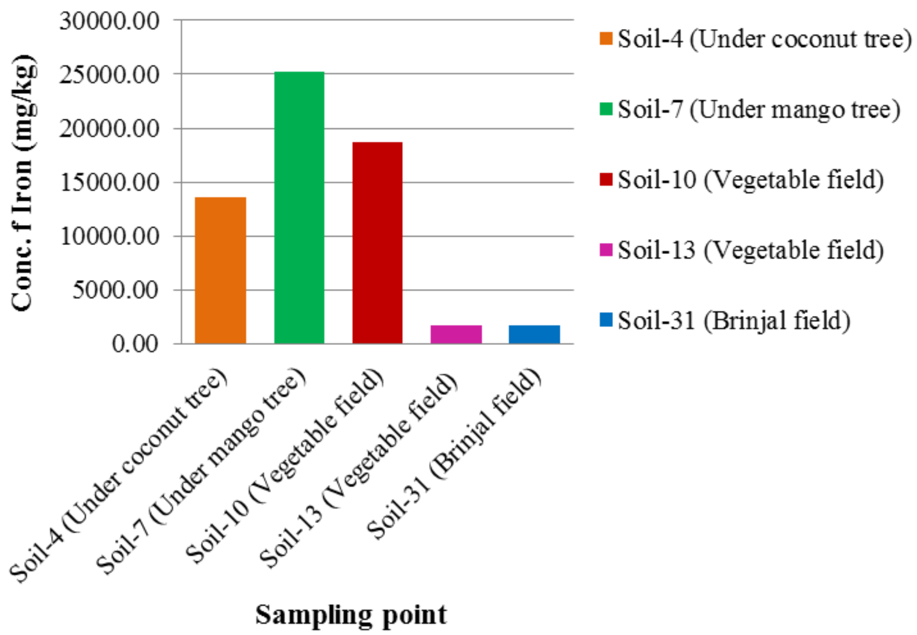

Figure 4.22: Concentration of iron in soil samples

Average concentration of iron was monitored 31.13 mg/Kg in fruits sample which is lower than WHO standard (425 mg/Kg) [91]. Maximum concentration of iron is measured 55.53±1.00 mg/kg in S-21 (guava) and minimum concentration of iron is detected 13.79±0.44 mg/kg in S-22 (sapodilla).

In fruity vegetable samples, average concentration of iron was monitored 60.38 mg/Kg which is lower than WHO standard. Maximum concentration of iron is detected 105.27±2.49 mg/kg in S-12 (okra) and minimum concentration of iron is measured 15.55±0.25 mg/kg in S-32 (jackfruit). It is observed that, rich iron contents in Okra sample can be effective for iron deficiency diseases in human body.

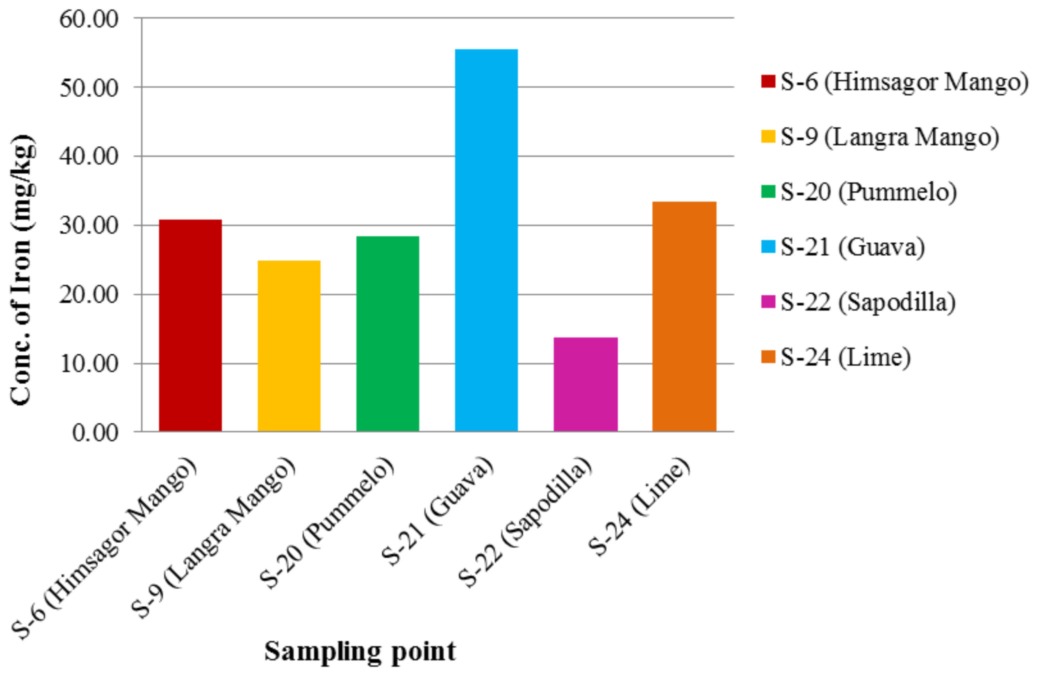

Figure 4.23: Concentration of iron in fruit samples

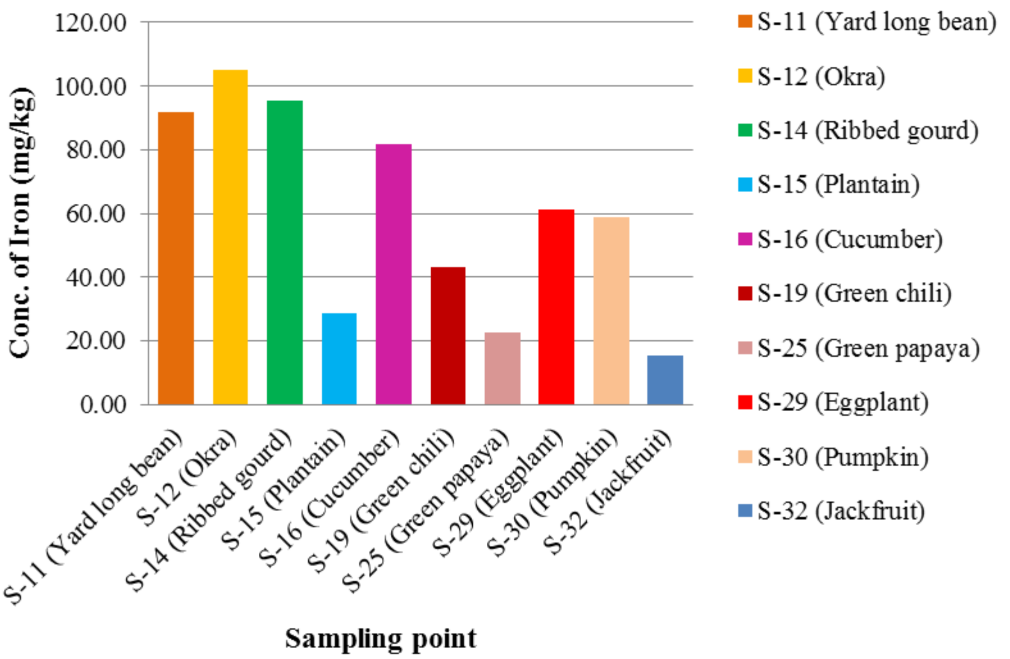

Figure 4.24: Concentration of iron in fruity vegetable samples

Among stem and root vegetable samples, concentration of iron was detected 69.86±0.97 mg/kg in S-26 (stem amaranth leaf) which is lower than WHO food standard.

In leafy vegetable samples concentration of iron is detected 534.91±2.50 mg/kg in S-27 (red amaranth) and 142.46±0.63 mg/kg in S-28 (indian spinach). Concentration of iron in red amaranth sample was showed higher than other vegetables, which is higher than WHO food standard [92]. It indicates that accumulation tendency of iron in red amaranth is higher than other vegetables.

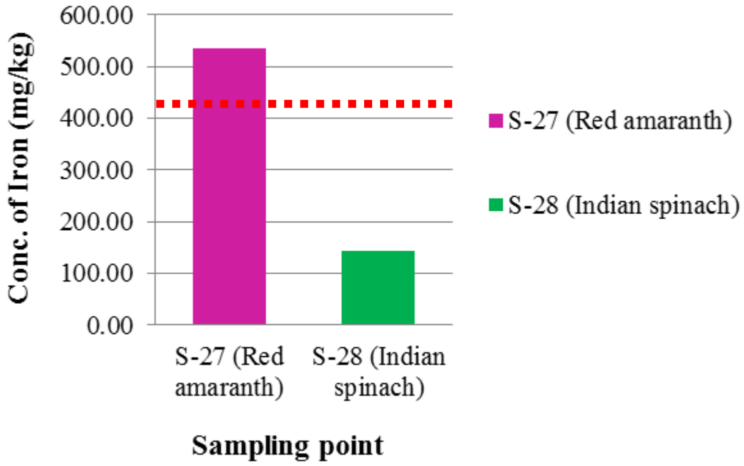

Figure 4.25: Concentration of iron in leafy vegetable samples

Among seed vegetable samples, concentration of iron was showed 47.39±1.10 mg/kg in S-33 (pea seed) and 38.27±1.00 mg/kg in S-34 (coconut Cornell) which is lower than WHO food standard.

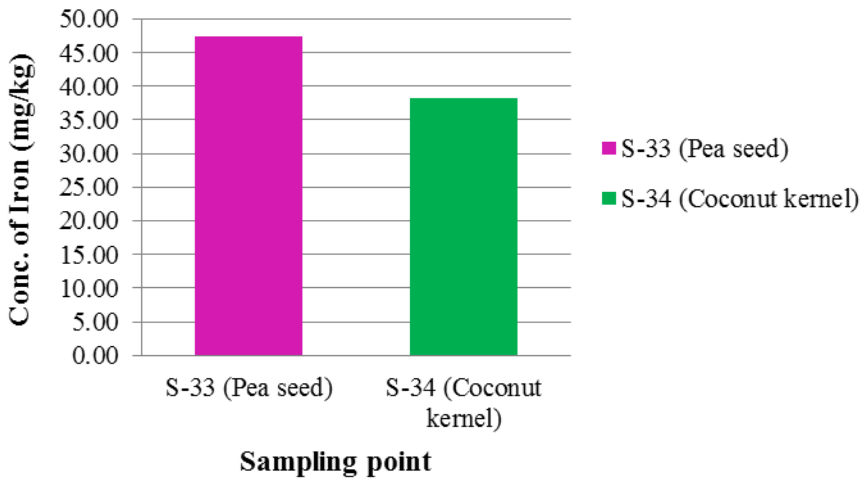

Figure 4.26: Concentration of iron in seed vegetable samples

4.2.4 Copper concentrations in water, soil, fruits pulp and vegetable

Concentration of copper and zinc in water sample was not detected which concentration is lower than detection level. In soil samples, average concentration of copper was measured 21.91 mg/Kg which concentration is lower than EU standard (100 mg/Kg) for soil sample. Maximum concentration of copper in soil samples is detected 30.29±2.49 mg/Kg in Soil-13 (vegetable field). On the other hand the minimum concentration of copper is found 13.20±0.50 mg/Kg in Soil-4 (under coconut tree).

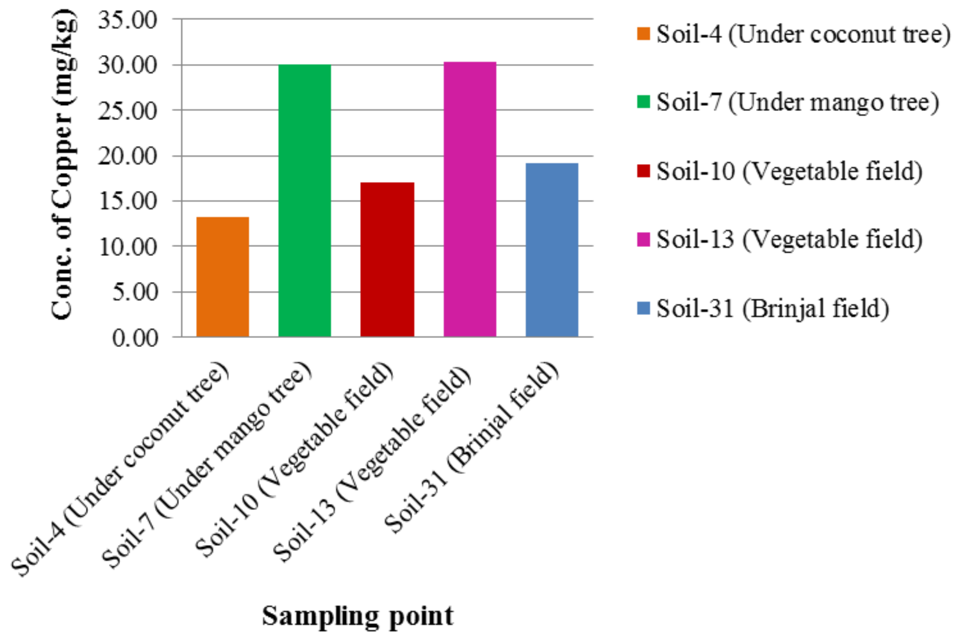

Figure 4.27: Concentration of copper in soil samples

In fruit samples, average concentration of copper was measured 3.40 mg/Kg which is lower than EU food standard. Maximum concentration of copper in fruits is detected 5.74±0.08 mg/Kg in S-9 (langra mango). On the other hand minimum concentration of copper is found 1.41±0.05 mg/Kg in S-20 (pummelo).

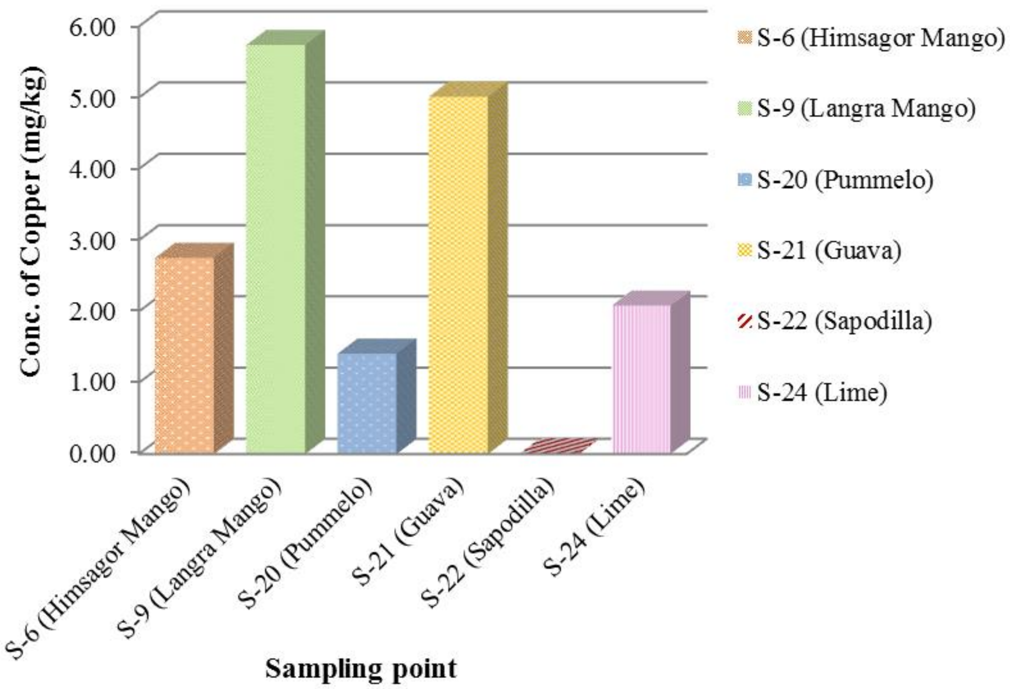

Figure 4.28: Concentration of copper in fruit samples

Average concentration of copper was 9.36 mg/Kg in fruity vegetables which value is lower than EU food standard (<20mg/Kg). Maximum concentration of copper in fruity vegetable sample was monitored 29.54±0.45 mg/Kg in S-14 (ribbed gourd) which concentration is higher than EU food standard. On the other hand the minimum concentration of copper is found 1.41±0.00 mg/Kg in S-25 (green papaya). Copper accumulation in ribbed gourd sample is showed higher than other vegetables.

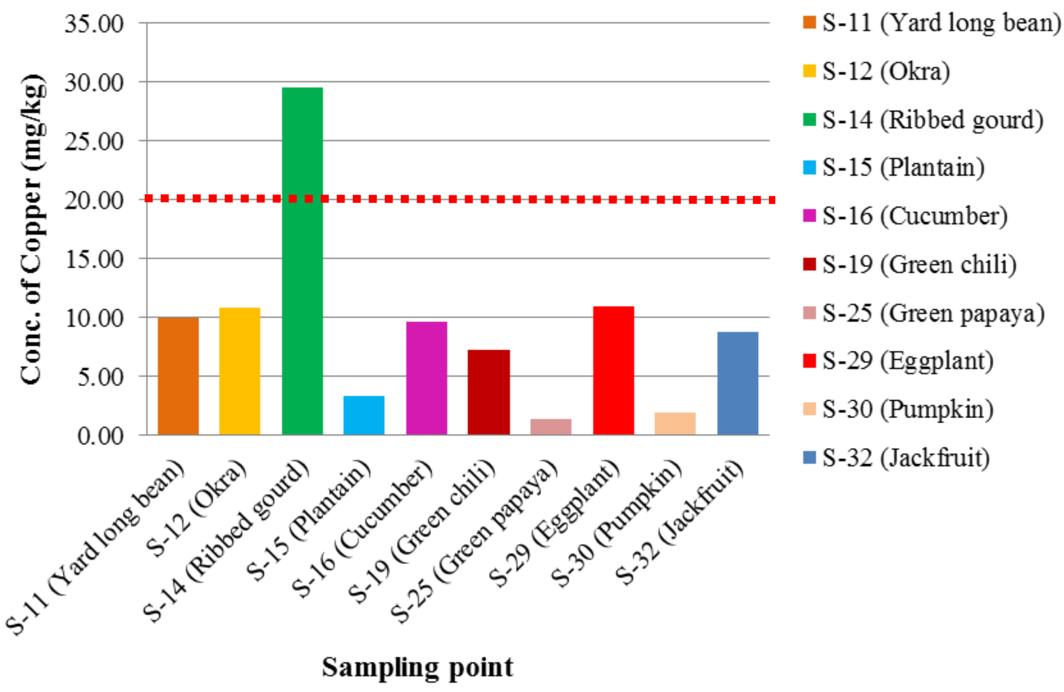

Figure 4.29: Concentration of copper in fruity vegetable samples

Among stem and root vegetable samples, concentration of copper was measured 1.70±0.04 mg/kg in S-26 (stem amaranth leaf) which value is lower than EU food standard.

In leafy vegetable samples, concentration of copper was 3.87±0.05 mg/kg in S-27 (red amaranth) and 5.66±0.07 mg/kg in S-28 indian spinach which is lower than European Union food standard (<20mg/Kg) [97].

Among seed vegetable samples, concentration of copper was showed 11.81±0.10 mg/kg in S-33 (pea seed) and 7.59±0.05 mg/kg in S-34 (coconut kernel) which concentration is lower than European Union food standard (<20mg/Kg) [97].

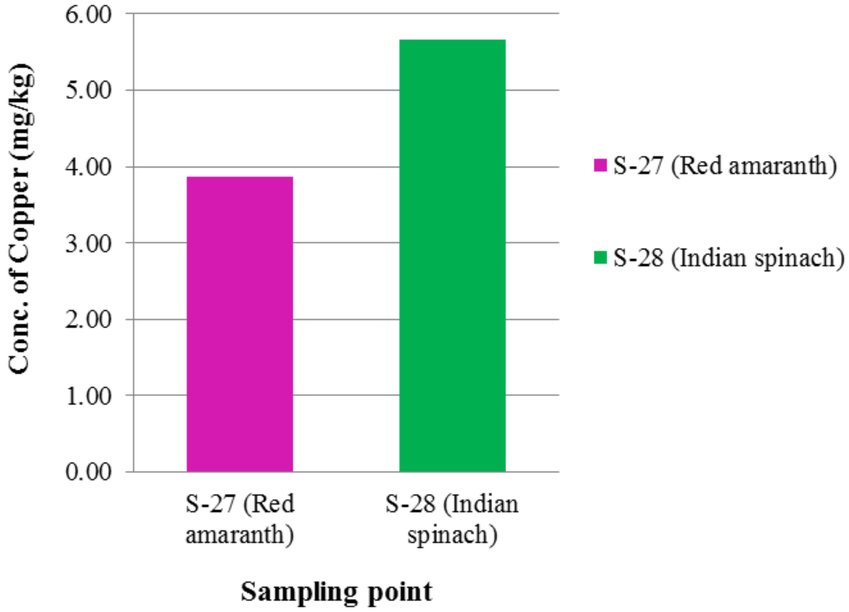

Figure 4.30: Concentration of copper in leafy vegetable samples

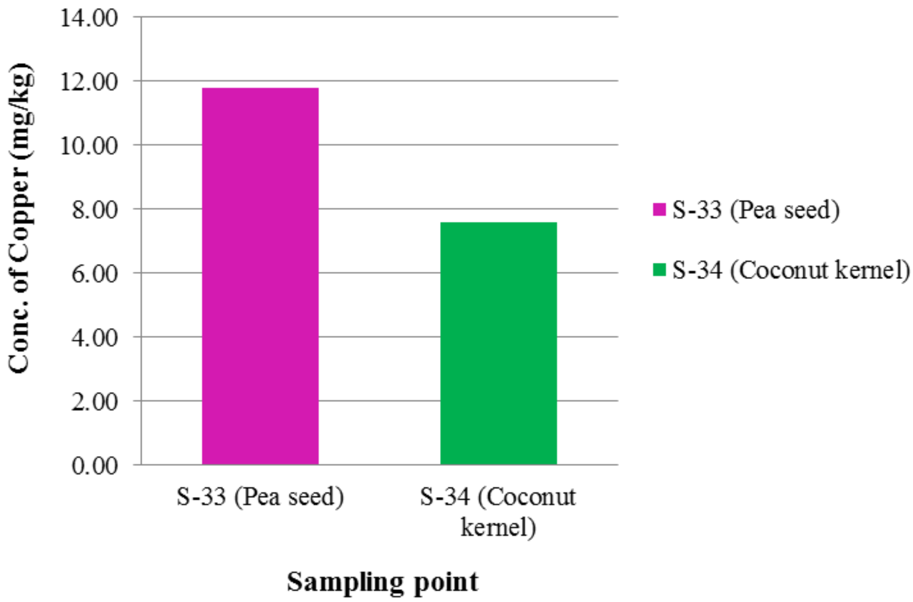

Figure 4.31: Concentration of copper in seed vegetable samples

4.2.5 Zinc concentrations in water, soil, fruits pulp and vegetable

In soil samples, average concentration of zinc was showed 57.40 mg/Kg which value is lower than EU soil standard. Maximum concentration of zinc in soil sample is detected 70.95±1.75 mg/Kg in S-7 (under mango tree). On the other hand the minimum concentration of zinc is found 41.18±0.50 mg/kg in Soil-4 (under coconut tree).

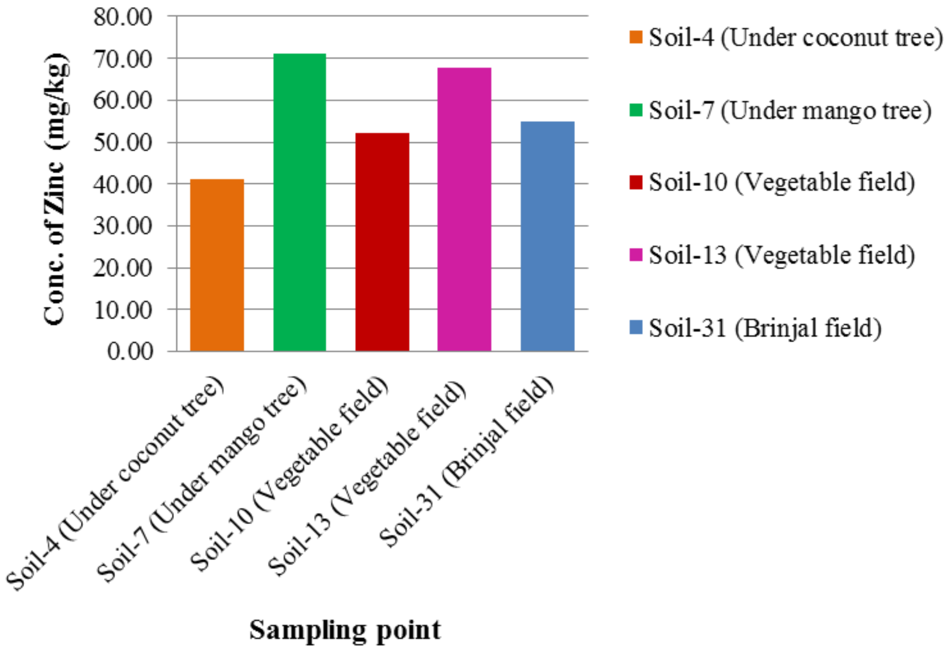

Figure 4.32: Concentration of zinc in soil samples

Average concentration of zinc was monitored 14.72 mg/Kg in fruits sample which is lower than EU food standard (<50 mg/Kg) [97]. Maximum concentration of zinc is measured 20.37±0.26 mg/kg in S-21 (guava) and minimum concentration of zinc is detected 8.73±0.09 mg/kg in S-9 (langra mango).

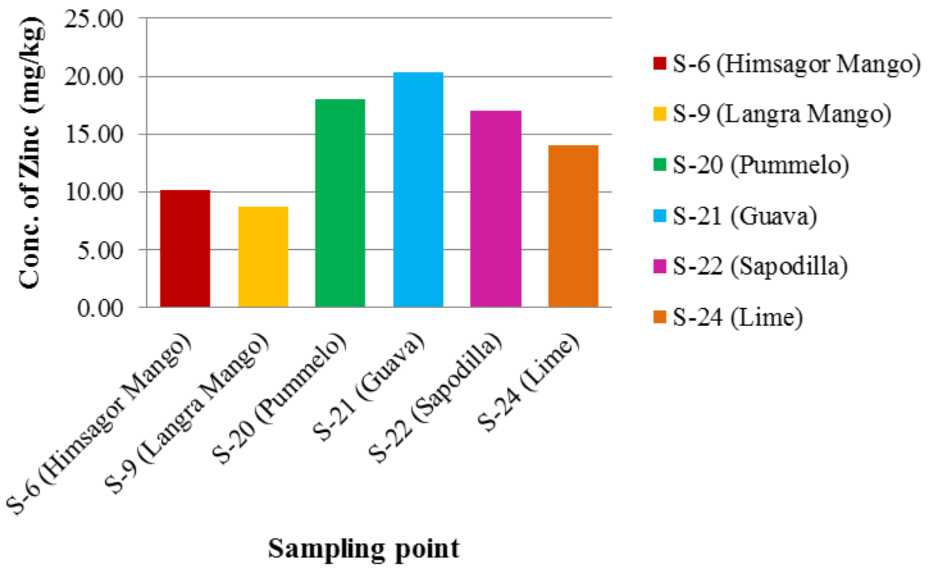

Figure 4.33: Concentration of zinc in fruit samples

In fruity vegetable samples, average concentration of zinc was monitored 28.48 mg/Kg which is lower than EU food standard. Maximum concentration of zinc is detected 50.19±2.01 mg/kg in S-12 (okra) and minimum concentration of zinc is measured 13.85±0.13 mg/kg in S-25 (green papaya). It is indicated that enrich of zinc in okra can be effective for zinc deficiency in human body.

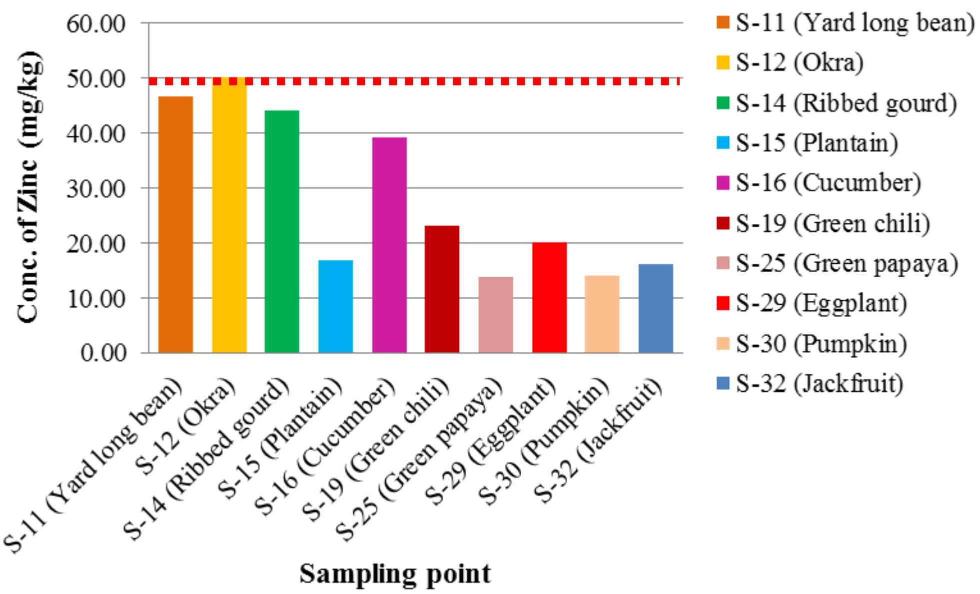

Figure 4.34: Concentration of zinc in fruity vegetable samples

Among stem and root vegetable samples, concentration of zinc was 16.39±0.20 mg/kg in S-26 (stem amaranth leaf) which value is lower than European Union food standard. In leafy vegetable samples, concentration of zinc was 28.00±0.43 mg/kg in S-27 (red amaranth) and 18.75±0.20 mg/kg in S-28 Indian Spinach which is lower than European Union food standard [100]. Among seed vegetable samples, concentration of zinc was 28.11±0.49 mg/kg in S-33 (pea seed) and 26.18±0.44 mg/kg in S-34 (coconut kernel) which concentration is lower than European Union food standard [97].

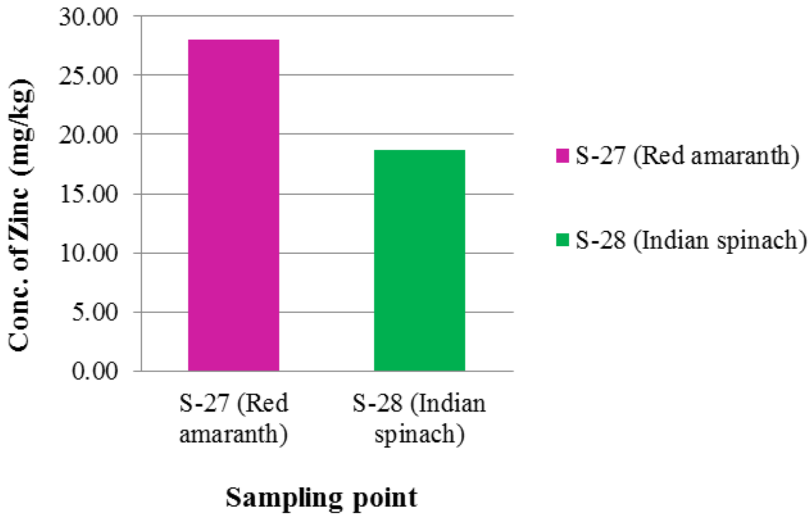

Figure 4.35: Concentration of zinc in leafy vegetable samples

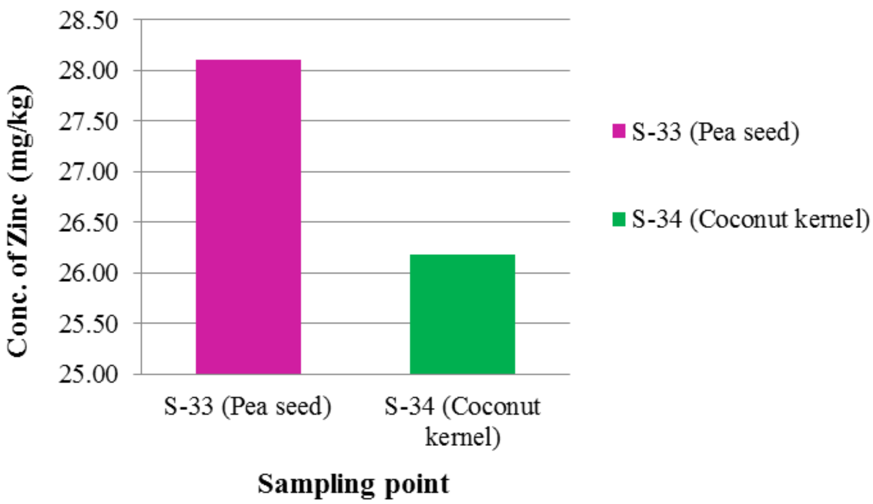

Figure 4.36: Concentration of zinc in seed vegetable sample

Table 4.9: Arsenic and heavy metal concentrations of water Samples

Sample ID	Sample sources	Conc. of arsenic (mg/L)	Conc. of Iron (mg/L)	Conc. of Manganese (mg/L)	Conc. of Copper (mg/L)	Conc. of Zinc (mg/L)	Conc. of Lead (mg/L)
S-1	DWSF Raw Water	0.136±0.002	9.59±0.10	0.99±0.090	<0.01	<0.04	<0.04
S-2	DWSF Treated Water	0.012±0.001	0.15±0.04	0.02±0.001	<0.01	<0.04	<0.04
S-3	Green Coconut water	0.001±0.000	0.76±0.05	1.43±0.110	<0.01	0.57	<0.04
S-5	STW (120ft)	0.318±0.001	8.11±0.09	0.02±0.000	<0.01	<0.04	<0.04
S-8	STW (202ft)	0.340±0.001	7.58±0.06	0.06±0.001	<0.01	<0.04	<0.04
S-17	Pond water	0.035±0.001	7.29±0.06	0.05±0.001	<0.01	<0.04	<0.04
S-18	River water	0.017±0.001	0.43±0.04	0.50±0.030	<0.01	<0.04	<0.04
S-23	Coconut Water	0.003±0.000	0.33±0.03	0.75±0.050	<0.01	0.28	<0.04
Maximum		0.34	9.59	1.43			
Minimum		0.00	0.15	0.02			
Average		0.11	4.28	0.48			
WHO standard (2001) [92]		0.01					
FAO standard (2001) [93]		0.10					
Indian standard (2000) [96]				0.1	0.05	5.00	0.1
Bangladeshi standard [99]		0.05	0.3-1.00	0.1	1.00	5.00	0.05
EQS standard [95]		0.05	0.3-1.00			5.00	0.05
DoE standard [98]			0.3-1.00		1.00	5.00	0.05

Table 4.10: Arsenic and heavy metal concentrations of soil Samples

Sample ID	Sample sources	Conc. of arsenic (mg/Kg)	Conc. of Iron (mg/Kg)	Conc. of Manganese (mg/Kg)	Conc. of Copper (mg/Kg)	Conc. of Zinc (mg/Kg)	Conc. of Lead (mg/Kg)
S-4	Soil	5.01±0.05	13582.50±1.50	192.15±1.00	13.20±0.50	41.18±0.50	<0.04
S-7	Soil	8.54±0.08	25223.55±2.50	299.95±1.98	30.00±2.37	70.95±1.75	<0.04
S-10	Soil	9.71±0.09	18644.28±2.36	257.18±1.34	16.98±1.67	52.21±0.57	<0.04
S-13	Soil	8.44±0.06	1698.05±2.18	287.05±1.67	30.29±2.49	67.72±1.69	<0.04
S-31	Soil	11.47±0.11	1665.51±1.89	244.05±1.19	19.10±1.79	54.94±0.53	<0.04
Maximum		11.47	25223.55	299.95	30.29	70.95	
Minimum		5.01	1665.51	192.15	13.20	41.18	
Average		8.63	12162.78	256.07	21.91	57.40	
European union standard (2006) [97]				2000	100	300	100
Indian standard (2000) [96]					135-270	300-600	250-500
USEPA [94]		75.00		1830	4300	75000	420

Table 4.11: Arsenic and heavy metal concentrations of fruit Samples

Sample ID	Sample sources	Conc. of arsenic (mg/Kg)	Conc. of Iron (mg/Kg)	Conc. of Manganese (mg/Kg)	Conc. of Copper (mg/Kg)	Conc. of Zinc (mg/Kg)	Conc. of Lead (mg/Kg)
S-6	Mango (himsagar)	0.12±0.00	30.76±0.47	0.50±0.00	2.75±0.08	10.14±0.11	<0.04
S-9	Mango (langra)	0.12±0.00	24.87±0.40	2.22±0.04	5.74±0.08	8.73±0.09	<0.04
S-20	Pummelo	0.20±0.01	28.39±0.46	0.55±0.00	1.41±0.05	18.06±0.20	<0.04
S-21	Guava	0.24±0.02	55.53±1.00	8.45±0.08	5.01±0.09	20.37±0.26	<0.04
S-22	Sapodilla	0.16±0.01	13.79±0.44	0.02±0.00	0.01±0.00	17.01±0.20	<0.04
S-24	Lime	0.21±0.02	33.47±0.49	2.57±0.04	2.08±0.06	14.03±0.19	<0.04
Maximum		0.24	55.53	8.45	5.74	20.37	
Minimum		0.12	13.79	0.50	1.41	8.73	
Average		0.17	31.13	2.86	3.40	14.72	
WHO standard (2001) [92]			425.00	500.00	40.00		0.3
FAO standard (2001) [93]					40.00	60.00	
European union standard (2006) [97]				500.00	20.00	50.00	0.43
Indian standard (2000) [96]					30.00	50.00	2.50
NFA (1993) [100]		1.00					

Table 4.12: Arsenic and heavy metal concentrations of fruity vegetable Samples

Sample ID	Sample sources	Conc. of arsenic (mg/Kg)	Conc. of Iron (mg/Kg)	Conc. of Manganese (mg/Kg)	Conc. of Copper (mg/Kg)	Conc. of Zinc (mg/Kg)	Conc. of Lead (mg/Kg)
S-11	Yard long bean	0.11±0.01	91.80±2.18	39.55±1.01	10.01±0.10	46.77±1.56	<0.04
S-12	Okra	0.14±0.01	105.27±2.49	15.50±0.13	10.80±0.14	50.19±2.01	<0.04
S-14	Ribbed gourd	0.16±0.01	95.46±2.19	8.18±0.05	29.54±0.45	44.05±1.00	<0.04
S-15	Plantain	0.15±0.01	28.59±0.50	15.79±0.18	3.33±0.05	16.90±0.19	<0.04
S-16	Cucumber	0.27±0.03	81.88±2.23	10.80±0.10	9.60±0.09	39.26±0.99	<0.04
S-19	Green Chili	0.16±0.02	42.99±1.09	12.30±0.11	7.27±0.06	23.27±0.48	<0.04
S-25	Green papaya	0.24±0.03	22.47±0.48	2.81±0.04	1.41±0.00	13.85±0.13	<0.04
S-29	Eggplant	0.10±0.00	61.08±2.10	8.45±0.06	10.98±0.07	20.25±0.21	<0.04
S-30	Pumpkin	<0.001	58.68±1.37	2.72±0.02	1.90±0.00	14.02±0.11	<0.04
S-32	Jackfruit	0.02±0.00	15.55±0.25	0.02±0.00	8.82±0.04	16.25±0.20	<0.04
Maximum		0.27	105.27	39.55	29.54	50.19	
Minimum		0.00	15.55	2.72	1.41	13.85	
Average		0.14	60.38	12.90	9.36	28.48	
WHO standard (2001) [92]			425.00	500.00	40.00		0.3
FAO standard (2001) [93]					40.00	60.00	
European union standard (2006) [97]				500.00	20.00	50.00	0.43
Indian standard (2000) [96]					30.00	50.00	2.50
NFA (1993) [100]		1.00					

Table 4.13: Arsenic and heavy metal concentrations of stem and root vegetable Samples

.

Sample ID	Sample sources	Conc. of arsenic (mg/Kg)	Conc. of Iron (mg/Kg)	Conc. of Manganese (mg/Kg)	Conc. of Copper (mg/Kg)	Conc. of Zinc (mg/Kg)	Conc. of Lead (mg/Kg)
S-26	Stem amaranth leaf	0.17±0.01	69.86±1.97	9.06±0.10	1.70±0.04	16.39±0.20	<0.04
S-37	Taro stem	0.16±0.00	NA	NA	NA	NA	<0.04
S-38	kachur loti	0.49±0.04	NA	NA	NA	NA	<0.04
S-39	Wild aroid	0.45±0.05	NA	NA	NA	NA	<0.04
S-40	Corm of yam	0.06±0.00	NA	NA	NA	NA	<0.04
S-41	stem of yam	0.08±0.00	NA	NA	NA	NA	<0.04
Maximum		0.49	69.86	9.06	1.70	16.39	
Minimum		0.06	69.86	9.06	1.70	16.39	
Average		0.23	69.86	9.06	1.70	16.39	
WHO standard (2001) [92]			425.00	500.00	40.00		0.3
FAO standard (2001) [93]					40.00	60.00	
European union standard (2006) [97]				500.00	20.00	50.00	0.43
Indian standard (2000) [96]					30.00	50.00	2.50
NFA (1993) [100]		1.00					

NA = Not analyzed

Table 4.14: Arsenic and heavy metal concentrations of leafy vegetable Samples

Sample ID	Sample sources	Conc. of arsenic (mg/Kg)	Conc. of Iron (mg/Kg)	Conc. of Manganese (mg/Kg)	Conc. of Copper (mg/Kg)	Conc. of Zinc (mg/Kg)	Conc. of Lead (mg/Kg)
S-27	Red Amaranth leaf	0.85±0.05	534.91±2.50	28.08±0.45	3.87±0.05	28.00±0.43	<0.04
S-28	Indian spinach	0.07±0.00	142.46±0.63	20.44±0.31	5.66±0.07	18.75±0.20	<0.04
S-36	Leaf of taro	0.61±0.04	NA	NA	NA	NA	<0.04
Maximum		0.85	534.91	28.08	5.66	28.00	
Minimum		0.07	142.46	20.44	3.87	18.75	
Average		0.51	338.68	24.26	4.76	23.37	
WHO standard (2001) [92]			425.00	500.00	40.00		0.3
FAO standard (2001) [93]					40.00	60.00	
European union standard (2006) [97]				500.00	20.00	50.00	0.43
Indian standard (2000) [96]					30.00	50.00	2.50
NFA (1993) [100]		1.00					

NA = Not analyzed

Table 4.15: Arsenic and heavy metal concentrations of seed vegetable Samples

Sample ID	Sample sources	Conc. of arsenic (mg/Kg)	Conc. of Iron (mg/Kg)	Conc. of Manganese (mg/Kg)	Conc. of Copper (mg/Kg)	Conc. of Zinc (mg/Kg)	Conc. of Lead (mg/Kg)
S-35	Rice	0.37±0.02	NA	NA	NA	NA	<0.04
S-33	Pea seed	0.03±0.01	47.39±1.10	9.12±0.09	11.81±0.10	28.11±0.49	<0.04
S-34	Coconut kernel	0.06±0.01	38.27±1.00	7.85±0.06	7.59±0.05	26.18±0.44	<0.04
Maximum		0.37	47.39	9.12	11.81	28.11	
Minimum		0.03	38.27	7.85	7.59	26.18	
Average		0.15	42.83	8.48	9.70	27.15	
WHO standard (2001) [92]			425.00	500.00	40.00		0.3
FAO standard (2001) [93]					40.00	60.00	
European union standard (2006) [97]				500.00	20.00	50.00	0.43
Indian standard (2000) [96]					30.00	50.00	2.50
NFA (1993) [100]		1.00					

NA = Not analyzed

4.2.6 Average arsenic concentrations in fruits pulp and vegetables

Average concentrations of arsenic in all selected fruits and vegetables are shown in table 4.16 and figure 4.37.

Table 4.16: Average concentrations of arsenic and other metals in fruits and vegetables

Category Of Sample	Average Conc. Of Arsenic (mg/kg)	Average Conc. Of Iron (mg/kg)	Average Conc. Of Manganese (mg/kg)	Average Conc. Of Copper (mg/kg)	Average Conc. Of Zinc (mg/kg)
Fruits	0.17	31.13	2.86	3.4	14.72
Fruity vegetables	0.14	60.38	12.9	9.36	28.48
Root and stem vegetables	0.23	69.86	9.06	1.7	16.39
Leafy vegetables	0.51	338.69	24.26	4.76	23.37
Seed vegetables	0.15	42.83	8.48	9.7	27.15

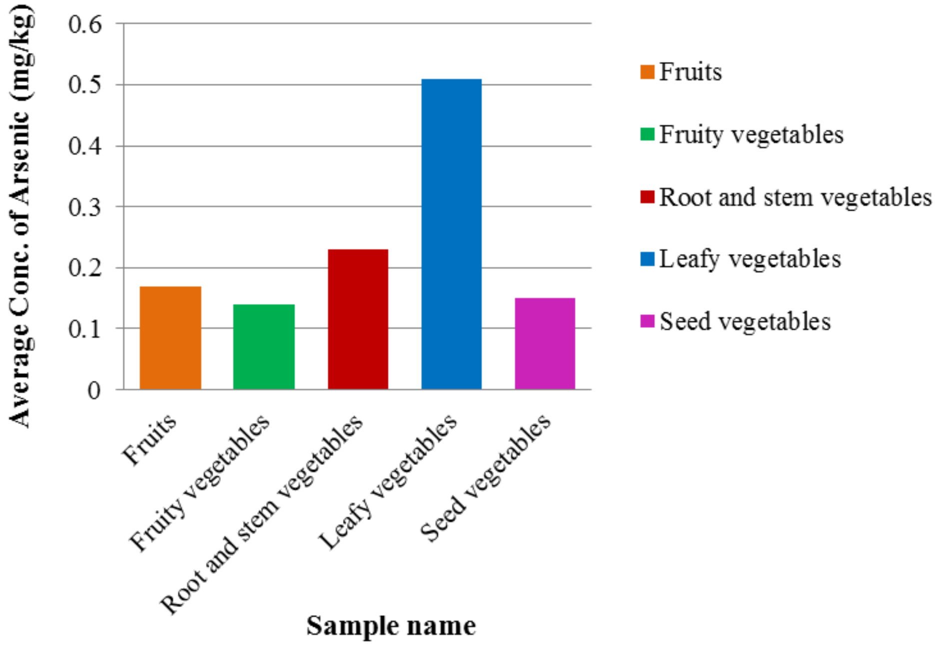

Figure 4.37: Average concentrations of arsenic in fruits and vegetables

Average concentrations of arsenic were followed the order which is mentioned in Figure-4.37.

Leafy vegetables > Root & stem vegetables > Fruits > Seed vegetables > Fruity vegetables.

So, average concentration of arsenic is higher in leafy vegetables (0.51 mg/kg) and lowers in fruity vegetables (0.14 mg/kg).

4.2.7 Average Iron concentrations in fruits pulp and vegetables

Average concentrations of iron in all selected fruits and vegetables are shown in table 4.16 and figure 4.38.

Here, average iron concentrations were followed the order:

Leafy vegetables > Root and stem vegetables > Fruity vegetables > Seed vegetables > Fruits.

So, average concentration of iron is higher in leafy vegetables (338.69 mg/kg) and lowers in fruits (31.13 mg/kg).

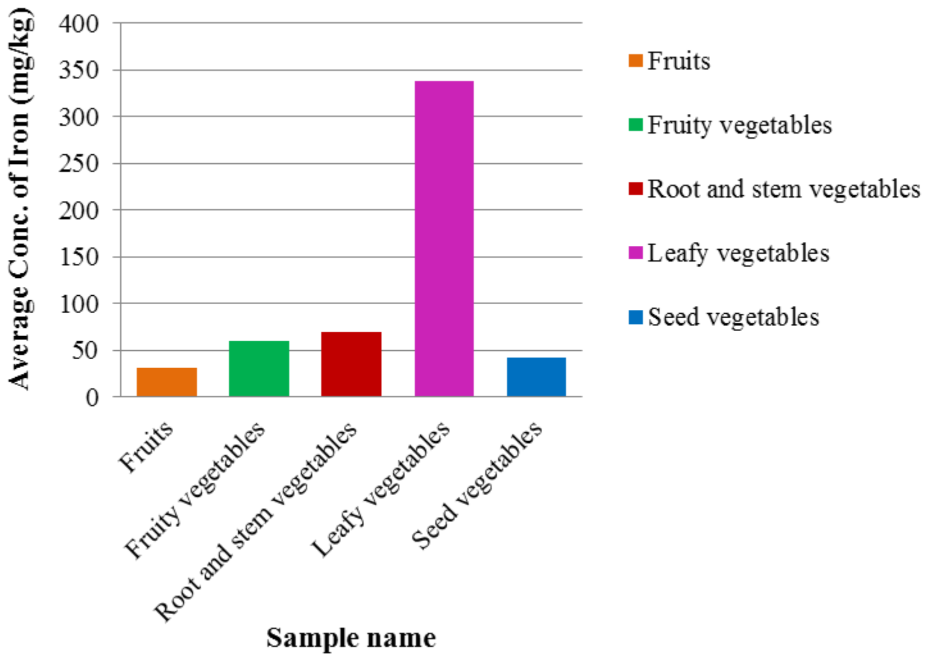

Figure 4.38: Average concentrations of iron in fruits and vegetables

4.2.8 Average manganese concentrations in fruits pulp and vegetables

Average concentrations of manganese in all selected fruits and vegetables are shown in table 4.16 and figure 4.39.

Here, average iron concentrations were followed the order:

Leafy vegetables > Fruity vegetables > Root and stem vegetables > Seed vegetables > Fruits.

So, average concentration of manganese is higher in leafy vegetables (24.26 mg/kg) and lowers in fruits (2.86 mg/kg).

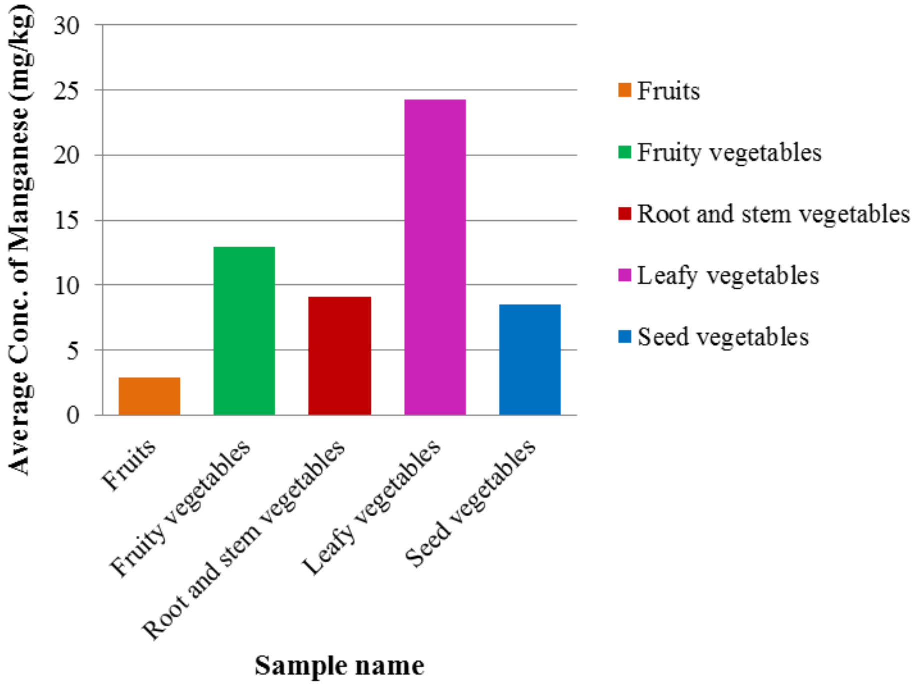

Figure 4.39: Average concentrations of manganese in fruits and vegetables

4.2.9 Average copper concentrations in fruits pulp and vegetables

Average concentrations of copper in all selected fruits and vegetables are shown in table 4.16 and figure 4.40.

Here, average copper concentrations were followed the order:

Seed vegetables > Fruity vegetables > Leafy vegetables > Fruits > Root and stem vegetables.

So, average concentration of copper is higher in seed vegetables (9.70 mg/kg) and lowers in root and stem vegetables (1.70 mg/kg).

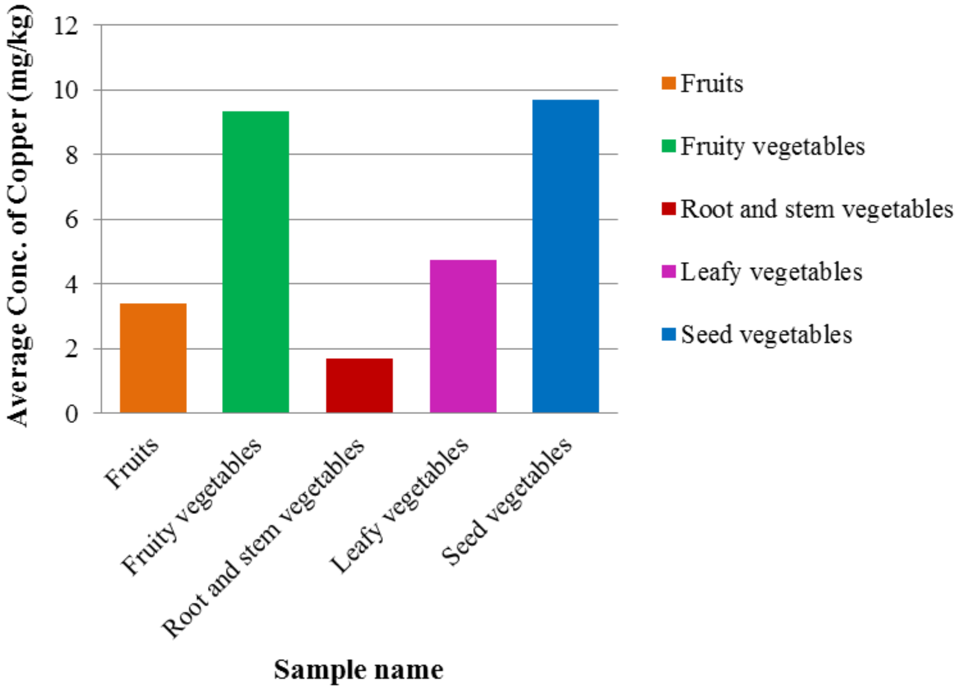

Figure 4.40: Average concentrations of copper in fruits and vegetables

4.2.10 Average zinc concentrations in fruits pulp and vegetables

Average concentrations of zinc in all selected fruits and vegetables are shown in table 4.16 and figure 4.41.

Here, average zinc concentrations were followed the order:

Fruity vegetables >seed vegetables> Leafy vegetables > Root and stem vegetables> Fruits.

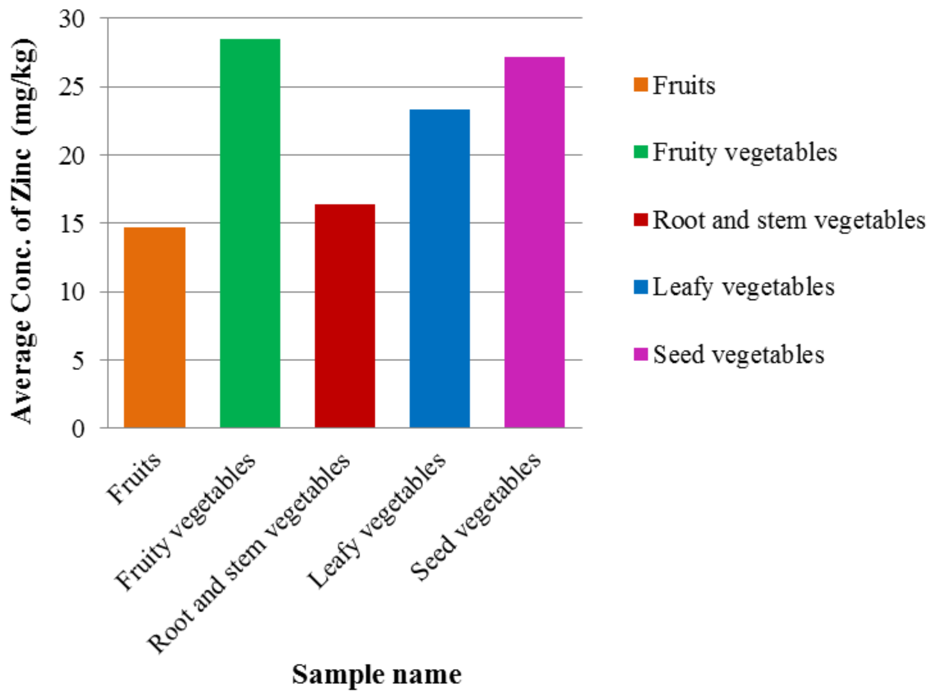

Figure 4.41: Average concentrations of zinc in fruits and vegetables

4.3.1 Transfer factor of metals from soil to crop (fruits and vegetables)

Metals transfer factor from soil to plants is a key module of human exposure to heavy metals via food chain. Transfer factor of metals is essential to investigate the human health risk index [101]. TF of metals varied significantly in different fruits and vegetables. Among fruits and vegetables, red amaranth leaf (0.0741), yard long bean (0.1378), red amaranth leaf (0.3212), ribbed gourd (0.9752), Okra (0.7411) showed a higher metal transfer factor from soil to plants than other fruits and vegetables for As, Mn, Fe, Cu and Zn respectively. Metals transfer factor in selected fruits and vegetables from the study area is summarized in table 4.17. TF for fruits and vegetables grown on study area ranges from 0.000–0.0741, 0.0001-0.3212, 0.0001-0.1151, 0.0008-0.5749, 0.0138-0.7411 for As^{3+}, Fe^{3+}, Mn^{2+}, Cu^{2+} and Zn^{2+} respectively.

Table 4.17: Transfer Factor (TF) of various fresh fruits and vegetables

Sample ID	Sample Name	TF of Arsenic	TF of Iron	TF of Manganese	TF of Copper	TF of Zinc
S-3	Green coconut water	0.0002	0.0001	0.0074	0.0008	0.0138
S-6	Himsagar mango	0.0141	0.0012	0.0017	0.0917	0.1429
S-9	Langra mango	0.0124	0.0013	0.0086	0.338	0.1672
S-11	Yard long bean	0.013	0.0541	0.1378	0.3305	0.6906
S-12	Okra	0.0166	0.062	0.054	0.3566	0.7411
S-14	Ribbed gourd	0.019	0.0562	0.0285	0.9752	0.6505
S-15	Plantain	0.0178	0.0168	0.055	0.1099	0.2496
S-16	Cucumber	0.032	0.0482	0.0376	0.3169	0.5797
S-26	Stem amaranth leaf	0.0148	0.042	0.0371	0.089	0.2983
S-27	Red amaranth leaf	0.0741	0.3212	0.1151	0.2026	0.5096
S-28	Indian spinach	0.0061	0.0856	0.0838	0.2963	0.3413
S-29	Eggplant	0.0087	0.0367	0.0346	0.5749	0.3686
S-30	Pumpkin	0.00	0.0352	0.0111	0.0995	0.2552
S-32	Jackfruit	0.004	0.0011	0.0001	0.6682	0.3946
Maximum		0.0741	0.3212	0.1378	0.9752	0.7411
Minimum		0.00	0.0001	0.0001	0.0008	0.0138
Average		0.0166	0.0544	0.0437	0.3179	0.3859

4.3.2 Daily intake (DI) and health risk index (HRI) of arsenic and other metals in fruits and vegetables

Heavy metals accumulation effect on human body depends on daily intake of metal through contaminated water and food, body weight and health risk factor which was calculated from heavy metals response factor for human body. The study team was collected data on daily intake of food & water, age, body weight from 40 peoples who are living more than five years at this study area. Average values of age, body weight and daily intake of water, rice, vegetables and fruits are 28.48 years, 46.60Kg, 2.80L, 0.39kg, 0.12kg and 0.14kg respectively. In this study area average daily intake of vegetables was 0.140Kg which quantity is lower than WHO food intake standard 0.30Kg [92]. Table-4.17 and figure-4.42 to 4.46 are showing the daily intake of arsenic, iron, manganese, copper and zinc per person per Kg of body weight which was calculated from the equation [87]. Daily intake of arsenic from water, rice, vegetables and fruits are 0.02mg, 2.60×10^{-4} mg, 4.71×10^{-5} mg and 3.5×10^{-5} mg per Kg of each person body weight respectively. Daily intake of arsenic, iron, manganese, copper and zinc are 0.0160±0.0000, 0.5282±0.0276, 0.0236±0.0019, 0.0011±0.0007 and 0.0042±0.0018 mg per Kg of each person body weight respectively which was consumed through water and food (rice, vegetables and fruits). Health risk index of arsenic, iron, manganese copper and zinc are 0.2665±0.0005, 0.7288±0.0394, 1.5852±0.1354, 0.0212±0.0181 and 0.0082±0.0060 mg per Kg of each person body weight respectively which was calculated from equation [89]. According to health risk index data the order are Fe>Mn>As>Zn>Cu. In this analysis the total DI and HRI of heavy metals (arsenic, iron, manganese, copper and zinc) in all selected fruits and vegetables are followed the order: Leafy vegetables> fruity vegetables>stem& root vegetables>fruits>seed vegetables. This study is showed that daily intake of metals and health risk index value in all of vegetables, rice and fruits are safe for health. Because these values are lower than WHO recommended oral dose (R_{fd}) concentration.

Table 4.18: Average daily intake of metals from food and water

Category of sample	Average DI of arsenic from food and water (mg/person/day)	Average DI of Iron from food and water (mg/person/day)	Average DI of Manganese from food and water (mg/person/day)	Average DI of Copper from food and water (mg/person/day)	Average DI of Zinc from food and water (mg/person/day)	Total DI of heavy metals from food & water
Fruits	0.01593	0.51410	0.02212	0.00124	0.00414	0.55753
Fruity vegetables	0.01593	0.52202	0.02416	0.00226	0.00677	0.57115
Stem and root vegetables	0.01596	0.51779	0.02292	0.00028	0.00269	0.55963
Leafy vegetables	0.01600	0.57687	0.02667	0.00106	0.00503	0.62563
Seed vegetables	0.01599	0.51014	0.02219	0.00085	0.00246	0.55163
Maximum	0.01600	0.57687	0.02667	0.00226	0.00677	0.62563
Minimum	0.01593	0.51014	0.02212	0.00028	0.00246	0.55163
Average	0.01596	0.52819	0.02361	0.00114	0.00422	0.57311
Total DI	0.07981	2.64093	0.11806	0.00569	0.02109	2.86557

DI = Daily intake

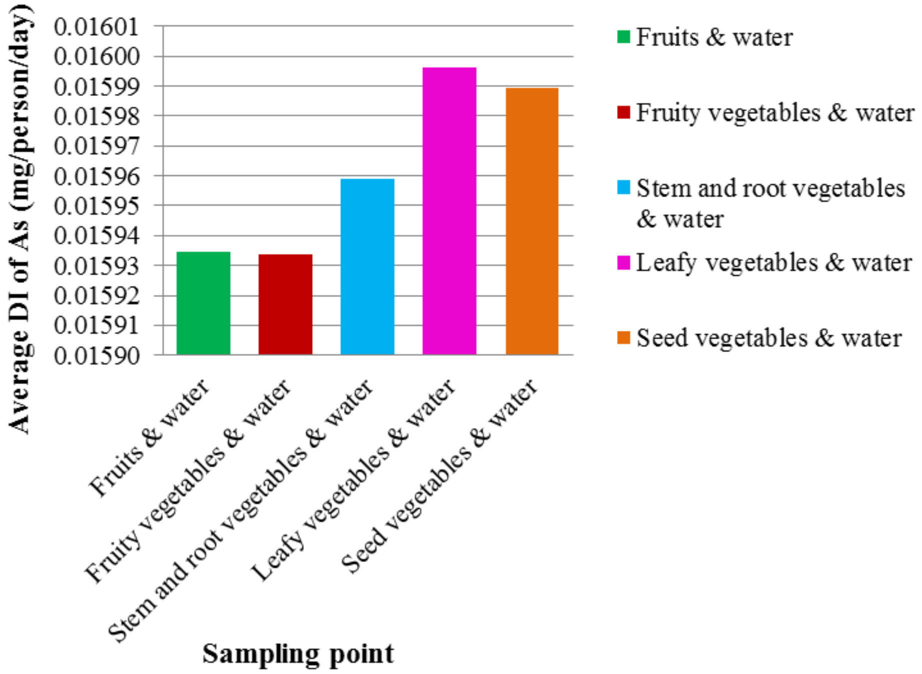

Figure 4.42: Average daily intake of arsenic from food (fruits and vegetables) & water

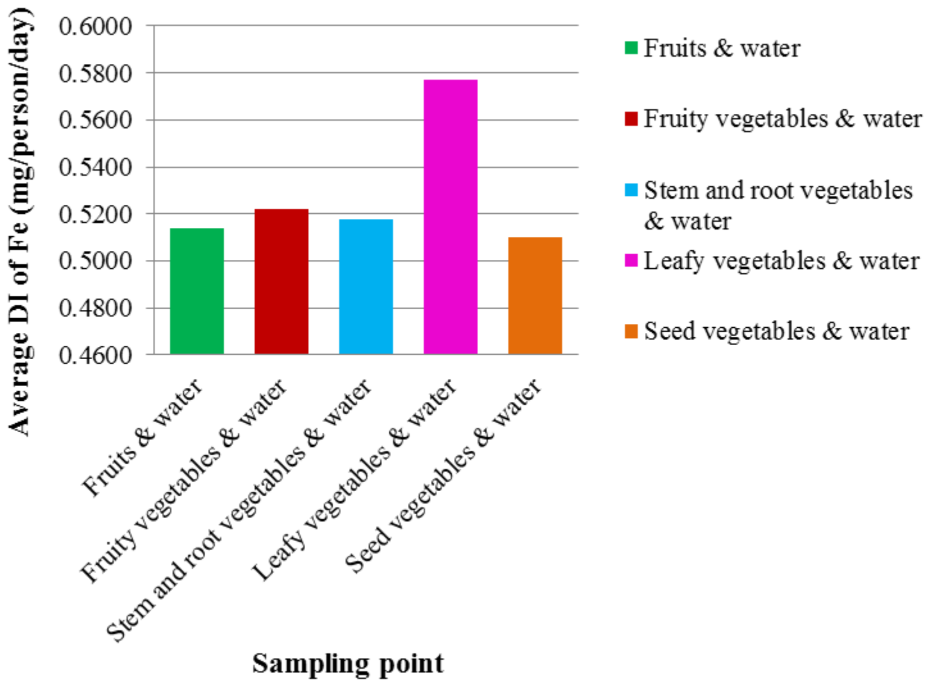

Figure 4.43: Average daily intake of iron from food (fruits and vegetables) & water

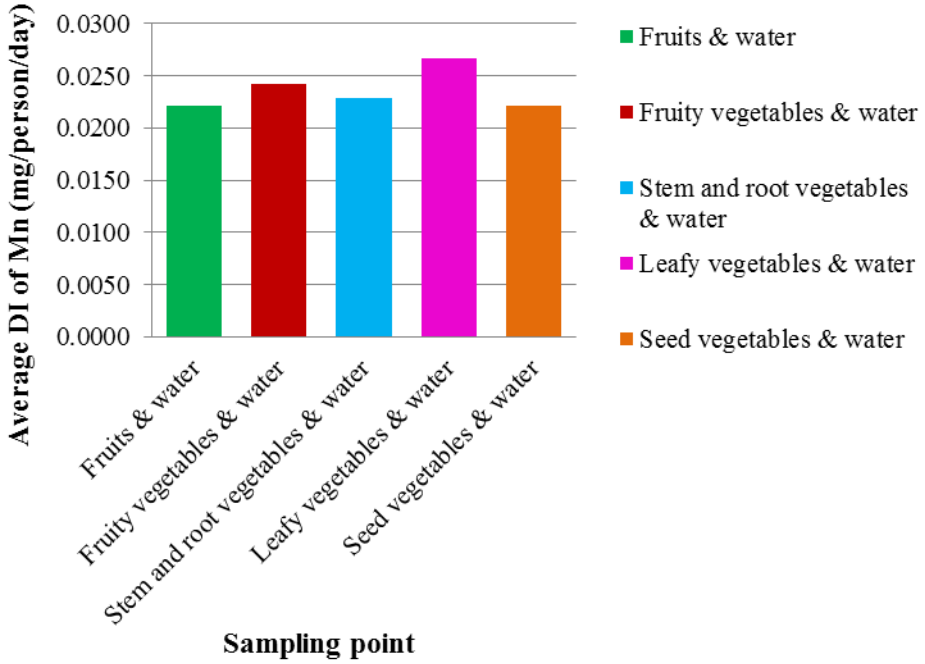

Figure 4.44: Average daily intake of manganese from food (fruits and vegetables) & water

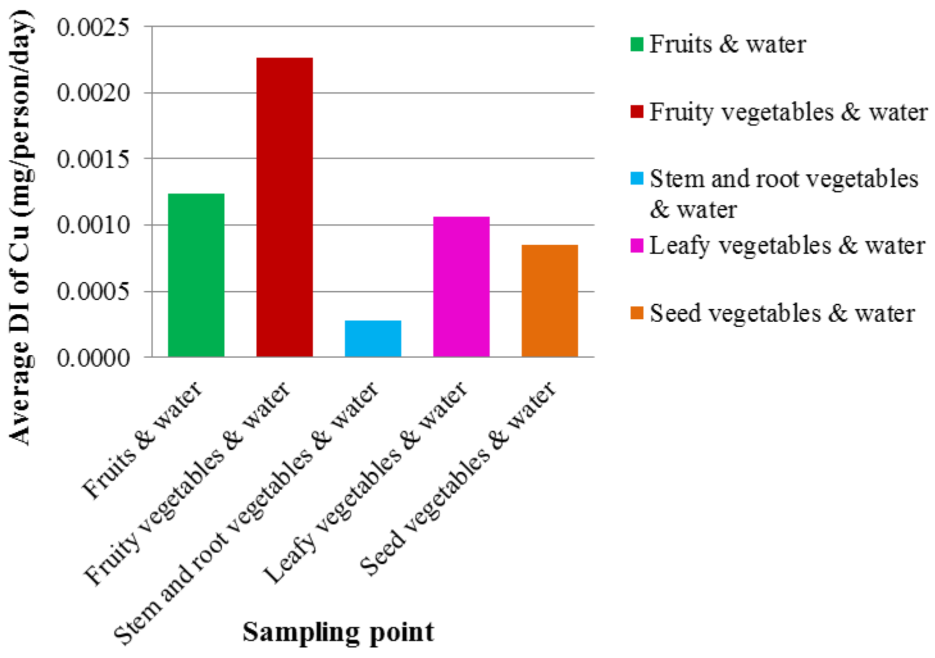

Figure 4.45: Average daily intake of copper from food (fruits and vegetables) & water

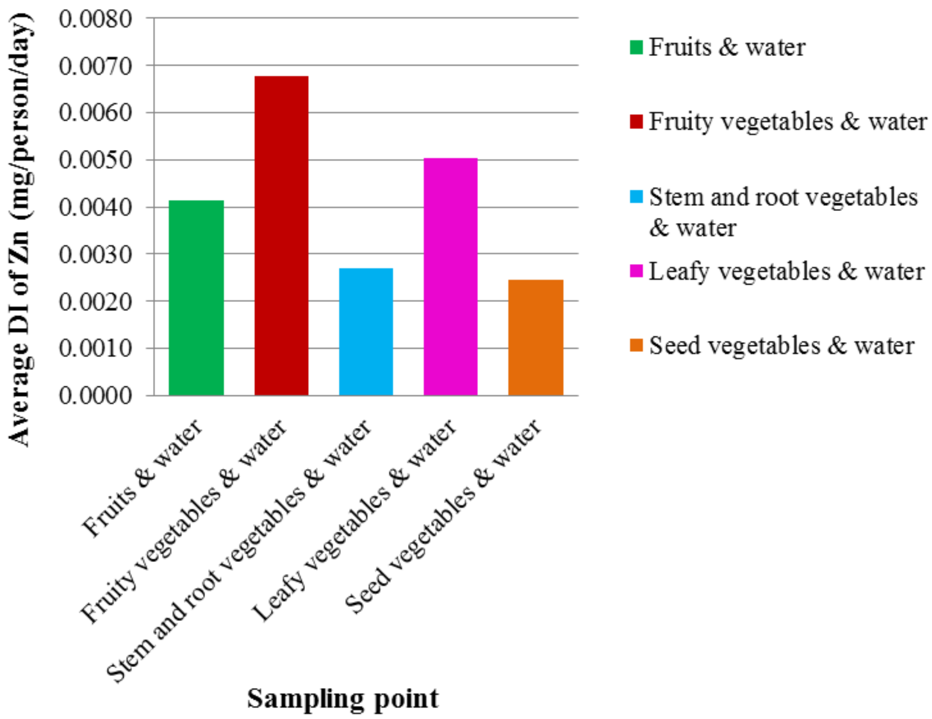

Figure 4.46: Average daily intake of zinc from food (fruits and vegetables) & water

Table 4.19: Average health risk index of metals from food and water

Category of sample	Average HRI of arsenic from food and water (mg/kg/person/day)	Average HRI of Iron from food and water (mg/kg/person/day)	Average HRI of Manganese from food and water (mg/kg/person/day)	Average HRI of Copper from food and water (mg/kg/person/day)	Average HRI of Zinc from food and water (mg/kg/person/day)	Total HRI of heavy metals from food & water
Fruits	0.26563	0.73443	1.58019	0.03093	0.01379	2.62497
Fruity vegetables	0.26561	0.74576	1.72574	0.05659	0.02256	2.81625
Stem and root vegetables	0.26604	0.73970	1.63700	0.00698	0.00897	2.65869
Leafy vegetables	0.26665	0.82411	1.90511	0.02648	0.01677	3.03912
Seed vegetables	0.26654	0.72878	1.58520	0.02115	0.00819	2.60987
Maximum	0.26665	0.82411	1.90511	0.05659	0.02256	3.03912
Minimum	0.26561	0.72878	1.58019	0.00698	0.00819	2.60987
Average	0.26654	0.72878	1.58520	0.02115	0.00819	2.60987
Total HRI	1.33047	3.77278	8.43324	0.14213	0.07029	13.74890

HRI = Health risk index

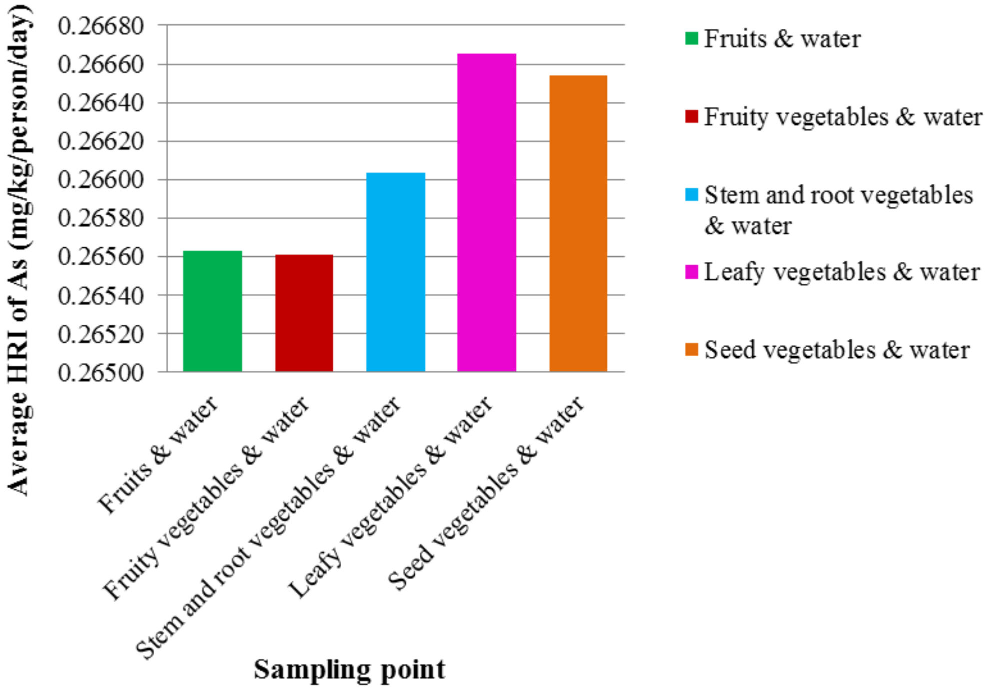

Figure 4.47: Average health risk index of arsenic from food (fruits and vegetables) & water

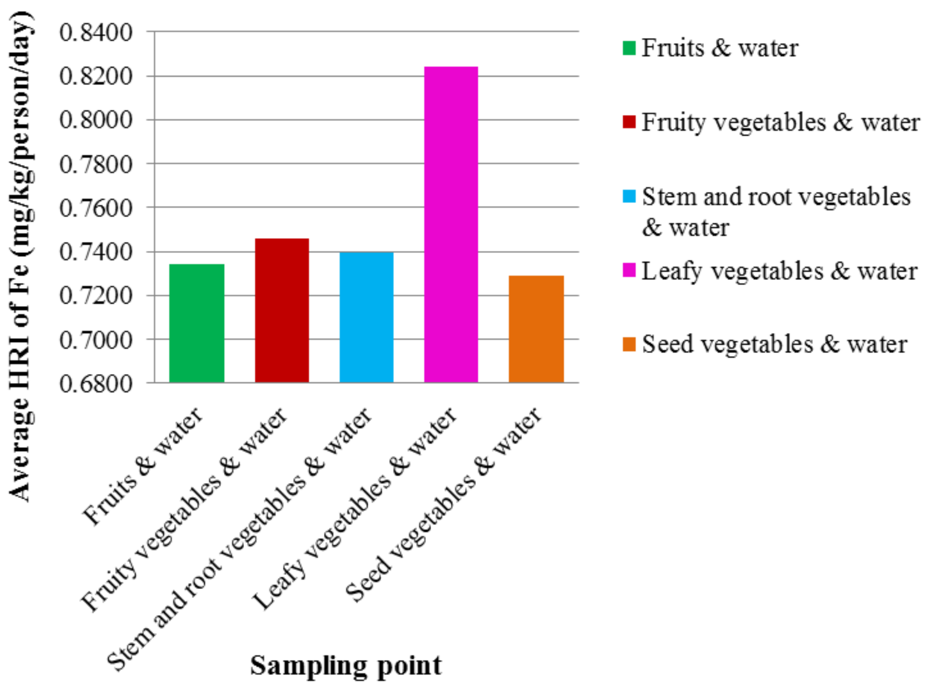

Figure 4.48: Average health risk index of iron from food (fruits and vegetables) & water

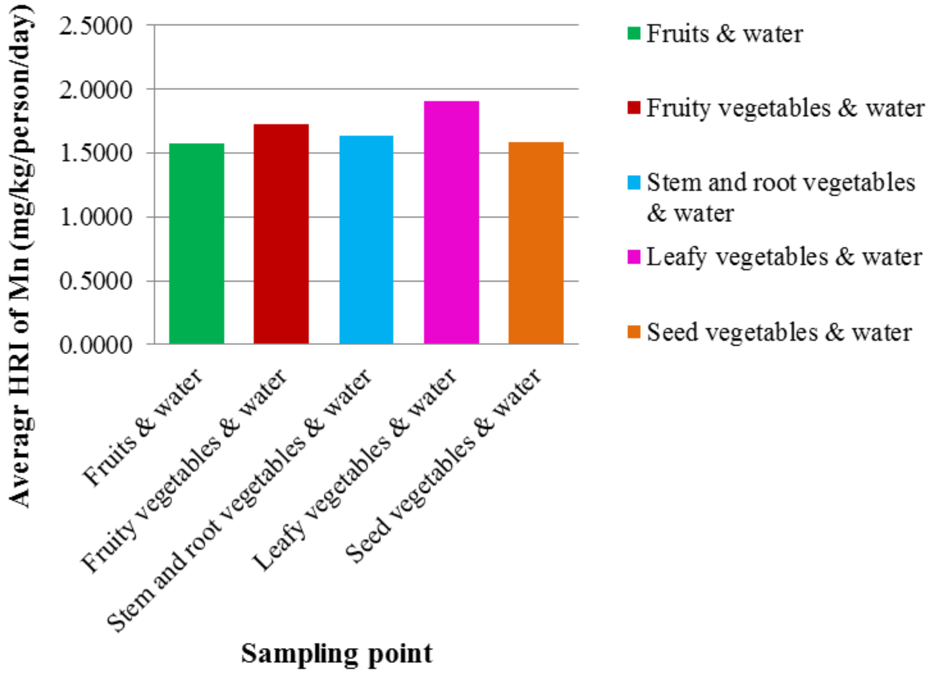

Figure 4.49: Average health risk index of manganese from food (fruits and vegetables) & water

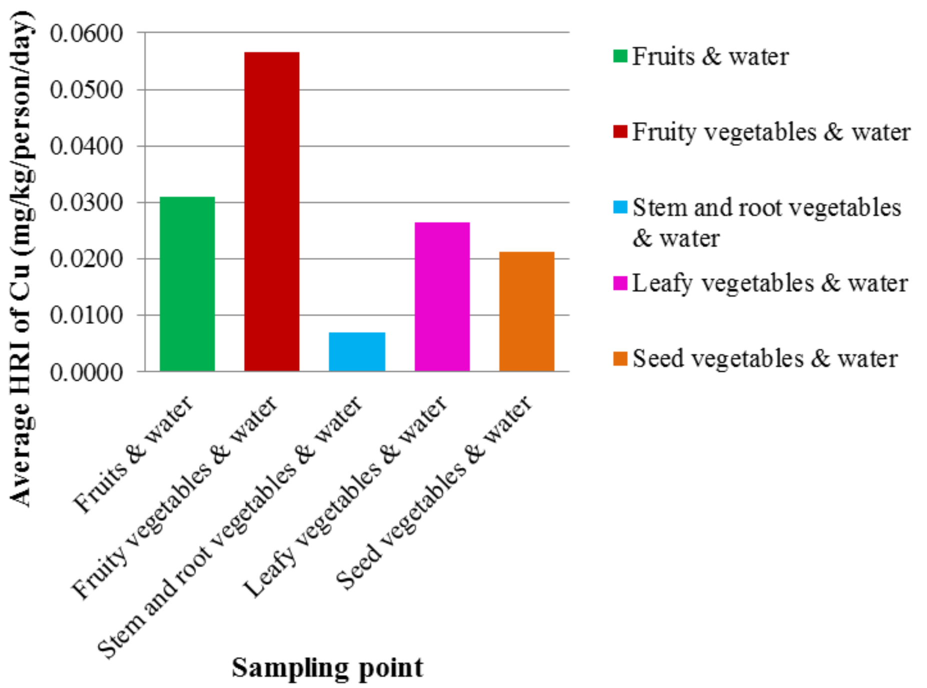

Figure 4.50: Average health risk index of copper from food (fruits and vegetables) & water

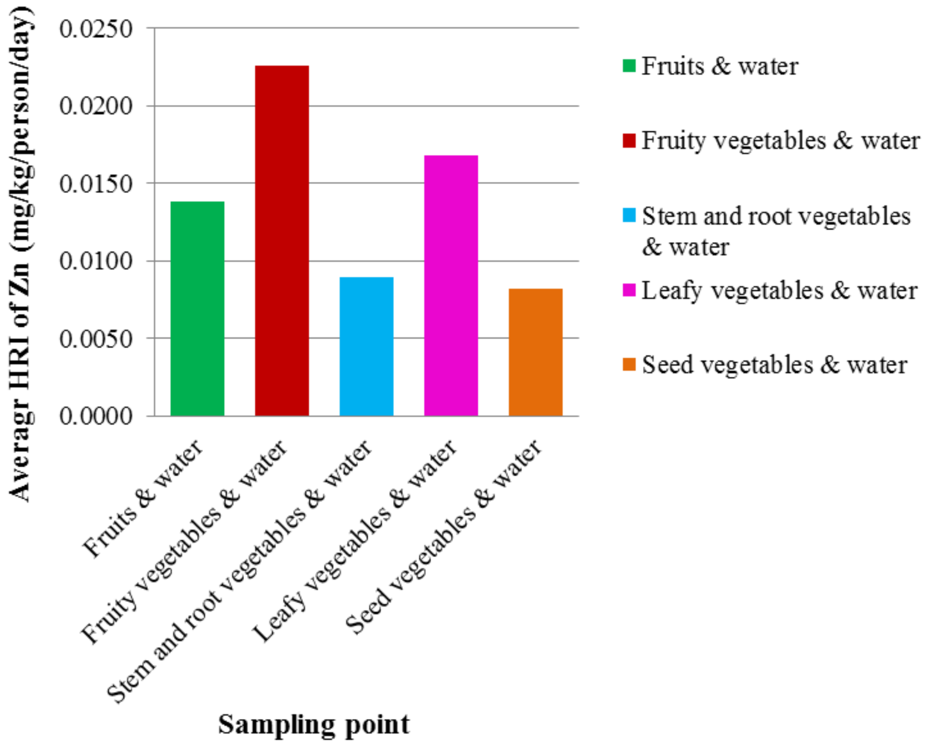

Figure 4.51: Average health risk index of zinc from food (fruits and vegetables) & water

4.4 Irrigation water-soil-crop relationship with respect to arsenic contamination

Figure 4.52 and table 4.20 show the relationship between the arsenic concentrations in surface soils and irrigation water samples in Harischandrapur village. The arsenic concentrations ranged from 5.01 to 11.47 mg/kg in surface soil, and from 0.017 to 0.340 mg/L in irrigation water.

According to figure-4.52, the arsenic concentration of surface soil tended to increase with increased arsenic concentration of the irrigation water in general in crop fields. This finding shows that arsenic concentration of the surface soils in crop fields is positively affected by the arsenic concentration of irrigation water.

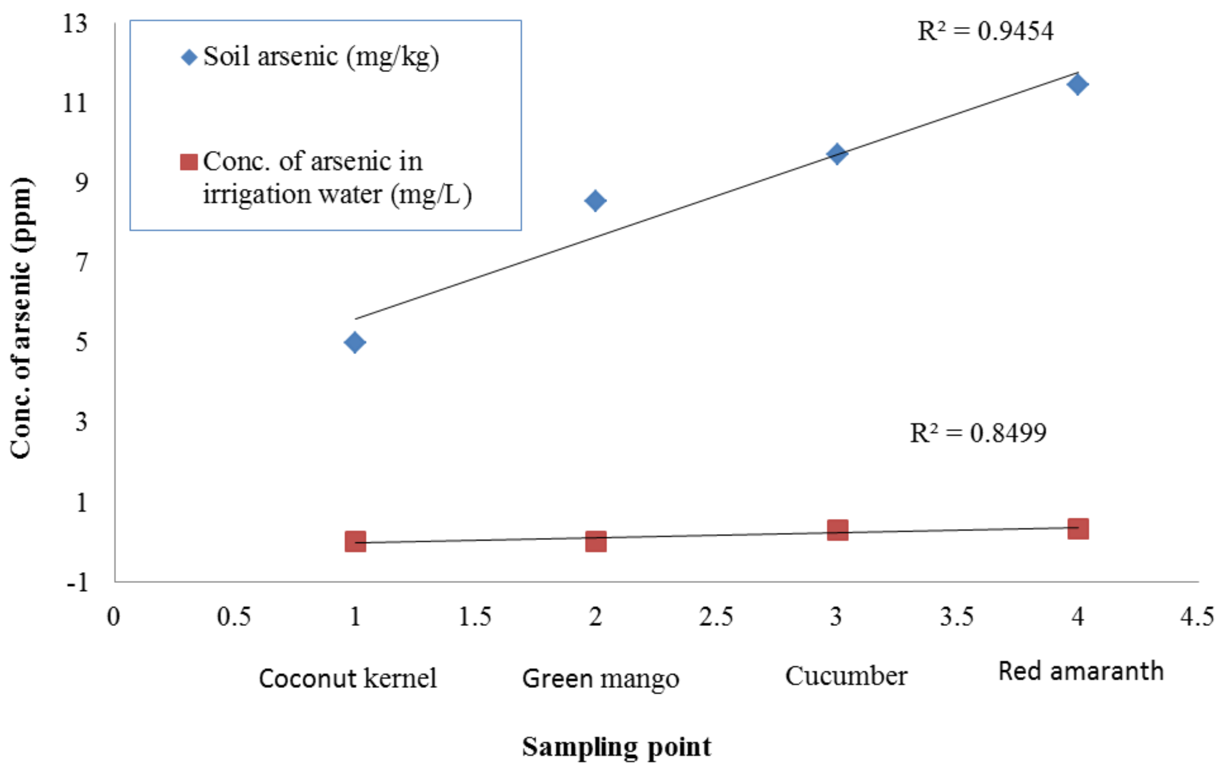

Figure 4.52: Relationship between arsenic concentrations in irrigation water samples and surface soil samples at crops field in the Harischandrapur village

Figure 4.55 and table 4.20 show the positive correlations between the arsenic concentrations in crops (coconut kernel, mango, cucumber and red amaranth) and surface soils which were collected from crop field's area in Harischandrapur village. Here, the arsenic concentrations ranged from 5.01 to 11.47 mg/kg in surface soil, and from 0.06 to 0.85 mg/kg in crops (fruits and vegetables).

According to figure-4.52, the arsenic concentration of fruits and vegetables tended to increase with increased arsenic concentration of the surface soils in crop's field. This finding shows that arsenic concentration of the crops is positively affected by the arsenic concentration of surface soil in crop's field.

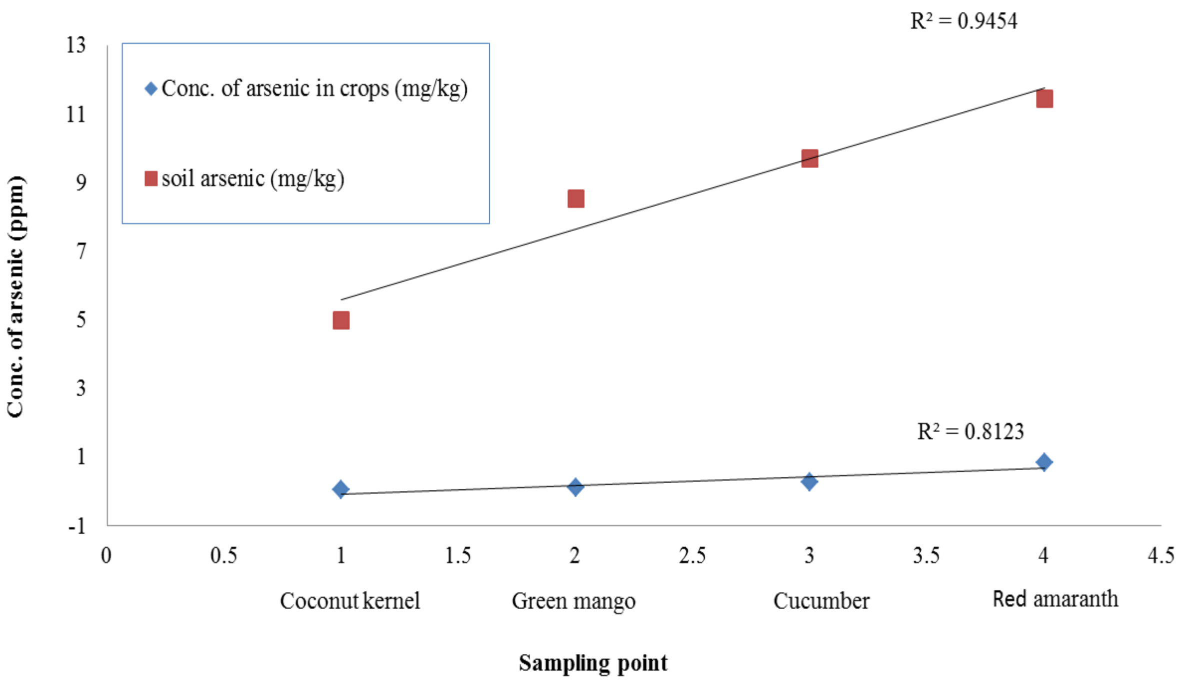

Figure 4.53: Relationship between arsenic concentrations in crops (fruits and vegetables) and surface soil samples in the Harischandrapur village

Table 4.20: Irrigation water-soil-crop relationship with respect to arsenic contamination

Sample Name	Conc. of arsenic in crop (mg/kg)	Soil arsenic (mg/kg)	Conc. of arsenic in irrigation water (mg/L)
Coconut kernel	0.06	5.01	0.017
Green mango	0.12	8.54	0.035
Cucumber	0.27	9.71	0.318
Red amaranth	0.85	11.47	0.340

4.5 Comparison of arsenic concentration in fruits between Harischandrapur and Samta village

The concentration of arsenic in fruits between Harischandrapur and Samta village is shown in table 4.21. From this table it is found that, the concentration of arsenic in mango, sapodilla, papaya, jackfruit and coconut kernel is lower at Hahischandrapur village than samta village. On the other hand, this concentration in pummel, guava and lime is higher at Harischandrapur village than Samta village. These variations may occur due to the transfer factor of arsenic from soil to fruits.

Table 4.21: Comparison of arsenic concentration in fruits between Harischandrapur and Samta village, Sharsha upazila, Jessore district [102]

Fruits Name	Conc. of Arsenic (mg/kg) in Harischandrapur Village	Conc. of Arsenic (mg/kg) in Samta Village
Mango	0.12	0.40
Pummelo	0.20	0.15
Guava	0.24	0.10
Sapodilla	0.16	0.21
Lime	0.21	0.12
Papaya	0.24	0.53
Jackfruit	0.02	0.18
Coconut	0.06	0.10

4.6 Discussion

Metals accumulation tendency in food (fruits and vegetables) depends on metals transfer factor from soil to crops. In this research, arsenic accumulation tendency is higher in red amaranth than other vegetables and fruits due to higher transfer factor of arsenic from soil to red amaranth. On the other hand this accumulation tendency is lower in pumpkin than detection limit due to lower transfer factor of arsenic from soil to crop. So in order to minimize metal accumulation tendency in fruits and vegetables, application of metal contaminated irrigation water in crops field should be avoided.

Metals contaminated drinking water is not the only source of metals accumulation in human body. Human being can also uptake metals from contaminated rice, fruits, vegetables, milk and meet hence plant–human'' and ''plant–animal–human'' could be other potential food chain pathways of metal's accumulation in human body (figure 4.52). This study also wants to point out that the people who live in arsenic and other metals contaminated regions are not only at risk but also other people (who live in non-contaminated zones) are in danger as they are also consuming metals contaminated food stuffs.

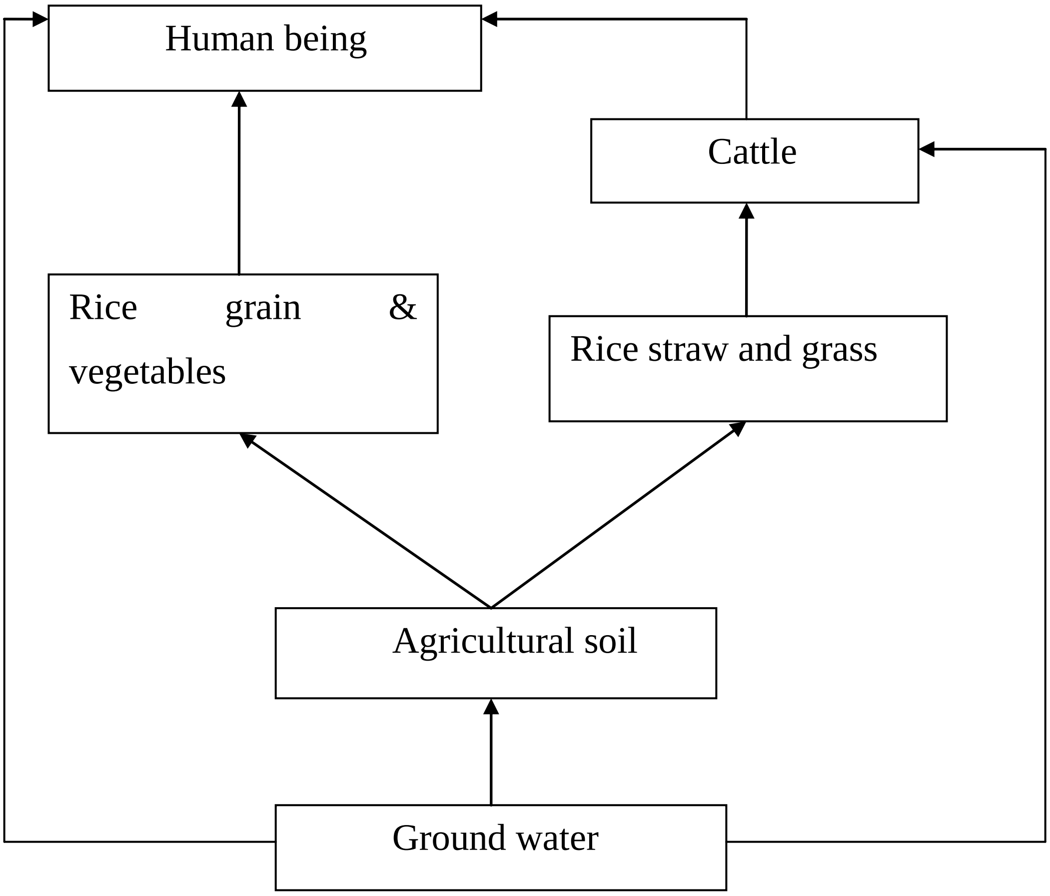

Figure 4.54: Possible routes of metals exposure to human- being in Bangladesh

CHAPTER V

Conclusions and Recommendations

Fruits and vegetables are excellent source of human diet for vitamins and minerals. Contaminated irrigation water and soil can transfer arsenic, lead, iron, manganese, copper and zinc from soil to fruits and vegetables through irrigation water. It is observed that heavy metals level in different fruits and vegetables varies significantly. Arsenic, lead and other heavy metals (manganese, copper and zinc) not only can contaminate water but also intoxicate soil, food grains and fruits. These are also consequently endangering human and animal health by various routes of ingestion. Some amount of arsenic, iron, manganese, copper and zinc are found in soil, fruits and vegetables sample. The concentration of lead is not found in the soil, water, fruits and vegetables. But the amount of arsenic is found higher in water samples of Harischandrapur village in the study area in this research. From this analysis, the obtained results can be summarized as:

i. New informations about arsenic (As) and heavy metals (Pb, Fe, Mn, Cu and Zn) concentrations in crops and vegetables are found out.
ii. The concentration of arsenic in all studied fruit samples ranges from 0.12±0.00 to 0.24±0.02 mg/Kg.
iii. Among the collected vegetables, Red amaranth contains 0.85±0.05 mg/Kg of arsenic that is higher than that of other vegetables, but lower than WHO food standard (1.00 mg/kg).
iv. Among leafy vegetables, iron concentration in Red amaranth (534.51±2.50 mg/kg) is higher than WHO food standard (425 mg/kg).
v. On the other hand, copper and zinc concentration is higher in fruity vegetables, which range from 1.41±0.00 to 29.54±0.45 mg/kg and 13.85±0.13 to 50.19±2.01 mg/kg respectively. Copper and zinc accumulation in ribbed gourd and okra is higher than European Union food standard.

vi. Among all water samples, the shallow tube well's water (202ft and 120ft) contain higher amount of arsenic (0.3396±0.001 mg/L and 0.3177±0.001 mg/L) respectively which is higher than drinking and irrigation water standard.

vii. The concentration of arsenic in soil samples ranges from 5.00-12.0 mg/Kg in the study area.

The results of this study indicate that these amounts of arsenic may be hazardous if highly metal contaminated fruits and vegetables are taken in large quantities. It is therefore suggested that the use of contaminated fruits and vegetables in large quantities must be strictly prohibited in order to prevent excessive build-up of these metals in the human food chain. Considering its hazardous aspects, the use of contaminated fruits and vegetables must be strongly monitored and controlled. Further studies are needed in order to assess more closely the heavy metals intake as well as to identify sources of heavy metal intake in those populations.

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