Heavy Metal Contamination in Vegetables from Industrial Waste Water Polluted Soils

Hammadullah Al Mashuk[1]

Abstract

It has been summarized from the findings of the numerous articles that vegetables seed germination directly affected by toxicity of industrial effluent. But the toxicity effect of effluent could be varied from one effluent to another effluent. The different heavy metal (Pb, Cd, Ni, Co and Cr) concentrations in vegetables increased with increasing the age of the plant while the increasing trend was not linear. Heavy metal content gradually increased in vegetables at the early growing stage and declined at the matured stages of growth. The significant differences ($P < 0.01$) were observed between the mean heavy metal concentrations and the tested vegetables species. The Pb and Co concentrations in amaranth were found higher as compared to spinach and red amaranth. Spinach showed higher levels of Cd and Cr than those of other leafy vegetables. For all the leafy vegetables, the degree of heavy metal contamination was followed the order as Cd<Co<Pb<Ni<Cr. On the other hand, the contamination was varied from one heavy metal to another heavy metal in different vegetables other than leafy vegetables. The Pb contamination intensity order: eggplant>tomato>bottle gourd>pumpkin>cauliflower>cabbage. While Cd contamination order: tomato> eggplant>bottle gourd>pumpkin>cabbage>cauliflower and nickel (Ni) contamination trend was bottle gourd>cauliflower>cabbage> pumpkin>tomato>eggplant. Untreated industrial irrigation water is the primary source of metal accumulation in food crops, which might be provided the food crop contamination and future health risk.

Keywords: Heavy metal, vegetables, contamination and health risk

[1]Hammadullah Al Mashuk, MS Student, Department of Soil Science, BSMRAU, Gazipur

Contents

List of Tables

List of Figures

Chapter 1
Introduction

At present, the environmental pollution through industrialization is a serious problem throughout the world. Soil and environment are under tremendous pressure due to industrial expansion during last few decades. Thus, soil and water pollution are becoming a major concern all over the world. In Bangladesh, rapid and unplanned urbanization, industrialization and their untreated wastes water are creating pollution.

The discharged untreated effluents into the natural ecosystems causing environmental pollution especially with heavy metals and organic pollutants. The identified heavy metals in different industrial sources of Bangladesh are cadmium (Cd), lead (Pb), chromium (Cr), mercury (Hg), zinc (Zn), arsenic (As) and in few cases copper (Cu) and manganese (Mn) (Islam et al. 2015). Irrigation water crisis increasing day by day. Hence, people are using wastewater as irrigation water. Long-term use of industrial or municipal wastewater as irrigation water may be significantly contributed to build up heavy metal in surface soil (Zebunnesa et al. 2009). Excessive accumulation of trace elements in agricultural soils through wastewater irrigation may not only result in soil contamination but also affect food quality and safety (Islam et al. 2017).

The uptake of heavy metals by plants from contaminated soils is of great concern because an excess of dietary intake of some of these heavy metals might be hazardous for any living being including human. The application of wastes water for the crop production has been practiced in Bangladesh **(Fig. 1).** The accumulation of heavy metals in soils treated with raw municipal and industrial waste water or the sludge with the contaminated waste water is now widely practiced for crop production in our country. As a consequence, a great environmental pollution arises. Thus, the heavy metals are widely build up in the environment, which may create toxicity and cancer for any living being.

Fig. 1. Irrigation performing using contaminated water

Heavy metal pollution of agricultural soil and vegetables has been considered as one of the most severe ecological problems on a world scale and also in Bangladesh. The food chain contamination is the major pathway of heavy metal exposure for humans (Khan *et al*., 2008). Some trace elements or heavy metals are essential for plant nutrition but plants growing adjacent to the zone of industrial areas display increased concentration of heavy metals, serving in many cases as bio-monitors of pollution loads (Mingorance *et al*., 2007). Vegetables cultivated in industrial polluted soils or used contaminated waste water as irrigation water might be taken up heavy metals and accumulated them in food chain. Which quantities high enough to cause cancer both to animals and human beings consuming these metal contaminated foods because there is no good mechanism for their elimination from the physiological system of human body (Arora *et al.*, 2008; Alam *et al*., 2003). In the low concentrations, many metals are essential to life but in excess, the same chemicals can be poisonous. Therefore, a better understanding of heavy metal sources, their accumulation in the soil and the effect of their presence in soil and on plant systems seem to be particularly important issues of present day research on risk assessment. Information regarding the accumulation of essential and non-essential heavy metals in vegetables in industrially polluted areas in Bangladesh is scarce. Knowledge on the contamination of vegetables with heavy metals from the vicinity of the industrial areas is of interest for the seminar paper. Considering the above findings, the present review study was undertaken to achieve the following objectives:

(i) to evaluate the contaminated industrial effluent toxicity on vegetable seed germination.
(ii) to know the heavy metal accumulation pattern in vegetables; and
(iii) to identify the heavy metal content in vegetables grown in industrial polluted area soils.
(iv) to identify the health risk of heavy metal in vegetables.

Chapter 2
Materials and Methods

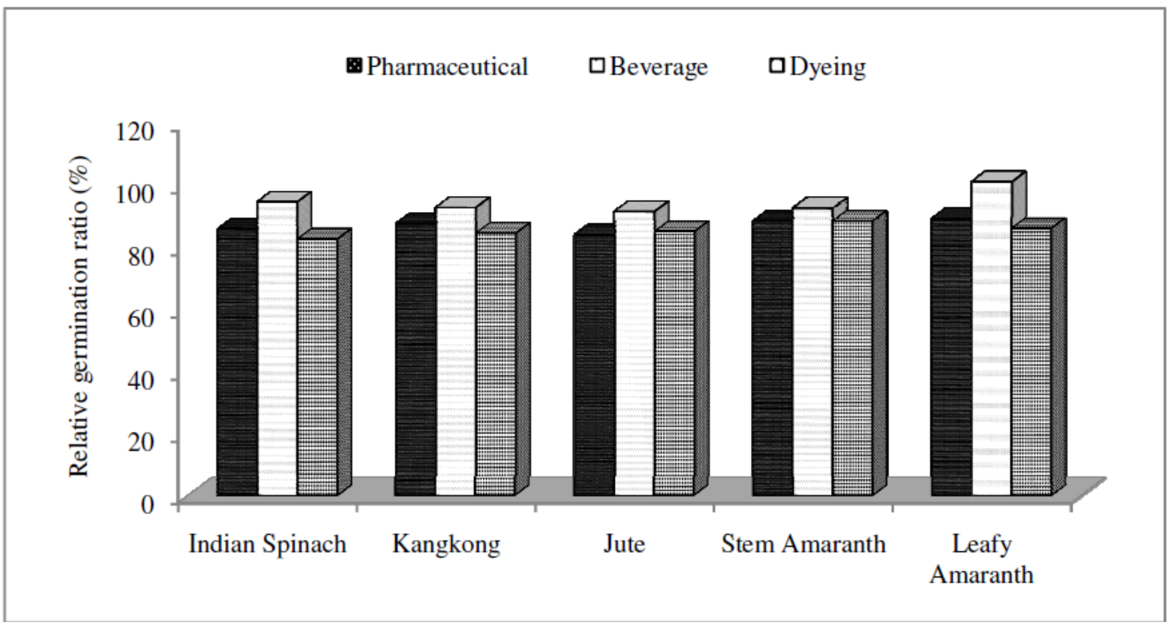
This is absolute a review article, therefore all of the information has been collected as secondary data. The various related books and journal papers have been studied thoroughly for preparing this paper. The related topics have searched and reviewed with the help of library facilities of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU) and also from internet browsing. After collection all the related information then the seminar paper has been prepared and described the secondary data systematically and chronologically based on the objectives of this paper.

Chapter 3

Review of the findings

3.1 Toxicity of industrial effluent on seed germination of different vegetables

Fig. 2 showed the toxicity of different industrial effluent on seed germination of different vegetables. It was found that the effluent of dyeing industry showed more toxic effect on seed germination of tested all four vegetables followed by pharmaceutical and beverage. The lowest relative germination ratio (RGR%) of 83, 85, 85, 88 and 86% was recorded in dyeing treated petri dish for Indian spinach, kangkong, jute, stem amaranth and Leafy amaranth respectively. While the higher RGR of 95, 93, 92, 93 and 101% were recorded in beverage treated petri dish for all vegetables. These findings indicated that dyeing effluent showed more toxic against the seed germination of vegetables.



Source: Islam et al. 2015

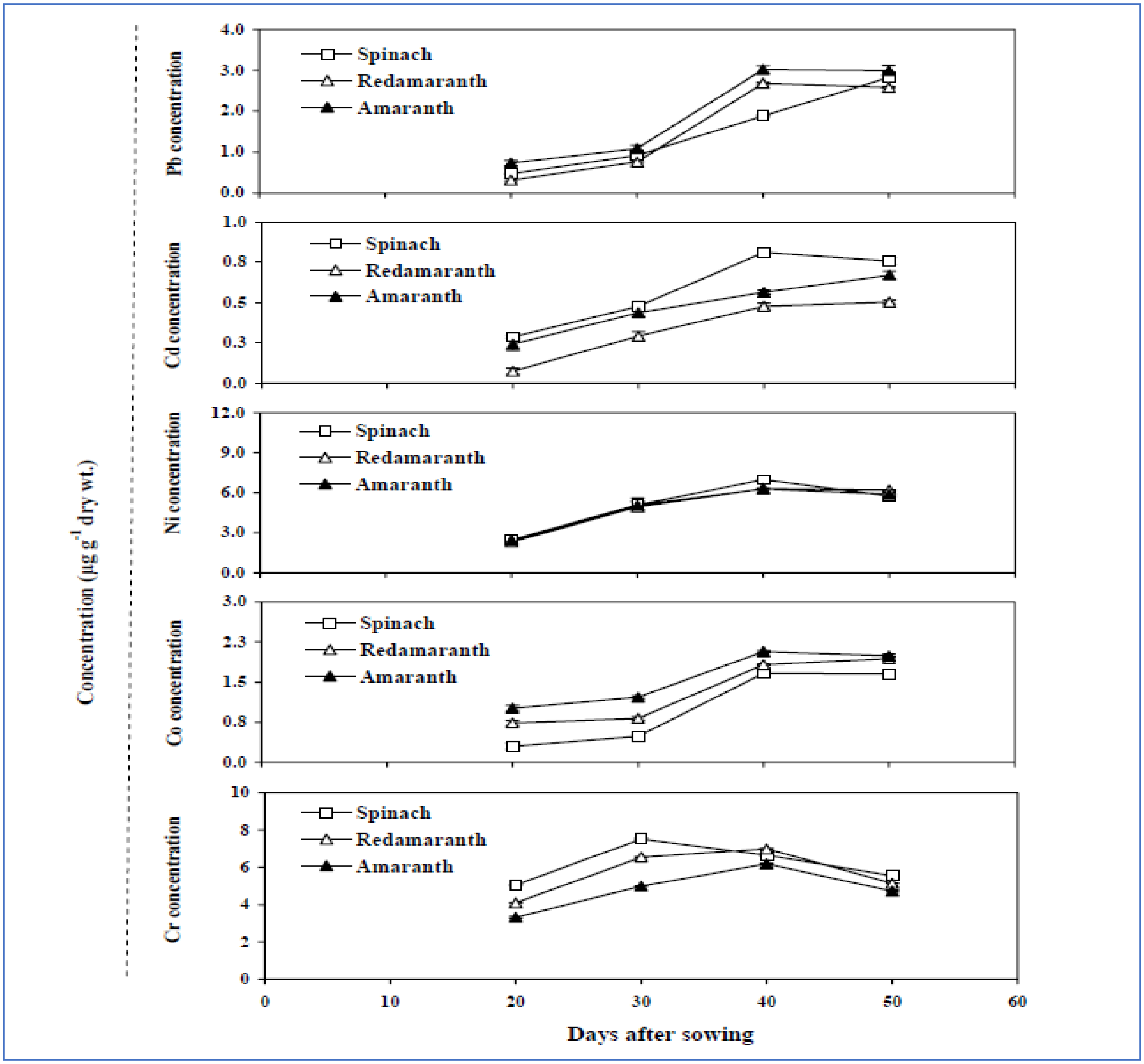
Fig. 2. Effects of effluents on Relative Germination Ratio (%) of different vegetables

3.2 Heavy metal accumulation pattern in vegetables from industrial contaminated soil

Naser et al. 2011 conducted a study in highly industrial polluted soils using three popular leafy vegetables like spinach (*Spinacia oleracea*), red amaranth (*Amaranthus tricolor*) and amaranth (*Amaranthus oleraseus*). The concentrations of heavy metals like Pb, Cd, Ni and Cr in initial soil were 4.04, 0.69, 14.4,11.9, and 21.9 µg g-1 respectively in dry weight basis in the experimental soils. The heavy metal content in initial soil was quite high due to highly industrial polluted soils collected from Kodda, Gazipur.

They found that the concentrations of Pb, Cd, Ni, Co, and Cr in vegetables increased with the age of the plant up to 40 DAS with the exception of Cr but the increasing trend found not linear. The uptake pattern was different for different heavy metal **(Fig. 3)**. Chromium concentrations in spinach increased up to 30 DAS and then concentration decreased up to the final harvest at 50 DAS. The concentrations of heavy metal in vegetable at the third harvested (40 DAS) were higher than those of others with the exception of Pb concentration in spinach and Cd in amaranth. Similar trend was observed only Ni concentration in three vegetable species. Higher amount of Cd was detected in spinach while it was very low in red amaranth. On the other hand, Pb concentration was detected higher in amaranth whereas Cd concentration was higher in spinach. The similar trend was observed for cobalt concentration like Pb in three vegetables. The rate of increasing or slope of metal concentrations was found different at different growth stages. The heavy metal increasing rate at 20 DAS to 30 DAS was lower as compared to increasing rate at 30 DAS to 40 DAS, except Cr. The increasing range of Cd concentration concentrations were 66–182%, 286–534%, 81–132% in spinach, red amaranth and amaranth respectively for the same number of days as Pb. Similarly, Ni, Co, and Cr concentrations in the three vegetables showed increasing trend (in percentage) of metal content, with the exception of Cr concentration in spinach.

It was recorded from this study that heavy metal content gradually increased at the early growing stages of leafy vegetables but declined during the later stages of growth. The results of this study are revealed in good agreement with the result obtained by Oliveira et al. (1994); and Lutts et al. (2004). Mensah et al. (2008) reported that the Pb concentrations in lettuce increased consistently during the period of growth with time. However, the heavy metal concentration in plant can be varied depending on the magnitude of time based on the findings of this study.



Source: Naser et al. 2011

Fig. 3. Heavy metal concentration in plant at different growth stages of vegetables

3.3 Comparison the heavy metal content in different vegetables from contaminated and uncontaminated soil

Tasrina et al. (2015) conducted a study adjacent to the nuclear plant at Chor Rooppur soil using different vegetables. It was found red amaranth and amaranth were taken higher amount of heavy metal as compared to other vegetables like carrot, spinach and potato **(Fig. 4).**

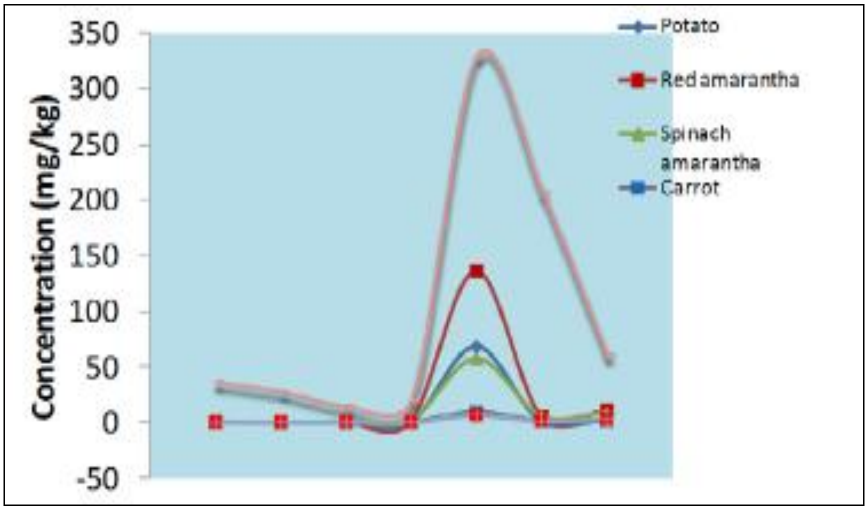
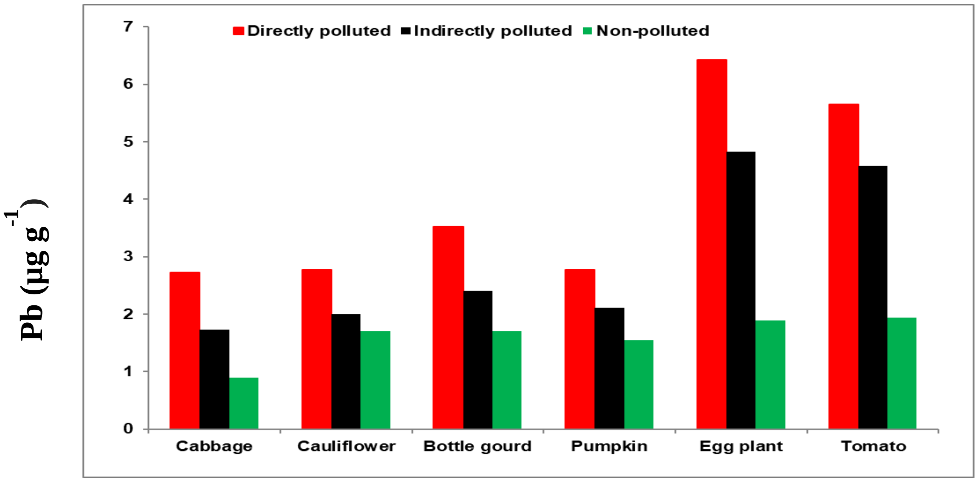


Fig. 4. Comparison of heavy metals content in vegetables during their growing periods

(Source: Tasrina et al., 2015)

Lead (Pb) content status in vegetables

There were significant differences in the Pb, Cd, and Ni concentrations (µg g^{-1} dry weight basis) of different vegetable species (cabbage, cauliflower, bottle gourd, pumpkin, eggplant and tomato) in different locations of contaminated and uncontaminated soils **(Figs. 5, 6 and 7).** Lead (Pb) content (dry weight basis) was found to be the highest in eggplant with a range of 1.89 to 6.42 µg g^{-1} followed by tomato with a range of 1.94 to 5.65 µg g^{-1}. Thus, the safe limit of Pb was over in eggplant and tomato based on FAO/WHO standard. All vegetables were highly contaminated by directly polluted soils followed by indirectly and non-polluted soils. The extend of Pb concentration can be regarded in the order eggplant>tomato>bottle gourd>pumpkin>cauliflower>cabbage **(Fig. 5)**. Jamali *et al.,* (2007) also reported from their findings that Pb concentrations in vegetables grown in agricultural sites dressed and irrigated with domestic wastewater were significantly (P<0.01) higher than control vegetable samples.



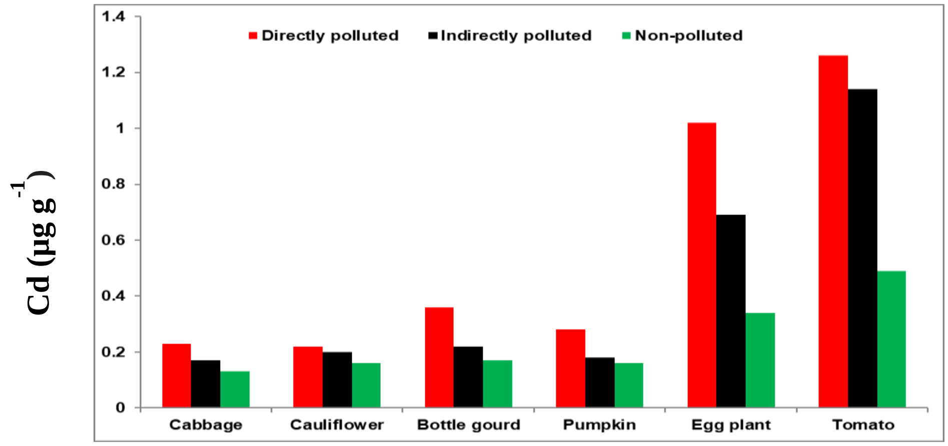
Source: Nashir Uddin Mahmud, MS Thesis, 2010

Safe Limit: 05 (µg g^{-1}) (FAO/WHO Standard), Codex Alimentarious Commission (1984).

Fig. 5. Pb content in different vegetables from contaminated and uncontaminated soils

Cadmium (Cd) content status in vegetables

Cadmium (Cd) level as the highest in tomato with a range of 0.49 to 1.26 µg g^{-1} followed by eggplant with a range of 0.34 to 1.02 µg g^{-1} and bottle gourd having 0.17 to 0.0.36 µg g^{-1} and other vegetables. The higher amount of Cd was detected in directly polluted soils followed by indirectly polluted soils and non-polluted soils **(Fig. 6).** In fact, significant differences ($P<0.01$) were found in the level of Cd in all tested vegetables between polluted and non-polluted areas. Similar to Pb as reported by Jamali *et al.*, (2007) that, the concentration of Cd in vegetables sampled from wastewater irrigated soils was high, ranging between 0.14 µg g^{-1} (spinach) and 0.30 µg g^{-1} (eggplant) on a dry weight basis, whereas in fresh water irrigated soils showed less of Cd ranging between 0.01 µg g^{-1} (spinach) and 0.02 µg g^{-1} (eggplant).



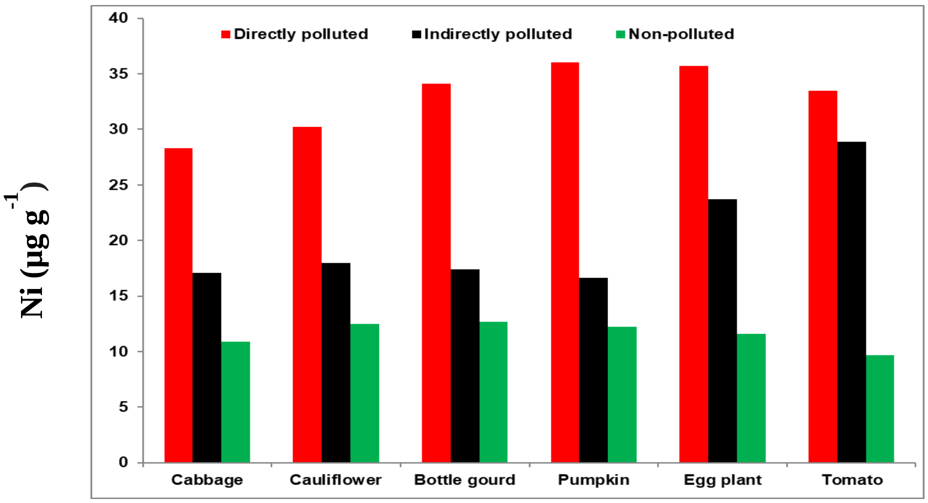
Source: Nashir Uddin Mahmud, MS thesis, 2010

Safe Limit: 0.3 (µg g^{-1}) (FAO/WHO Standard), Codex Alimentarious Commission (1984).

Fig. 6. Cd content in different vegetables from contaminated and uncontaminated soils

Nickel (Ni) content status in vegetables

The nickel (Ni) contamination trend in different vegetables was followed the order as bottle gourd>cauliflower>cabbage>pumpkin>tomato>eggplant for directly polluted (Kalakoir) areas, whereas it was cauliflower>cabbage>bottle gourd>pumpkin>tomato>eggplant for indirectly polluted (Zorun) and non-polluted (BARI) areas **(Fig. 7).** In directly polluted area the Ni (dry weight basis) content was highest in bottle gourd with a mean of 43.5 µg g^{-1} followed by cauliflower with a mean of 41.8 µg g^{-1} and minimum in eggplant i.e. 9.17 µg g^{-1}. In indirectly polluted and non-polluted areas Ni content was found highest in cauliflower with a range of 19.2 to 34.3 µg g^{-1} followed by cabbage with a range of 17.9 to 32.9 µg g^{-1} and bottle gourd was 16.6 to 31.4 µg g^{-1}. According to FAO/WHO all the vegetables are unsafe due to cross the safe lime of Ni content in the polluted area.



Source: Nashir Uddin Mahmud, MS thesis, 2010

Safe Limit: 20 (µg g^{-1}) (FAO/WHO Standard), Codex Alimentarious Commission (1984).

Fig. 7. Ni content in different vegetables from contaminated and uncontaminated soils

Although concentrations of Cu, Cr and Pb were below the limits, these metals were taken to different extent by different vegetables and translocated to vegetables and fruits grown in that area. Wastewater use for irrigational purposes is reported to cause heavy metal magnification in plants i.e. heavy metals goes to plants without retaining in soil (Achakzai *et al.*, 2011). From the findings of vegetable samples analysis **(Table 1)**, it was observed that concentration of Cu ranged from 0.4 - 18.9 mg/Kg with Mean + SD value 4.11 + 6.639mg/ kg which was within safe limit (40 mg/Kg) of EU (2006), in all vegetables samples. Chromium concentration in vegetables ranged from 0.6 - 13.2 mg/Kg (Average 2.943 + 4.542 mg/kg) and was exceeding the permissible levels given by WHO/FAO and EU (2.3 mg/kg). The maximum chromium content (13.2 mg/Kg) was found in lady finger plant grown at Chota Ravi drain area; other plants such as eggplant, tomato, spinach and pilak also had trace amounts of metals but very high level of chromium in lady finger would be due to absorption capacity and ability of the plant. Chromium absorbs rapidly in soil but retain there for short interval because it goes to the other medium such as plants. The level of heavy metal concentration varies with parts of the plant as most of the plants have higher quantity of heavy metals in roots and stems; however, their quantity lowers down in the leaves.

Table 1. Heavy metal concentration in vegetables grown by using irrigation water of drains and their comparison with WHO/FAO standards (Source: Hamid et al. 2017)

Area	Sample No.	Vegetable Sample	Cu mg/Kg	Cr	Pb mg/Kg
	1	Spinach	0.6	0.6	1.0
BabuSabu Drain	2	Egg plant	1.2	1.2	1.6
	3	Bottle gourd	0.4	1.7	1.0
Hudiara Drain	4	Tomato	1.3	1.4	0.7
Chota Ravi Drain	5	Lady finger	4.1	13.2	8.1
Kharak Drain	6	Lady finger	2.3	1.7	1.9
	7	Pilak	18.9	0.8	2.0
*WHO/FAO,			40	2.3	0.05 - 0.3
**EU standards					

* WHO/FAO (2007),**EU (2006)

It was found from a field and basket survey experiment that the heavy metal concentrations varied between the production sites and vegetables. The Zn was highest in all the vegetables tested followed by that of Cu, Cd and Pb at the production sites as well as at the market sites. Zn concentrations (μg g^{-1}) ranged from 32.5 to 66.2, 42.3 to 92.3 and 25.2 to 94.3, respectively, in lady's finger, palak and cauliflower at market sites **(Table 2)**. The mean concentration of Cu (μg g^{-1}) was recorded minimum in lady's finger (18.02) and maximum in cauliflower (35.72) at the market sites **(Table 2)**. The mean concentrations of Cd (μg g^{-1}) were 1.41, 1.96 and 2.57, and of Pb were 1.03, 1.44 and 1.56, respectively, in lady's finger, palak, and cauliflower collected from the market sites **(Table 2).**

Table 2. Heavy metal concentration (µg g^{-1}) in the tested vegetables collected from different production and market sites of a tropical urban area of India (Source: Sharma et al. 2009)

Heavymetals	Production sites			Market sites		
	Palak	Lady's finger	Cauliflower	Palak	Lady's finger	Cauliflower
Copper						
Mean	20.27	16.07	16.63	27.59	18.02	35.72
Min	12.80	9.50	9.80	20.10	12.20	21.20
Max	25.60	21.80	24.10	40.10	27.10	56.30
Zinc						
Mean	38.40	34.69	51.52	57.56	45.96	63.63
Min	30.10	29.60	38.60	42.30	32.50	25.20
Max	45.50	39.20	63.30	92.30	66.20	94.30
Cadmium						
Mean	0.98	0.90	1.26	1.96	1.41	2.57
Min	0.40	0.50	0.60	0.80	0.10	0.80
Max	1.50	1.20	2.10	3.80	2.60	4.30
Lead						
Mean	1.00	0.88	1.02	1.44	1.03	1.56
Min	0.70	0.30	0.20	1.10	0.20	0.90
Max	1.40	1.20	1.80	1.90	2.56	2.40

There were 28 production sites **(Fig. 12)** and within these sites, the mean concentrations of the heavy metals were recorded maximum in lady's finger, cauliflower and palak respectively at sites 10, 14 and 25 for Cu **(Fig. 8)**, at sites 7, 24 and 28 for Zn, at sites 10, 17 and 28 for Cd and at sites 12, 17 and 28 for Pb **(Figs. 8 - 11).** The higher concentrations of heavy metals in the vegetables tested at sites 10, 12, 17 and 28 might be due to their location adjacent to the brick kiln industries or proximity to national highway.

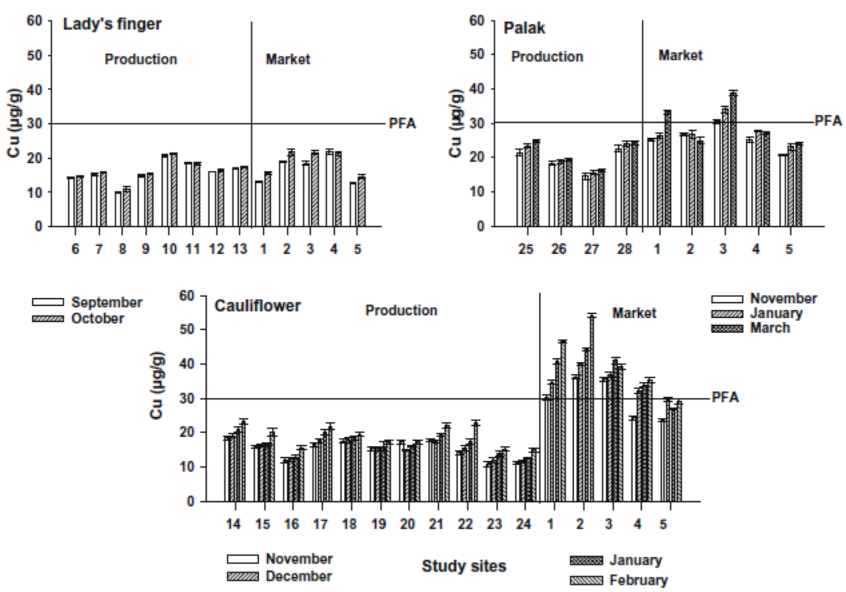


Fig. 8. Copper (Cu) concentration in the vegetables collected from different production and market sites of a tropical urban area of India (Source: Sharma et al. 2009).

Within the market sites, the mean concentration of Cu was recorded maximum at site 2 in lady's finger and cauliflower, and at site 3 in palak **(Fig. 8).** Mean Zn concentration was recorded maximum at sites 2, 4 and 5, respectively, in cauliflower, palak and lady's finger **(Fig. 9).** The mean concentrations of Cd and Pb between the market sites were, respectively, recorded maximum at sites 3 and 5 in lady's finger, at site 3 in cauliflower, and at sites 1 and 3 in palak **(Figs. 10 and 11).**

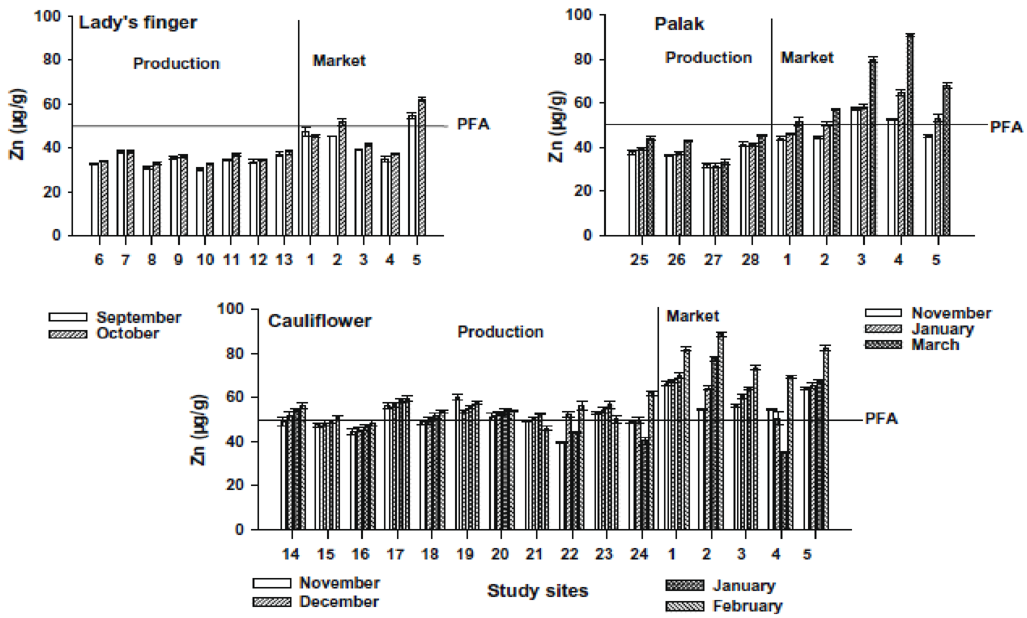


Fig. 9. Zinc (Zn) concentration in the vegetables collected from different production and market sites of a tropical urban area of India (Source: Sharma et al. 2009).

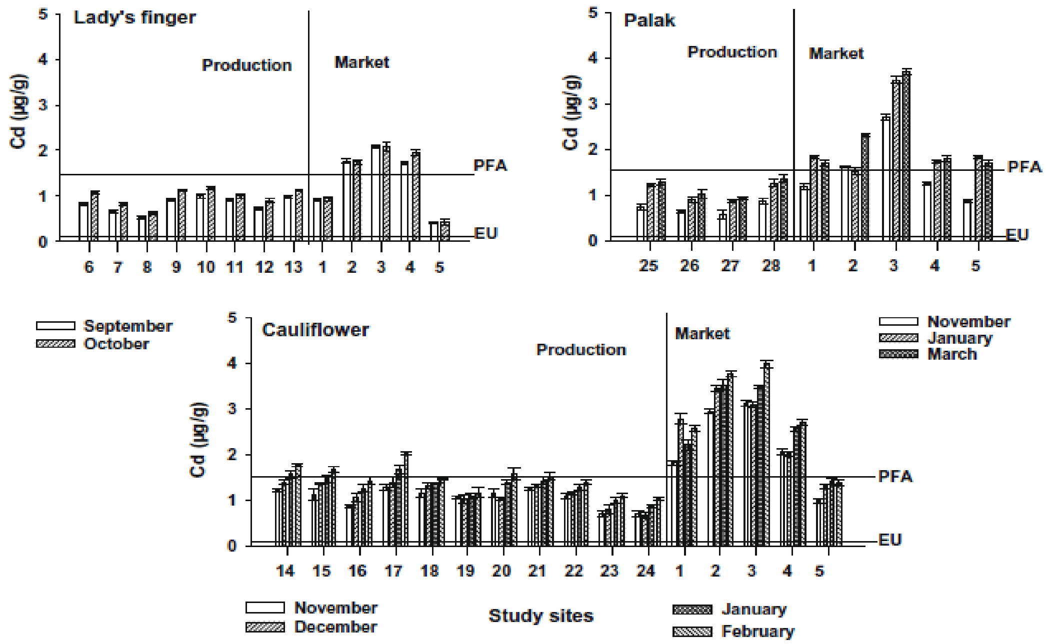


Fig. 10. Cadmium (Cd) concentration in the vegetables collected from different production and market sites of a tropical urban area of India (Source: Sharma et al. 2009).

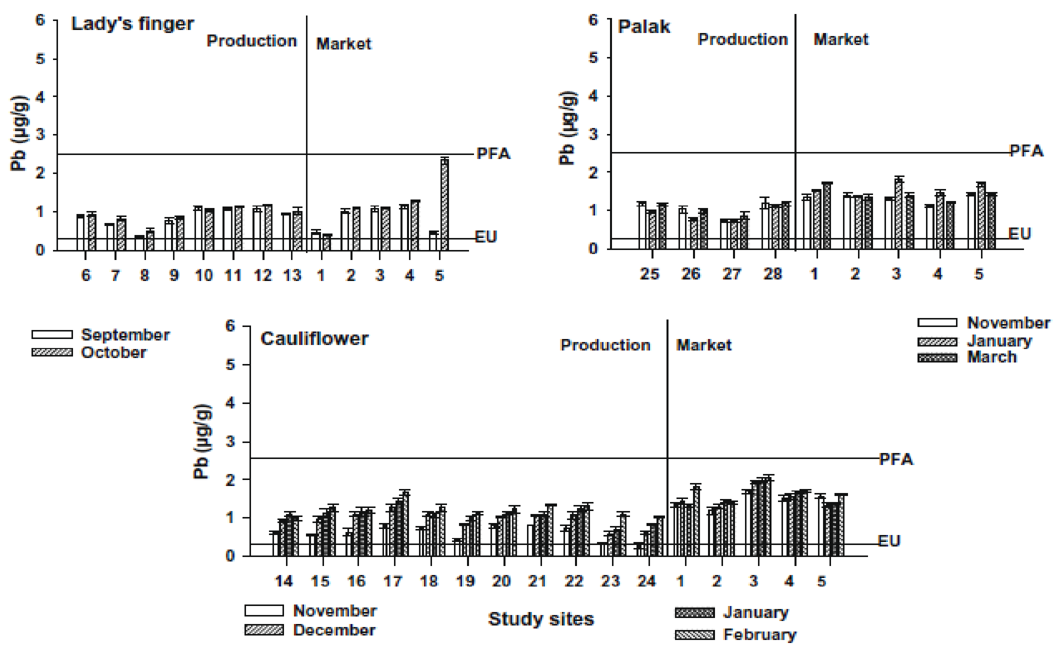


Fig. 11. Lead (Pb) concentration in the vegetables collected from different production and market sites of a tropical urban area of India (Source: Sharma et al. 2009).

The average values of heavy metals in the vegetables tested collected from production sites are lower than the PFA standard (Awasthi, 2000). While at market sites, the mean concentration of Cu in cauliflower, Zn and Cd in both palak and cauliflower had exceeded the PFA standard. On the other hand, Cd concentrations in vegetables tested from both production and market sites were many folds higher than the EU standard (Marshall, 2004). In contrast, Pb in vegetables tested from both production and market sites was below the PFA standard but was many folds above the EU standard **(Table 2).** Cu concentration exceeded the PFA standard at all the market sites in cauliflower, and at sites 1 and 3 in palak **(Fig. 8).** Zinc concentration exceeded the PFA standard in cauliflower at most of the production and market sites **(Fig. 9).** Cadmium level in all the vegetables tested exceeded the EU standard (0.1 µg g^{-1}) at all the production sites but was lower than PFA standard (1.5 µg g^{-1}) in both lady's finger and palak **(Fig. 10).** The average values of Cd in all the vegetables tested at market sites were higher than both the PFA and EU standards. Pb concentration was, however, below the PFA standard, but was many folds higher than the EU standard at all the study sites **(Fig. 11).**

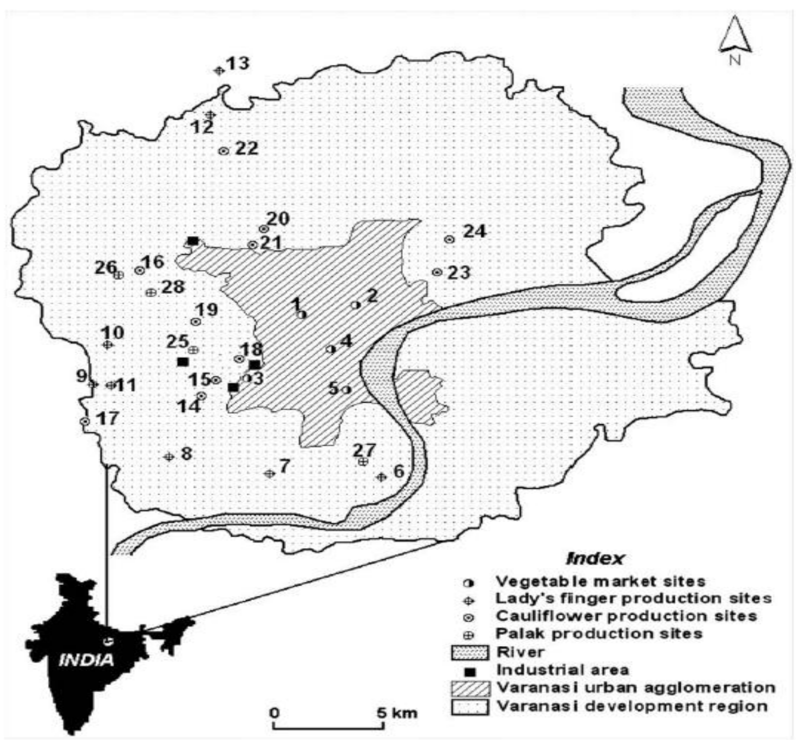


Fig. 12. Map showing the relative positions of different production and market sites of Varanasi of India (Source: Sharma et al. 2009).

This result clearly showed that the location of study sites and growing periods of vegetables influenced the levels of heavy metals in the vegetables. The variations in the concentrations of the heavy metals in vegetables observed during the present study may be ascribed to the physical and chemical nature of the soil of the production sites, absorption capacities of heavy metals by vegetables, atmospheric deposition of heavy metals, which may be influenced by innumerable environmental factors such as temperature, moisture and wind velocity, and the nature of the vegetables, i.e. leafy, root, fruit, exposed surface area, hairy or smoothness of the exposed parts (Zurera et al., 1989). The variations in the concentrations of heavy metals in the vegetables tested may also be ascribed to the variations in the anthropogenic activities such as brick kiln activities, addition of phosphate fertilizers or use of metal-based pesticides around production sites and urban industrial activities at market sites **(Fig.12)**. The production sites **(Fig.12)** showing higher levels of heavy metals are either located in the areas having a number of brick kiln industries (sites 7, 10, 12 and 14) or located close to national highways (17 and 28).

3.4 Risk assessment of heavy metal

Metal concentrations in the soil, sewage water and okra plants

The mean concentrations of Cr, Zn, Ni, Cd, Mn, Pb, Cu and Fe in the okra plants were 1.96, 1.88, 1.42, 1.20, 1.10, 0.88, 0.56 and 0.10 mg/kg respectively **(Fig. 13).** The present study indicated that all of the heavy metal concentrations in the wastewater-irrigated food crops were higher than the permissible limits. Our results showed that the Cd, Zn, Ni, Cd and Pb exceeded the permissible limits in all the wastewater samples. The Cu and Fe contents were also above the permissible limits in sewage water-irrigated food crops, with the exception of *L. esculentum.* Various scientists have reported elevated levels of heavy metals in sewage and industrial effluent-irrigated vegetables. (Mohammad Rusan et al., 2007) have stated that the levels of plant Pb and Cd increased with wastewater irrigation, and a longer period of wastewater irrigation led to a higher concentration of heavy metals. (Singh and Kumar, 2006) have collected samples of vegetables (spinach and okra), soil and irrigation water from 5 peri-urban sites of New Delhi to monitor their heavy metal loads. These authors have concluded that although the heavy metal load of the irrigation water was above the maximum allowable limit, it was lower in the soils and higher in the vegetable samples. The spinach and okra samples showed Zn, Pb and Cd levels that were higher than the WHO limits.

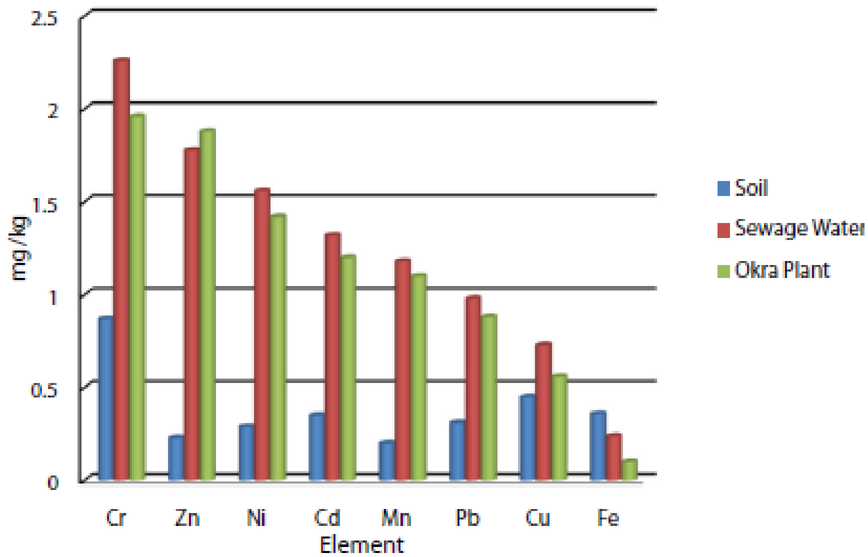


Fig. 13. Heavy metal concentration in soil-water-plant system irrigated with wastewater

(Source: Balkhair and Ashraf 2016)

Metal Concentrations in the soils and translocation factors

The concentrations of Cr in the soils of the study area ranged from 0.87–1.00 mg kg^{-1}, whereas those of Fe ranged between 0.36–0.75 mg kg^{-1}. These ranges exceed the permissible limits for mineral soils in arid regions (Brady and Weil, 1996). The ate of absorption of elements by plants depends upon the cultivated plant and the soil properties, such as the pH, CEC and distribution of metals in different soil fractions (Kos et al., 2003). At an acidic pH, high Mn concentrations in cultivated soils could pose a risk of toxicity to the okra plant. Under an acidic pH, free Mn may be the predominant form in the soil solution, making it readily available for the okra plants. (Renella et al., 2004) have reported that in Mn- and Zn polluted soils, the solubility of Mn and Zn was significantly higher in the presence of organic acids, which are typically released by plant roots, thus suggesting that plants can mobilize trace elements via their root exudates. The metal AF in plants is used to describe the extent of accumulation of a compound in an identified biological system. **Table 3** presents the AF values of the metals in the consumed parts of the studied plants. The accumulation factors of the metals in the consumed parts of the plants were less than the values obtained for Fe and Cr. Chromium, with AF values in the range of 1.6730–1.8240, was the most accumulated.

Thus, the bio-concentration factor (BCF) values of metals in the food crops showed a trend in the order of Cr > Zn> Ni> Cd> Mn> Pb> Cu ~ Fe. The best accumulators for Cr are okra plants that preferentially concentrate metals in their leaves, the consumable part of the plant.

Table 3. Accumulation risk of heavy metals in vegetables through contaminated waste water (Source: Balkhair and Ashraf 2016)

Metals	Translocation factor AF[a]	Risk assessment index			RDA[b] (mg day^{-1})	RfD[c] (mg kg^{-1} day^{-1})
		DIM	HRI	THQ		
Cu	0.0122–0.0246	3.30E-03	2.20E-03	0.873	6.0–9.0	0.2
Ni	0.1265–0.1489	3.20E-03	1.62E-01	0.902	2.0–8.0	0.4
Mn	1.0777–1.0964	4.06E-02	2.90E-01	1.164	1.8–2.3	0.14
Pb	1.0124–1.0429	2.85E-02	8.14E-00	1.803	2.0–6.5	0.6
Cd	0.0991–0.1820	1.70E-03	1.67E-00	2.904	1.8–6-8	0.5
Zn	1.1422–1.1622	4.00E-04	3.00E-04	0.065	8.0–11.0	0.3
Fe	0.6162–0.8354	1.90E-03	9.68E-02	0.442	8.0–18.0	0.8
Cr	1.6730–1.8240	2.28E-02	1.63E-01	2.279	5.0–9-0	0.3

Daily intake of metals and human health risk assessment

To observe the health risk of each pollutant, it is important to estimate the level of exposure by detecting the routes of exposure to target organisms. There are several possible pathways of exposure to humans, but among them the food chain is the most important pathway. In our study, the only intake pathway considered for Cr, Zn, Ni, Cd, Mn, Pb, Cu and Fe was assumed to be vegetable consumption. The DIM values were estimated according to the average vegetable consumption for adults **(Table 3)** and compared with the recommended daily intakes (WHO, 1996; Trumbo et al., 2001). The results for the evaluation of the DIM and HRI from the heavy metal-contaminated okra crop are presented in **Table 3** for sewage water irrigation. The results showed that the DIM and HRI values were high in the okra crop. The DIM of the sewage water-irrigated crop ranged from 1.2E-02 to 4.9E-02, 2.7E-03 to 5.2E-03, 1.2E-03 to 1.6E-02, 1.8E-02 to 3.3E-02 and 1.0E-03 to 3.1E-03 mg kg^{-1} person^{-1} d^{-1} for Cr, Ni, Pb and Cd, respectively **(Table 3)**. Similarly, in sewage water-irrigated food crops, the HRI values for Cr, Ni, Mn, Pb and Cd ranged from 8.0E-02 to 3.3E-01, 1.4E-01 to 2.6E-01, 8.6E-01 to 1.2E-00, 5.2E-00 to 9.4E-00 and 9.5E-01 to 3.1E -00, respectively (**Table 3).**

The THQ has been recognized as a useful parameter for evaluating the risk associated with the consumption of metal-contaminated food crops (Agbenin et al., 2009). An important number of the results obtained in this study were above this limit and suggested possible metal contamination through the okra plant. According to the THQ values **(Table 3),** Cr present in consumed plants has the potential to pose a health risk to the local population. (Horiguchi et al., 2004) have suggested that the ingested dose of heavy metals is not equal to the absorbed pollutant dose in reality because a fraction of the ingested heavy metals may be excreted, with the remainder being accumulated in body tissues where they can affect human health. The present study is very important in terms of health perspectives, indicating the health risk to the human population from the consumption of heavy metals in food crops.

Chapter 4

Conclusions and Recommendations

4.1 Conclusions

Based on the review findings, it can be concluded that

1. The untreated industrial effluent could be toxic on vegetable seed germination but the degree of toxicity might be varied depending on the source of effluent.
2. The greater heavy metal contamination occurs in early growth stage of vegetable than later stage.
3. Heavy metal content fluctuates from one species to another species of vegetable even in the same contaminated soil.
4. Untreated industrial effluents create heavy metal pollution, which contaminates vegetable and health risk for human being.

4.2 Recommendations

1. Government should take initiative not to discharge untreated industrial effluent in the environment from any industry to save the ecosystem and living being.

References

Achakzai, A. K. K., Bazai, Z. A., & Kayani, S. A. (2011). Accumulation of heavy metals by lettuce (Lactuca sativa l.) irrigated with different levels of wastewater of Quetta city. *Pakistani Journal of Botany*, *43*(6), 2953.

Agbenin, J. O., Danko, M., & Welp, G. (2009). Soil and vegetable compositional relationships of eight potentially toxic metals in urban garden fields from northern Nigeria. *Journal of the Science of Food and Agriculture*, *89*(1), 49-54.

Alam, M. G. M., Snow, E. T., & Tanaka, A. (2003). Arsenic and heavy metal contamination of vegetables grown in Samta village, Bangladesh. *Science of the Total Environment*, *308*(1-3), 83-96.

Arora, M., Kiran, B., Rani, S., Rani, A., Kaur, B., & Mittal, N. (2008). Heavy metal accumulation in vegetables irrigated with water from different sources. *Food chemistry*, *111*(4), 811-815

Prevention of Food Adulteration Act (Act no. 37 of 1954), along with central & state rules, as amended in 1997 & 1998, & Awasthi, S. K. (1998). *Prevention of Food Adulteration Act (Act No. 37 of 1954), Along with Central & State Rules*, *as Amended in 1997 & 1998*. International Law Publishing Company Pvt. Limited.

Balkhair, K. S., & Ashraf, M. A. (2016). Field accumulation risks of heavy metals in soil and vegetable crop irrigated with sewage water in western region of Saudi Arabia. *Saudi journal of biological sciences*, *23*(1), S32-S44.

Brady, N. C., & Weil, R. R. (2002). The nature and properties of soils, 13th. *Pearson education (Singapore) Pte. Ltd. Indian Branch*, *482*, 621-624.

Horiguchi, H., Oguma, E., Sasaki, S., Miyamoto, K., Ikeda, Y., Machida, M., & Kayama, F. (2004). Dietary exposure to cadmium at close to the current provisional tolerable weekly intake does not affect renal function among female Japanese farmers. *Environmental research*, *95*(1), 20-31.

Islam M.R., Rahman G.K.M. M., Saleque, M. A., and Uddin M J.(2017). Effect of Industrial Effluents on Seed Germination and Seedling Growth of Rice. *Dhaka University Journal of Biological Science, 26*(1): 59-68.

Islam, M. R., Rahman, G. M., Karim, A. S., Miah, M. G., & Saleque, M. A. (2015). Quality assessment of different industrial effluents for irrigation in agriculture. *Journal of Earth Science and Engineering*, *5*, 134-145.

Jamali, M. K., Kazi, T. G., Arain, M. B., Afridi, H. I., Jalbani, N., & Memon, A. R. (2007). Heavy metal contents of vegetables grown in soil, irrigated with mixtures of wastewater and sewage sludge in Pakistan, using ultrasonic-assisted pseudo-digestion. *Journal of Agronomy and Crop Science*, *193*(3), 218-228.

Khan, S., Cao, Q., Zheng, Y. M., Huang, Y. Z., & Zhu, Y. G. (2008). Health risks of heavy metals in contaminated soils and food crops irrigated with wastewater in Beijing, China. *Environmental pollution*, *152*(3), 686-692.

Lutts, S., Lefevre, I., Delpérée, C., Kivits, S., Dechamps, C., Robledo, A., & Correal, E. (2004). Heavy metal accumulation by the halophyte species Mediterranean saltbush. *Journal of Environmental Quality*, *33*(4), 1271-1279.

Mingorance, M. D., Valdes, B., & Oliva, S. R. (2007). Strategies of heavy metal uptake by plants growing under industrial emissions. *Environment International*, *33*(4), 514-520.

Oliveira, J. A., Oliva, M. A., Cambraia, J., & Venegas, V. H. A. (1994). Absorption, accumulation and distribution of cadmium by two soybean cvs. *Revista Brasileira de Fisiologia Vegetal*, *6*(2), 91-95.

Renella, G., Mench, M., Van der Lelie, D., Pietramellara, G., Ascher, J., Ceccherini, M. T., ... & Nannipieri, P. (2004). Hydrolase activity, microbial biomass and community structure in long-term Cd-contaminated soils. *Soil Biology and Biochemistry*, *36*(3), 443-451.

Rusan, M. J. M., Hinnawi, S., & Rousan, L. (2007). Long term effect of wastewater irrigation of forage crops on soil and plant quality parameters. *Desalination*, *215*(1-3), 143-152.

Sharma, R. K., Agrawal, M., & Marshall, F. M. (2009). Heavy metals in vegetables collected from production and market sites of a tropical urban area of India. *Food and chemical toxicology*, *47*(3), 583-591.

Singh, S., & Kumar, M. (2006). Heavy metal load of soil, water and vegetables in peri-urban Delhi. *Environmental Monitoring and Assessment*, *120*(1-3), 79-91.

Trumbo, P., Yates, A. A., Schlicker, S., & Poos, M. (2001). Dietary reference intakes: vitamin A, vitamin K, arsenic, boron, chromium, copper, iodine, iron, manganese, molybdenum, nickel, silicon, vanadium, and zinc. *Journal of the American Dietetic Association*, *101*(3), 294-301.

World Health Organization. (1996). Guidelines for drinking-water quality. Vol. 2, Health criteria and other supporting information.

Zebunnesa,Rahman M.M., and Rahman G.K.M.M., (2009). Accumulation of Trace Metals in Soils and Plants from Industrial Effluents. *Journal of Environmental Science & Natural Resources, 2*(1), 211-214.

Zurera-Cosano, G., Moreno-Rojas, R., Salmeron-Egea, J., & Lora, R. P. (1989). Heavy metal uptake from greenhouse border soils for edible vegetables. *Journal of the Science of Food and Agriculture*, *49*(3), 307-314.