

## QUANTITATIVE EVALUATION OF BIOACCUMULATING TOXIC AND ESSENTIAL METALS IN VEGETABLES PROCURED FROM LOCAL MARKETS OF PAKISTAN AND THEIR PUBLIC HEALTH RISK ASSESSMENT

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### ABSTRACT

Heavy metals uptake were determined in eleven vegetables procured from local market of Karachi and Lahore while results were compared with permissible safe limits set by WHO, SEPA (China) and FSSA (India) to ascertain their public dietary exposure and health hazards. Important findings included: Average concentrations of Pb were exceeding permissible level of WHO and FSSA in onion procured from Karachi and in carrot, potato, bitter gourd and apple gourd from Lahore. Although Cd metal was more accumulated than safe limits set by SEPA in most of vegetable samples from Karachi however it was within permissible range in all vegetables from Lahore. Moreover, average quantity of Zn were exceeded than FSSA set values in onion, bell pepper, ridge gourd, bitter gourd and apple gourd from Karachi as well as in onion, bell pepper, cucumber, taro, carrot and apple gourd from Lahore whereas amount of Fe and Mn metals were found well within safe control of WHO standards in all vegetables from both cities. Daily Intake of Fe and Mn metals were yielded within safe range of reference oral dose values but exceeded in case of Pb, Cd and Zn metals. Calculated Health Risk Index values were found more than one (>1) for Pb, Cd and Zn metals while less than one (<1) for Fe and Mn metals.

**Key words:** Heavy metals, Vegetables and Health Risk Index.

### INTRODUCTION

Vegetables are generally consumed with the main course of meal in both cooked and uncooked forms (Potter and Hotchkiss, 1995). Vegetables provide essential vitamins, fibers and minerals, which are vital for human health (Marbaniang *et al.*, 2012). Based on their function, metals can be classified as toxic and essential metals (Belitz *et al.*, 2009). Results of various research studies have shown that vegetables contain both toxic and essential metals over a wide range of concentrations (Radwan and Salama, 2006; Sharma *et al.*, 2009; Othman, 2010; Sobukola *et al.*, 2010; Marbaniang *et al.*, 2012; Singh *et al.*, 2012). Ingestion of contaminated vegetables is an important route of heavy metals migration into human body. Factors that influenced the uptake of these metals by plant roots and its subsequent translocation to the stem, leaves and vegetables/fruits are: plant genetics, metal concentration in the soil solution, ease of transport from root to shoot, and irrigation malpractices (Pehluvan *et al.*, 2012; Khadeeja *et al.*, 2013; Yasar *et al.*, 2013; Aslam *et al.*, 2015).

Pb and Cd metals are cytotoxic and capable to accumulate in various vegetables. Pb can cause damages to kidneys, cardiovascular tissues, immune, hematopoietic, central nervous and reproductive systems while Cd associated with bone demineralization, renal dysfunction, impair lung function and increase the risk of

lung cancer (Graeme and Pollack, 1998). Fe is an essential metal and required about 60 mg/person/day for normal functioning of human body. Fe is mainly present in hemoglobin (blood) and myoglobin (muscle tissue) pigments (Belitz *et al.*, 2009). Zn and Mn are also essential elements. However, high intake of Zn is toxic for human, on contrary Mn is relatively nontoxic even in higher amount. Daily intake requirements of human body are 10-40 mg of Mn and about 2-48 mg of Zn (Belitz *et al.*, 2009).

### MATERIALS AND METHODS

All the chemicals and reagents used in this study were of analytical grade and purchased from Merck (Darmstadt, Germany).

**Sample Preparation:** Eleven vegetables were selected and purchased from local markets of Karachi (campus shop of Karachi University and main vegetable market) and Lahore (Kot lakhpat vegetable market). These procured vegetables were identified by an agricultural scientist and included onion, bell pepper, cucumber, turnip, egg plant, taro, ridge gourd, carrot, potato, bitter gourd and apple gourd. All vegetables were washed properly with tap water and then rinsed with deionized water to remove dust and other contaminations. The vegetables were cut into small pieces and dried at 105 °C. Vegetables were ground with porcelain mortar and pestle

to fine particle size and stored in plastic container for further digestion. Vegetable were digested in the microwave digestion system. Digestion tubes were first washed and rinsed with distilled water then 0.1 M HNO<sub>3</sub> was filled in the digestion tube for two hour. After two hours HNO<sub>3</sub> was discarded and tubes were kept in an oven for drying. An exact amount of 0.5 g of ground dried sample was weighed and transferred to a digestion tube. Subsequently 10.0 ml of concentrated HNO<sub>3</sub> was added into it and the mixture was left for overnight. Next day 3.0 ml of concentrated HClO<sub>4</sub> was added in the mixture. The digestion tubes were then placed in a Microwave digestion system (MARS-5, CEM cooperation, USA). Operating parameters of microwave digestion system were set at 400 W power level with 15 minutes ramp time while 800 psi pressure and 200 °C temperature conditions were hold for 15 minutes time without stirring. After digestion the samples were carefully transferred into 100 ml volumetric flasks and the volumes were made up to the mark with 0.1 M HNO<sub>3</sub>.

**Determination of Heavy Metals in Vegetables:** Atomic absorption spectroscopy has been considered as a useful tool for the analysis of metals in samples (Khan *et al.*, 2010; Mahmood and Malik, 2014). Working standard solutions for Pb, Cd, Fe, Zn and Mn were prepared by using their respective stock standard solution (of 1000 ppm) purchased from Merck. A Perleim Elmer Model 3100 atomic absorption spectrophotometer equipped with air-acetylene flame atomizer and hollow-cathode lamp (electrode less discharge source lamp) was used for metal analysis of Fe, Zn and Mn. Absorption signals of Fe, Zn and Mn were read at 248.3, 213.9 and 279.5 nm wavelength respectively.

On the other hand, Cd and Pb metals were analyzed with graphite furnace atomic absorption spectrophotometer. Instrumental conditions were set as 3.0 L/min flow rate of argon filling gas and absorption reading logged at 2500 °C temperature. All samples were run in three replicates. Dry weight of vegetables was considered to calculate the metal levels.

**Determination of Daily Intake of Metals (DIM):** Daily intakes of all test metals (Pb, Cd, Fe, Zn and Mn) due to the consumption of vegetables were calculated by using following equation (Khan *et al.*, 2010):

$$DIM = C_{\text{metal}} \times D_{\text{food intake}} / B_{\text{average weight}}$$

Where, DIM = Daily intake of metals, C<sub>metal</sub> = Concentration of metals, D<sub>food intake</sub> = Daily intake of vegetables and B<sub>average weight</sub> = Average body weight.

For the calculation of DIM values, daily intake of vegetables was considered to be 0.345 kg person<sup>-1</sup>day<sup>-1</sup> while average body weight was considered to be 73 kg (Khan *et al.*, 2010).

**Determination of Health Risk Index (HRI):** The health risk index was calculated for Pb, Cd, Zn and Mn by using the following formula (Khan *et al.*, 2010):

$$HRI = DIM / RfD$$

Where, DIM = Daily intake of metals and RfD = Reference (oral permissible) dose

If the value of HRI is less than 1 it means that the population consuming the vegetables is safe.

## RESULTS AND DISCUSSION

In past decades, food safety became a public concern worldwide. Consequently, more and more research studies were conducted to evaluate the risks of consuming foodstuffs that were contaminated by pesticides, heavy metals and toxins (Radwan and Salama, 2006; Sharma *et al.*, 2009; Othman, 2010; Sobukola *et al.*, 2010; Singh *et al.*, 2012). Some research studies in Pakistan reported the concentration of metals in vegetables. A study conducted by Mahmood *et al.* (2014) had compared the metals accumulation and health risk assessment of vegetables that were grown in Lahore using waste water and ground water. Results of this study had shown that soil and vegetables irrigated with waste water were enriched with various heavy metals which were harmful for health. Khan *et al.* (2010), Ismail *et al.* (2011) and Ahmed *et al.* (2012) had reported the concentration of heavy metals in vegetables that were grown in Gilgit, Hyderabad and Rawalpindi respectively. Abbas *et al.* (2010) had reported the concentration of Pb, As and Hg in various vegetables of Sindh. Whereas Parveen *et al.* (2003) and Khadeeja *et al.* (2013) had reported the concentration of trace metals in some vegetables of Karachi.

**Toxic and Essential Metals in Vegetables:** Demand of food crops has increased in developing countries due to rapid urbanization. Hence, waste water irrigation became a common trend (Singh *et al.*, 2012). Karachi is one of the cities where farmers used waste water for irrigation due to shortage of fresh water (Yousufzai *et al.*, 2001; Saif *et al.*, 2005). In present study a survey was conducted to identify the major supply source of vegetables in different shops. It was found that most of the vegetables were delivered to the shops from Malir fields which have geographical positioning parameters of 24.9224029 latitude & 67.2509193 longitudes. As Malir fields are situated along bank of Malir drain therefore generally waste water is used to irrigate the food crops. Lahore is another city of Pakistan facing challenges of urbanization and industrialization where resultant anthropogenic activities had polluted fresh water resources (Mahmood and Malik, 2014). As this trend of polluted water irrigation is on rise therefore, it is important to start regular monitoring programs and surveys in order to study metal contents in vegetables.

This study is one step ahead towards this direction and results of this study presents the level of toxic (Pb & Cd) as well as essential metals (Fe, Zn & Mn) that were found in the vegetables that were purchased from the local markets of Karachi and Lahore cities (Table 1 & Fig. 1).

**Pb Profile:** Comparison of average concentrations of Pb in various vegetables procured from the local markets of Karachi and Lahore was exhibited in Fig. 1(a). Onion from Karachi and apple gourd from Lahore contained the highest level of Pb 7.484 ppm and 7.308 ppm respectively. On the other hand, lowest levels of Pb were detected in ridge gourd from Karachi and eggplant from Lahore which consist of 0.0014 ppm and 0.362 ppm of Pb respectively. Furthermore, three vegetables of Karachi (cucumber, bitter gourd and apple gourd) and six vegetables of Lahore (onion, bell pepper, cucumber, turnip, taro and ridge gourd) did not contain Pb. Results of present study revealed that 72.72 % vegetables from Karachi and 45.45 % vegetables from Lahore were contaminated with Pb. Average concentrations of Pb in vegetables procured from local market of Karachi were compared with the results of other studies in Table 2. It was found that the average concentration of Pb in eggplant, onion, and potato was higher than the values reported by Abbas *et al.* (2010), Ahmad *et al.* (2012) and Parveen *et al.* (2003). On contrary, the average concentration of Pb found in bell pepper was less as compared to the value reported by Ahmad *et al.* (2012). Table 2 also showed the comparison of average concentration of Pb in vegetables that were purchased from Lahore. The average concentration of Pb in eggplant, potato and bitter gourd was relatively higher than the values reported by Abbas *et al.* (2010) however, the average concentration of Pb in eggplant was lower than the values reported by Ahmad *et al.* (2012). On comparison with the permissible limits set by WHO (0.3 ppm) and FSSA (2.5 ppm) (Khan *et al.*, 2010), it was found that average concentration of Pb was beyond the limit in onion from Karachi and four other vegetables from Lahore (carrot, potato, bitter gourd and apple gourd). However, the average concentrations of Pb in different vegetables procured from Karachi and Lahore were found within the SEPA permissible limits as SEPA standards have set permissible limits for Pb at higher value i.e. 9 ppm (Khan *et al.*, 2010).

**Cd Profile:** Comparison of the average concentrations of Cd in vegetables procured from the local markets of Karachi and Lahore was exhibited in Fig. 1(b). Highest levels of Cd were observed in turnip (1.178 ppm) from Karachi and onion (0.162 ppm) from Lahore. On contrary, lowest levels of Cd were found in onion (0.266 ppm) from Karachi and bell pepper (0.122 ppm) from Lahore. Cd was not detected in four vegetables (bitter gourd, ridge gourd, cucumber and potato) of Karachi and eight vegetables (cucumber, turnip, taro, ridge gourd,

potato, carrot, bitter gourd and apple gourd) of Lahore. Result of current study has ascertained that about 63.63 % vegetables from Karachi and 27.27 % from Lahore were contaminated with Cd. Average concentrations of Cd in vegetables procured from local market of Karachi were compared with the results of different studies in Table 2. It was found that the average concentration of Cd in eggplant, onion, and turnip from Karachi was higher than the values reported by Abbas *et al.* (2010) and Parveen *et al.* (2003). On contrary, the average concentration of Cd found in bell pepper was less as compared to the value reported by Ahmad *et al.* (2012). Upon comparison of results in vegetables from Lahore (Table 2) it was observed that average concentration of Cd in onion was relatively higher than the values reported by Abbas *et al.* (2010) and Parveen *et al.* (2003) however, the average concentrations of Cd in eggplant and bell pepper were lower than the values reported by Ahmad *et al.* (2012) and Parveen *et al.* (2003). Moreover, the average concentrations of Cd in vegetables from Karachi were higher than permissible limits (0.2 ppm) set by SEPA (Khan *et al.*, 2010). On contrary the values were within the limits for the vegetables from Lahore. Furthermore, comparing results with the permissible limit set by FSSA have shown that the average concentrations of Cd were within safe range as FSSA standards have set permissible limit for Cd at higher value i.e. 1.5 ppm (Khan *et al.*, 2010) (Table 1 & Fig. 1(b)).

**Fe Profile:** Highest levels of Fe were found in onion from Karachi (34 ppm) and in taro from Lahore (84.4 ppm). On the other hand, the lowest levels were observed in eggplant from Karachi (1.28 ppm) and turnip from Lahore (9.3 ppm) (Table 1). Comparison of the average concentrations of Fe in vegetables procured from the local markets of Karachi and Lahore is exhibited in Fig. 1(c). According to the present study, the average concentration of Fe in most of the vegetables purchased from local market of Karachi was higher than the concentration reported by the other researchers (Parveen *et al.*, 2003; Sharma *et al.*, 2009; Abbas *et al.*, 2010; Ismail *et al.*, 2011; Ahmed *et al.*, 2012). However, average concentration of Fe in cucumber purchased from local market of Lahore was 10 ppm which was lower than the value (13.6 ppm) reported by Ahmed *et al.* (2012) but higher than the study reported by Ismail *et al.* (2011). Average concentrations of Fe in different vegetables procured from Karachi and Lahore were found within the WHO permissible limits in subject study as WHO standards have set permissible limit for Fe at higher value i.e. 425 ppm (Codex, 2007).

**Zn Profile:** Highest levels of Zn were found in apple gourd from Karachi (116 ppm) and bell pepper from Lahore (164 ppm). While lowest levels were observed in potato from Karachi (6.5 ppm) and egg plant from Lahore (20 ppm) (Table 1). Comparison of average

concentrations of Zn in vegetables procured from the local markets of Karachi and Lahore has shown in Fig. 1(d). Comparison of these results with previous studies revealed that the average concentration of Zn in cucumber (40 ppm), egg plant (34 ppm) and onion (74 ppm) from Karachi was higher than the values reported by Ismail *et al.* (2011), Parveen *et al.* (2003), Radwan and Salama (2006). Similarly, the average concentration of Zn in bell pepper from Karachi was 68 ppm, which was higher than the value reported by Ahmed *et al.* (2012). While average concentration of Zn in cucumber (116 ppm) and potato (22 ppm) from Lahore were higher than the values reported by Ismail *et al.* (2011), Radwan and Salama (2006). Likewise, average concentration of Zn in bitter gourd (42 ppm) from Lahore was higher than the values reported by Ismail *et al.* (2011) and Parveen *et al.* (2003).

Results showed that average concentrations of Zn in many vegetables procured from Karachi and Lahore were found within the SEPA and WHO permissible limits (100 ppm) (Khan *et al.*, 2010). However the average concentration of Zn in apple gourd procured from Karachi and in bell pepper and cucumber procured from Lahore were exceeded these permissible limits. Comparison of the results with the permissible limits set by FSSA (50 ppm) (Khan *et al.*, 2010) showed that the average concentrations of Zn in onion, bell pepper, ridge gourd, bitter gourd and apple gourd procured from Karachi were exceeded than permissible limits while in case of Lahore onion, bell pepper, cucumber, taro, carrot and apple gourd contained Zn concentrations higher than threshold standard set by FSSA (Table 1).

**Mn Profile:** Comparison of the average concentrations of Mn in vegetables procured from the local markets of Karachi and Lahore was displayed in Fig. 1(e). The highest levels of Mn were found in carrot from Karachi (5.4 ppm) and bitter gourd from Lahore (4.4 ppm). On contrary, lowest levels of Mn (0.4 ppm) were found in apple gourd from Karachi and bell pepper from Lahore. In addition, Mn was not detected in eight vegetables from Karachi (eggplant, ridge gourd, potato, cucumber, onion, bitter gourd, turnip and taro) and seven vegetables from Lahore (ridge gourd, potato, carrot, onion, apple gourd, turnip and taro).

According to present study, the average concentration of Mn in carrot of Karachi was found 5.4 ppm which was higher than the value (1.2 ppm) reported by Ismail *et al.* (2011). On the other hand the value in bell pepper (1.00 ppm) from Karachi was lower than the value (8.8 ppm) reported by Ahmed *et al.* (2012). Among the vegetables from Lahore, the average concentration of Mn in cucumber (0.6 ppm), bell pepper (0.4 ppm) and eggplant (3.8 ppm) was found lower than the values reported by Ahmed *et al.* (2012). Furthermore, concentration of Mn

in cucumber was also measured less than the value reported by Ismail *et al.* (2011). In addition, concentration of Mn in bitter gourd and eggplant was higher than the values reported by Ismail *et al.* (2011). Comparison of the results showed that the average concentrations of Mn in different vegetables procured from Karachi and Lahore were found within the WHO permissible limits as WHO standards have set permissible limit for Mn at higher value i.e. 500 ppm (Table 1; Codex, 2007).

**Daily Intake of Metals (DIM):** Computed values of daily intake of metals (DIM) due to the consumption of vegetables procured from local market of Karachi were shown in Fig. 2. Reference oral dose values for Pb, Cd, Zn and Mn were  $4 \times 10^{-3}$ ,  $1 \times 10^{-3}$ ,  $3 \times 10^{-1}$  and  $3.3 \times 10^{-2}$  mg/person/day respectively (Mahmood and Malik, 2014). The Reference oral dose for Fe was 60 mg/person/day (Jolly *et al.*, 2013). Comparison of the DIM values with reference oral dose had indicated that the values were within the limit for Fe and Mn. However the DIM values of Pb calculated for onion, turnip, eggplant, taro and ridge gourd had surpassed the reference oral dose value. The DIM values of Cd calculated for all the vegetables procured from Karachi were exceeded than reference oral dose value while only DIM values of Zn calculated for onion, bell pepper, ridge gourd and apple gourd were yielded above the reference oral dose value.

Calculated values for daily intake of metals (DIM) due to the consumption of vegetables procured from local market of Lahore were plotted in Fig. 2. Comparison of the DIM values with reference oral dose values indicated that the values were within the limit for Cd, Fe and Mn. However the DIM values of Pb calculated for carrot, potato, bitter gourd and apple gourd were exceeded from reference oral dose value while in case of Zn it had gone beyond the reference oral dose value for onion, bell pepper, cucumber, taro and carrot. DIM values of this study were compared with results of Khan *et al.* (2010) and were found to be consistent for Pb where the calculated DIM value elevated above reference oral dose value. However the DIM results of Cd obtained for the vegetables procured from Karachi, were not in agreement with results reported by Khan *et al.* (2010) where the calculated DIM was within the reference oral dose value.

**Health Risk Index (HRI):** Health risk index greater than one, indicates that the consumption of such vegetables can provoke health risk to the people using these vegetables in their daily diet. Computed HRI values for metals due to the consumption of vegetables procured from local market of Karachi have been exhibited in Fig. 2. It was found that the HRI of Pb obtained for onion, turnip, eggplant, taro and ridge gourd was more than one. HRI of Cd obtained for all the vegetables procured from Karachi was greater than one. HRI of Zn obtained for

**Table 1. Permissible limits of heavy metal and their concentrations in various vegetables of Karachi and Lahore.**

International Standards	Concentration of heavy metals in vegetables (ppm)											
	Pb		Cd		Fe		Zn		Mn			
SEPA China permissible limits	9		0.2		-		100		-			
FSSA India permissible limits	2.5		1.5		-		50		-			
WHO permissible limits	0.3		0.1		425		100		500			
Plant Species	Vegetable	KHI	LHR	KHI	LHR	KHI	LHR	KHI	LHR	KHI	LHR	
<i>Allium cepa</i> L.	Onion	7.484	0	0.266	0.162	34	17.8	74	84	0	0	
<i>Capsicum annuum</i>	Bell pepper	0.002	0	0.45	0.122	10	39.4	68	164	1	0.4	
<i>Cucumis sativus</i> L.	Cucumber	0	0	0	0	6	10	40	116	0	0.6	
<i>Brassica rapa</i> L.	Turnip	1.54	0	1.178	0	25	9.3	8	40	0	0	
<i>Solanum melongen</i> L.	Egg plant	1.97	0.362	0.368	0.136	1.28	24.8	34	20	0	3.8	
<i>Colocasia esculenta</i> L.	Taro	1.416	0	0.394	0	3.2	84.4	18	84	0	0	
<i>Luffa acutangula</i> L.	Ridge gourd	0.0014	0	0	0	31.2	25.8	96	30	0	0	
<i>Daucus carota</i> L.	Carrot	0.334	5.192	1.046	0	31.2	19.6	8.8	92	5.4	0	
<i>Solanum tuberosum</i> L.	Potato	0.816	6.266	0	0	31.2	21.2	6.5	22	0	0	
<i>Momordica charantia</i> L.	Bitter gourd	0	3.696	0	0	31.2	9.4	56	42	0	4.4	
<i>Praecitrullus fistulosus</i>	Apple gourd	0	7.308	0.684	0	31.2	11.8	116	56	0.4	0	

**Table 2. Comparison of the average concentration of Pb and Cd found in various vegetables of Karachi and Lahore with the results of other previous studies.**

Study Reference	Bitter gourd		Potato		Onion		Cucumber		Egg plant		Bell pepper		Turnip		Carrot	
	Pd	Cd	Pd	Cd	Pd	Cd	Pd	Cd	Pd	Cd	Pd	Cd	Pd	Cd	Pd	Cd
Present Study (KHI)	NT	NT	0.816	NT	7.484	0.266	NT	NT	1.97	0.368	0.002	0.45	1.54	1.178	0.334	1.046
Present Study (LHR)	3.696	NT	6.266	NT	NT	0.162	NT	NT	0.362	0.136	NT	0.122	NT	NT	5.192	NT
Mahmood <i>et al.</i> (2014)	ND	ND	0.21	0.21	ND	ND	ND	ND	ND	ND	ND	ND	0.36	0.36	0.29	0.29
Khadeeja <i>et al.</i> (2013)	ND	ND	ND	ND	1.28	0.03	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ahmed <i>et al.</i> (2012)	ND	ND	ND	ND	ND	ND	1.14	0.1	2.43	1.5	1.64	0.85	ND	ND	ND	ND
Abbas <i>et al.</i> (2010)	0.018	0.016	0.091	0.04	0.006	0.079	0.069	0.037	0.036	0.025	ND	ND	0.019	0.05	ND	ND
Parveen <i>et al.</i> (2003)	1.52	0.31	0.16	0.08	0.06	0.07	1.72	0.36	1.3	0.31	ND	ND	ND	ND	ND	ND

NT: not detected, ND: Not determined

onion, bell pepper, ridge gourd and apple gourd was more than one while it was less than one for Fe and Mn from all tested vegetables.

HRI values for metals due to the ingestion of vegetables procured from local market of Lahore have also been displayed in Fig. 2. It was found that the HRI of Pb obtained for carrot, potato, bitter gourd and apple gourd was more than one. HRI of Cd, Fe and Mn obtained for all the vegetables procured from Lahore was less than one while it was more than one for Zn from onion, bell pepper, cucumber, taro and carrot of Lahore.

Health risk assessment studies have been reported by some researchers who had identified high levels of Pb in the blood of Children in Karachi (Rahbar *et al.*, 2002) and high levels of Cd in school children of Lahore (Sughis *et al.*, 2011). HRI results of this study were compared with studies of Khan *et al.* (2010) and Singh *et al.* (2012) and were found to be consistent for Pb (HRI > 1). The HRI results of Cd and Zn obtained in this study were compared with the results reported by Jolly *et al.* (2013) and were found consistent where the values of health risk index also raised above one for some vegetables.

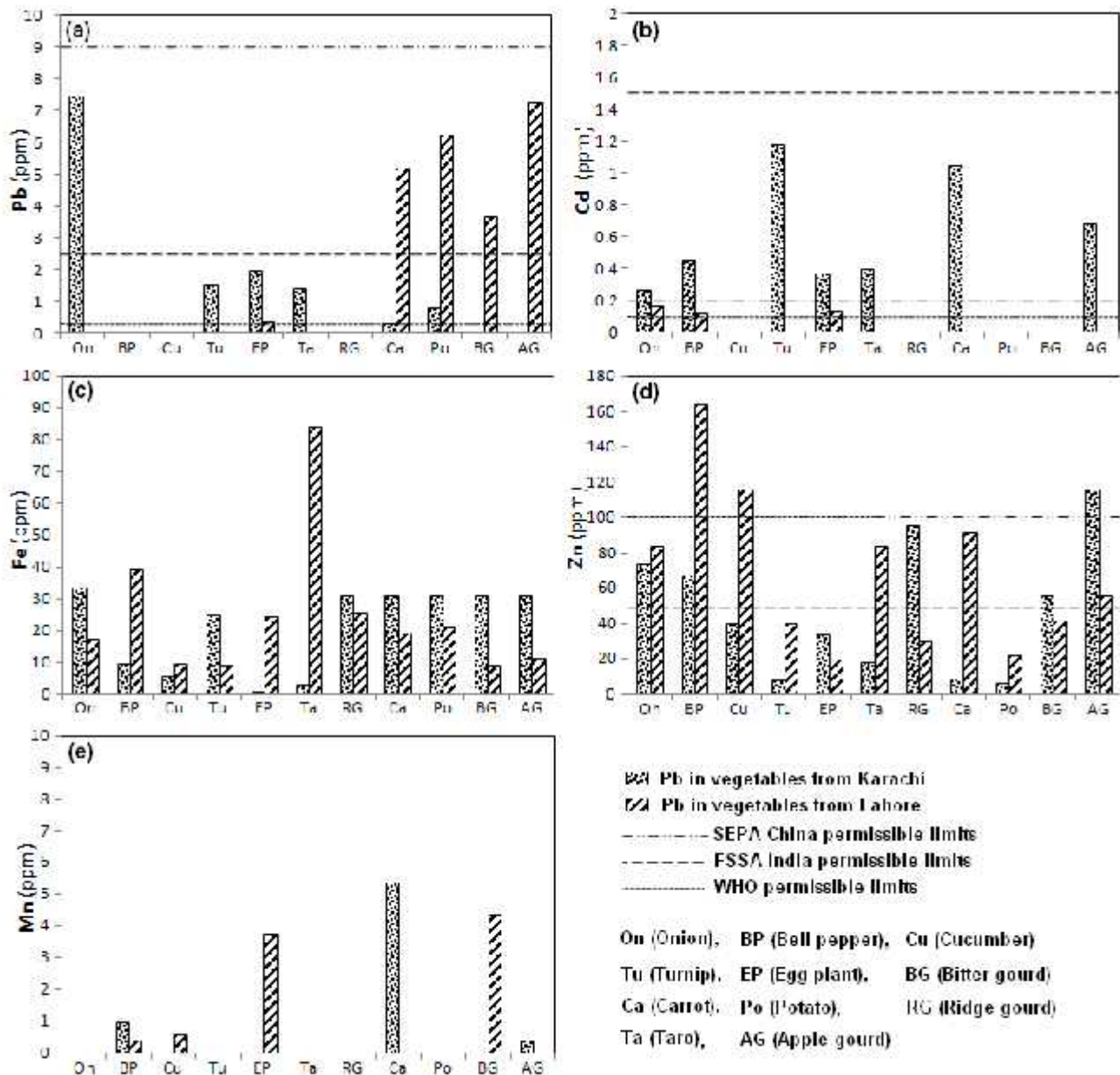
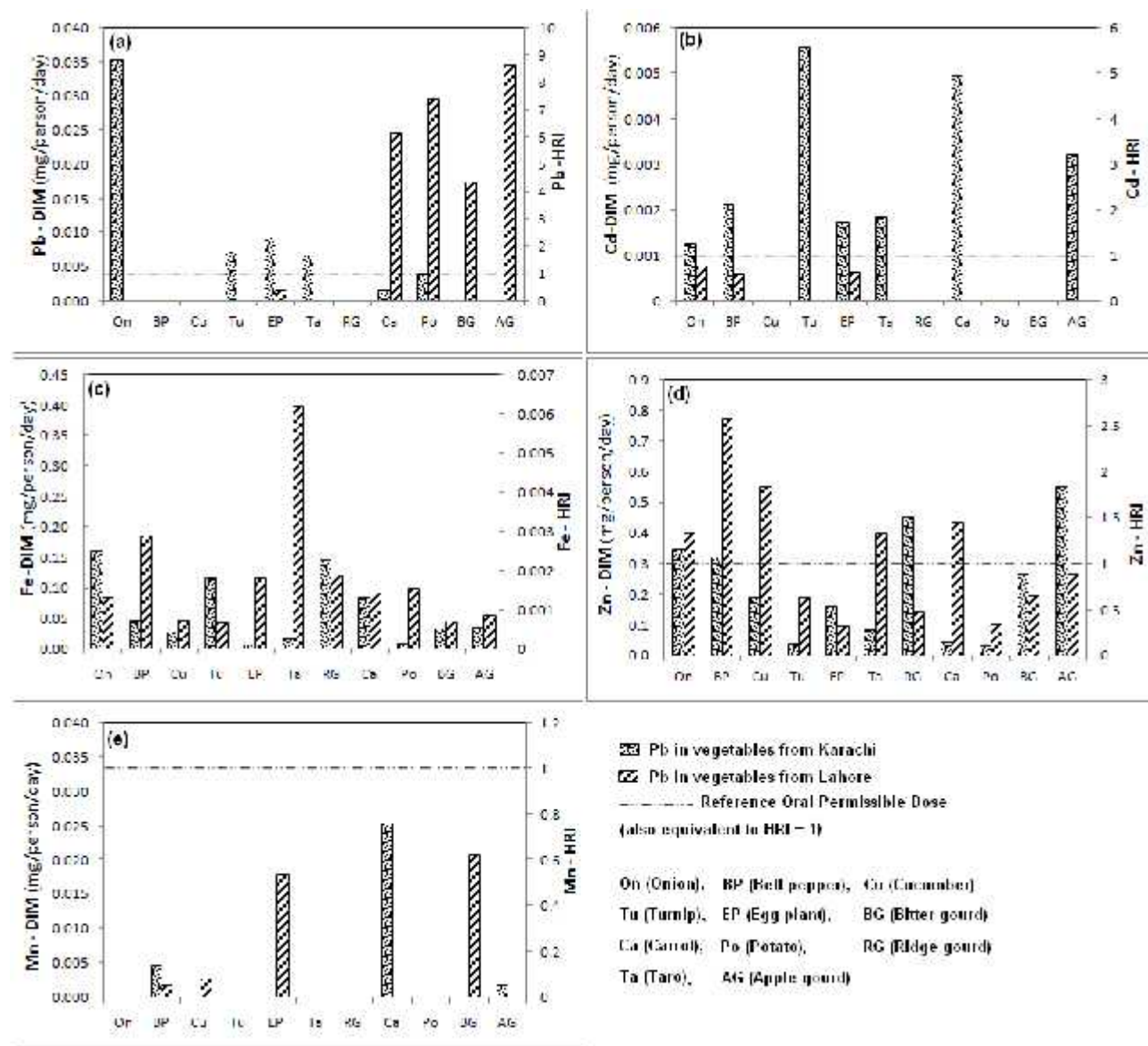


Fig. 1. Comparison of heavy metal concentrations in various vegetables of Karachi and Lahore along with international permissible limits.



**Fig. 2. Comparison of Daily Intake of Metals and Health Risk Index of various vegetables of Karachi and Lahore along with reference oral permissible dose limits.**

**Conclusion:** On the basis of above mentioned results it was concluded that significant amount of Pb and Cd toxic metals have been build up in different vegetables auctioned in Karachi and Lahore markets probably due to large scale anthropogenic activities in these mega cities whereas some essential metals were also more accumulated in these vegetables. Generally, the extent of heavy metal enrichment in terms of ppm was found in the order of Zn > Fe > Pb > Mn > Cd. Research revealed that most of underground vegetables (root/tuber/bulbs etc) have a higher tendency to accumulate heavy metals as compared with the others aerial vegetables (leafy, stem, flower, buds etc) which indicated that main route of heavy metal bioaccumulation in plants was contaminated soil irrigated with polluted water. HRI indicated that the

most of aerial vegetables sold in Karachi and Lahore markets were generally free from health risk; however, some underground vegetables pose a serious health risk, particularly in terms of Cd and Pb.

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