Estimation of Heavy Metals and Associated Health Risk in Selected Vegetables Grown in Peri-Urban Areas of Multan and Rawalpindi, Pakistan

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Abstract. Food security is a serious issue in developing countries like Pakistan because of ever-increasing population. To feed the hunger population, safe and nutritious vegetables are growing concern as they are being polluted by heavy metals. The present study was conducted to investigate the concentration of heavy metals such as cadmium (Cd), chromium (Cr), lead (Pb), nickel (Ni), iron (Fe), manganese (Mn), and zinc (Zn) in highly consumed vegetable collected from peri-urban markets of Rawalpindi and Multan region. Health risk associated with the consumption of these vegetables in term of estimated daily intake of metals (EDIM) and health risk index (HRI) was also evaluated among local consumers. Results showed that mean values of cadmium (Cd), and lead (Pb) in all vegetable samples from both region were exceeding the respective MAL set by FAO/WHO. Estimated daily intake of heavy metals was found below than the permissible limit. EDIM showed following decreasing trend Fe > Zn > Mn > Ni > Pb > Cr and Cd, respectively. The health risk index (HRI) for all heavy metals were less than the threshold level (1), indicating no significant threat to the local population through the consumption of these vegetables.

Keywords: food safety, EDIM, HRI, Pakistan

Introduction

Vegetables are a vital part of our diet and are known as an inexpensive. Pakistan is producing a variety of vegetables to satisfy local as well as international demand. Being agro-based economy about 70% of our population is directly or indirectly associated with this sector. The total area under vegetable cultivation is about 2% of the total crop production, while the export share is very low 0.22% GOP (2013). Vegetables are very rich sources of important biochemical and nutrients like carotene, carbohydrates, calcium, iron, ascorbic acid and extensive concentration of trace minerals Jimoh and Oladiji (2005). These are the basic sources of energy, especially in poor countries. The minimum daily consumption of fruits and vegetables should be more than 400 g per person as described by World Health Organization (WHO) in order to get numerous nutrients for optimum health studied by Lock *et al*. (2005). In Pakistan per capita daily intake of vegetable is 134 g which is 66.5% below than the minimum recommended levels of 400 g per day GOP (2013).

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Food safety is the key issue, especially in the developing countries. Production of the safe food is a big challenge and an important aspect of food quality assurance as well as public health. Generally, fruits and vegetables are irrigated with groundwater and other freshwater reservoirs. However, due to water scarcity in developing countries the reliance on groundwater has increased which is usually expensive and also poor in quality due to sodium adsorption, high electrical conductivity, sodium carbonate residues, and heavy metals Murtaza *et al*. (2008). Furthermore, domestic wastewater and industrial effluents have become an alternate source of irrigation, especially in the Peri-Urban areas. In developing countries, approximately 80% of the wastewater generated is estimated to be used to irrigate crops without prior treatment which is describe by Ensink *et al*. (2004). In Pakistan, approximately 30% of wastewater is used for irrigation, while rest of water is discharged into rivers without any treatment FAO (2002). The use of wastewater for irrigation purpose is controversial due to associated benefits and health concerns. Wastewater application has several disadvantages including the groundwater contamination, addition of heavy metals and organics in the soil resulting in a favourable environment for the growth of harmful micro-organisms Mapanda *et al*. (2007)

Dietary revelations to toxic metals (lead, cadmium and copper) and metalloid (arsenic) have been known as a danger to human health through the intake of different vegetables. This condition results in uneven degrees of health complications depending on the degree of exposures Demirezen and Aksoy (2006). Furthermore, the contaminated food intake with heavy metals can seriously decarease in immunological defences of malnutrition related disabilities, intrauterine growth retardation and a high incidence of upper gastrointestinal cancer (Zakir *et al*., 2009; Khan *et al*., 2008; Muchuweti *et al*., 2006). In addition, such metals like iron (Fe), zinc (Zn), copper (Cu) and manganese (Mn) require in small amount and known as trace elements. Among these, zinc and copper are essential for vital physiological and biochemical roles and necessary for sustaining health throughout the life. In developing countries, prompt and un-organized urbanization and industrialization have contributed to the high level of heavy metals in the urban environment (Wong *et al*., 2003). Heavy metals are persistent and non-biodegradable environmental pollutants which may be dumped on the surfaces of crop and later diffused into the tissues of the plants. In some areas, contamination of water by heavy metals is almost unavoidable because of the natural process (weathering of rocks) and human activities (domestic, agricultural and industrial effluents). Wastewater from the industries of electroplating, paint, mining or chemical laboratories frequently contains a high concentration of heavy metals including lead, cadmium and copper studies Raouf and Raheim (2016). These elements at above concentration not only could manage toxic effect in vegetables but also enter to the food chain, get bio-magnified and pose a significant threat to human health by Haiyan and Stuanes (2003). Application of wastewater for crop cultivation is known as an important source of heavy metals in soil Mapanda *et al*. (2005). Excessive level of metals in vegetables is specified due to use of untreated wastewater for a long time (Sharma *et al*., 2008). The presence of metallic compounds in fertilizers impart an extra source of metal contamination for vegetables (Yusuf *et al*., 2003). Atmospheric uptake of heavy metals from gas emission has also been known to contribute heavy metal pollution in vegetable crops Wiinikka *et al*. (2013).

The Pakistani population is increasingly growing leading to an immense demand for food to eat its needs. Most farmers are also illiterate and are unaware of the non-judicial use of agrochemicals. Pakistan is one of the leading country in which agrochemicals are widely used to increase their production. The frequent application of agrochemicals also contaminated the soil and water sources. Ultimatitly, these residues pave the way in the human body through oral, dermal and inhalation. The recent advances in the analytical chemistry have made it possible to even detect the traces of these toxic elements resulting in serious threat to the export of fruits and vegetables to the technically advanced countries in WTO scenario. This situation demands screening of locally produced vegetables for heavy metals as well as other toxins not only for export purpose but also for the safeguard of the human health. The aim of this study was to investigate the heavy metals concentration in highly consumed vegetables grown in Peri-Urban areas of two major divisions of Punjab and also evaluate their associated health risk among the local population. To the best of our knowledge, no or very few studies of this kind had been reported in the proposed study location with rarely focusing potential health risks of heavy metals exposure.

Materials and Methods

Procurement of raw material. Total of 51 vegetables samples *i.e.* potato (*Solanum tuberosum*), onion (*Allium cepa*), carrot (*Daucus carota*), turnip (*Brassica rapa*), cucumber (*Cucumis sativus*), tomato (*Solanum lycopersicum*), cauliflower (*Brassica oleracea*), pea (*Pisum sativum*), brinjal (*Solanum melongena*), bitter gourd (*Momordica charantia*), round gourd (*Praecitrullus fistulosus*), and okra (*Aesculantus malvaceae*) were collected from six Peri-Urban markets of two regions *i.e.* Multan and Rawalpindi, Punjab, Pakistan. The samples were packed into a polyethylene bag and immediately transferred to Food and Nutrition Laboratory of the National Institute of Food Science and Technology for subsequent analysis. All reagents analytical grade were procured from Merck (Merck KGa A, Darmstadt, Germany).

Preparation of vegetable samples. The selected vegetables were rinsed with tap water in order to remove adhered soil, dust, dirt and other contaminants. The collected samples were reduced to an appropriate size by using hand knife. The reduced samples were kept in the dehydrator (Harvest Saver R-5A, commercial dehydrator systems Inc. Oregon, USA) at 55-60 ºC till complete dryness. The dried vegetable samples were ground into fine powder using a household blender (WF-8814 West Point, France) and then stored in polyethylene bags. This dried sample was further used for determination of heavy metals.

Sample analysis. The heavy metals (cadmium, chromium, lead, nickel, zinc, manganese and iron) in vegetable samples were determined by following the procedure described by Huang *et al*. (2013). Briefly 5g powdered sample was added into 100 mL Erlenmeyer flask. Concentrated HNO_3 (10 mL) and $HCLO_4$ (5 mL) were added to the sample followed by heating on a hot plate at 180 °C for 1.5 h till the volume was reduced to 1-2 mL and the samples become colorless. Finally, the sample was filtered into a clean volumetric flask and diluted with double deionized water. The solution was analyzed by mean of atomic absorption spectrometer (AA240, Varian Inc. Victoria, Australia) equipped with a graphite furnace for Ni, Cr, Cd, and Pb content.

Validation of analytical method. Blank sample and certified reference material (CRM) was prepared using the aforementioned digestion procedure and then run to check the accuracy of the analytical procedure. The reference material GBW10011 was purchased from National Research Center for Certified Material, China (NRCCRM). Qualitative results were obtained and the recoveries for all metals were ranged b/w 83.7-99.4%.

Survey on vegetables consumption. A survey was performed, while collecting the samples. A self-administered questioner was used to obtain information about vegetable consumption. Total 250 people both male and female with age limit of 18-50 years were invited to participate in this survey. Basic information age, body weight and daily consumption rate including species was gathered to evaluate the daily intake of metals and health risk assessment. Average body weight calculated was 63.5 Kg and the consumption rate of each vegetable is presented in (Table 3).

Calculation. Basic descriptive test (mean, standard deviation) was calculated by using SPSS for window version 18.0 (SPSS Inc., Chicago).

Estimated daily intake of heavy metals. The estimated daily intakes of heavy metals were calculated by using their mean value in vegetable sample. To evaluate EDIM following formula was used;

$$EDIM = FIR \times C_f \times Cm/Bw$$

Here, FIR represent food ingestion rate, C_f conversion factor (0.085) for conversion of fresh to dry weight, Cm represent heavy metal concentration and Bw mean average body weight.

Health risk index (HRI). Health risk index was calculated by using the formula proposed by USEPA (1998).

$$HRI = EDIM / RfD$$

R_fD represents oral reference dose for each toxic heavy metal. The R_fD for different heavy metals set by WHO/ FAO are as follows; 0.007, 1.5, 0.025, 8.25, 0.3, 0.02, and 0.14 mg/Kg for Cd, Cr, Pb, Fe, Zn, Ni, and Mn, respectively . If the HRI > 1 then the exposed population likely to experienced significant health risk, if HRI < 1 then the population is considered as safe.

Results and Discussion

Metal concentrations in vegetables. Heavy metals have been widely known to adversely affect the nutritive value of agricultural goods on account of their lethal impact on a human being. Regulatory agencies such as Codex, EU, and FAO have identified the maximum residual levels (MRLs) of toxic metals and pesticides in human food in the WTO scenario. In Pakistan, the major apprehension is the non-judicial use of agrochemicals like fertilizers, pesticides and irrigation with sewage and industrial effluents especially in the Peri-Urban location of major cities. In the present study, the vegetables samples collected from Peri-Urban areas of Multan and Rawalpindi regions were analyzed for the determination of different heavy metals such as cadmium (Cd), chromium (Cr), lead (Pb), nickel (Ni), manganese (Mn), iron (Fe) and zinc (Zn) that compared with their maximum residual limits (MRLs). The mean values of the heavy metals in selected vegetables procured from Rawalpindi region are summarised in

(Table 1). Maximum and the minimum Cd contents in vegetable samples were found in pea (1.865 mg/Kg) and cauliflower (0.467 mg/Kg), respectively. Among Multan samples (Table 2) maximum Cd content was found in bitter gourd (0.786 mg/Kg) followed by okra (0.678), while the least content was observed in tomato (0.123 mg/Kg). Cd concentration in all vegetable samples exceeded the permissible limit (0.05 mg/Kg) as described by Joint FAO/WHO Expert Committee on Food Additive's Codex (2001). Rawalpindi samples were high in Cd content than Multan possibly because that site was close to the waste inclinator, which produces atmospheric pollution to the surrounding localities. Cadmium (Cd) being a serious accumulative body poison finds a way into the body through water, air, and food and cannot be removed by washing vegetables. Cadmium generally accumulates in liver and kidney Divrikli *et al*. (2003). In Pakistan, farmers are blindly using untreated wastewater for vegetable production especially in the Peri-Urban areas. High cadmium concentration in vegetables is attributed to the mechanism for its easy accumulation by plants Grant *et al*. (1998). In a previous study Naser *et al*. (2009) reported Cd concentration for tomato and cauliflower 3.83 and 3.67 mg/Kg, respectively. Likewise, in another study, Khan *et al*. (2013) reported the very high concentration of Cd in vegetables *i.e*. cauliflower and tomato grown in Peri-Urban areas of Lahore Pakistan. Maximum Cd concentration 6.7 mg/Kg was found in cauliflower followed by tomato 6.1 mg/Kg, respectively. Another study reported Cd contents in onion, cucumber and tomato 0.97, 0.64 and 0.41 mg/Kg, respectively Demirezen and Aksoy (2006).

In this study chromium (Cr) content in different vegetables ranged from (1.052-2.482 mg/Kg) with the highest level in onion and the lowest in pea (1.052), respectively (Table 1**).** As shown in (Table 2) samples collected from Multan region showed a wide variation in the ranges of Cr content. The highest Cr content was found in cucumber (5.637 mg/Kg), while the lowest in round gourd (0.955 mg/Kg) (Table 2). Results revealed that Cr content was within the permissible limit (2.3 mg/Kg) among Rawalpindi samples, while Cr content in Multan samples was several folds higher than the permissible limit (2.3 mg/Kg) set by WHO/ FAO Codex (2001). This may be due to the difference in the texture of soil, pH, cation exchange capacity, soil organic contents or due to wastewater irrigation. In another study Shaheen *et al*., 2016 reported low content of chromium (0.2-1.11 mg/Kg) in different vegetable samples grown in Bangladesh. Our results were higher to those reported by Rehman *et al*. (2017) and lower than to those reported by (Khan *et al*., 2015; Liu *et al*., 2005).

In this study lead (Pb) content ranged from (3.04-5.64 mg/Kg) and (1.183-6.96 mg/Kg) among both regions (Table 1 and 2). The following decreasing order was found for Rawalpindi region pea > cauliflower > potato > turnip > cucumber > tomato > carrot. Among Multan

Table 1. Mean concentration (mg/Kg dw) and standard deviation of heavy metals in the vegetable samples collected from Rawalpindi region.

Vegetables	Heavy metal (mg/Kg)						
	Cd	Cr	Pb	Ni	Mn	Fe	Zn
Fruity(n=36)							
Cauliflower	0.4678±0.180	1.189±0.256	5.002±0.473	9.072±0.647	24.715±2.903	52.359±7.840	21.944±7.003
Tomato	1.0500±0.360	2.459±0.494	3.309±0.360	7.086±0.596	18.158±2.578	52.231±16.654	25.929±4.023
Cucumber	1.1422±0.110	1.282±0.514	4.245±0.755	9.106±0.379	16.311±3.390	73.941±28.149	28.418±3.831
Pea	1.8656±0.143	1.053±0.131	5.648±0.477	3.658±0.216	27.854±7.984	64.576±11.341	24.071±4.387
Rooty (n=36)							
Onion	0.9578±0.130	2.483±0.364	4.202±0.951	9.266±0.966	15.526±5.409	76.767±34.465	16.641±3.340
Potato	1.1111±.072	1.551±0.148	4.973±0.263	7.292±0.450	8.333±1.108	42.019±2.764	20.447±4.332
Turnip	1.3256±.087	1.634±0.149	4.266±0.862	5.286±0.282	9.642±1.478	37.512±3.390	25.831±5.165
Carrot	1.0967±.046	1.967±0.312	3.045±1.110	3.356±0.211	19.728±2.305	47.086±7.890	24.824±5.132
MRL							
FAO/WHO	0.05	2.3	0.1	10	-	465	60
SEPAC	0.2	0.5	-	10	-	-	100

MRL= Maximum Residual Limit ; dw = dry weight; n = number of samples; SEPAC = State environmental protection administration, China region variation in lead content was in the following order; round gourd > potato > cucumber > bittergourd > onion > okra > tomato > cauliflower > brinjal. Lead content in all vegetable samples were above than the maximum permissible level (0.1 mg/Kg) as recommended by FAO/WHO Codex (2001). High concentration of lead (Pb) in these vegetables is attributed to pollutants in irrigation water and due to heavy traffic pollution. Parveen *et al*. (2003) also reported high concentration of lead in cucumber (1.72 mg/Kg) and tomatoes (1.56 mg/Kg), respectively and declare those vegetables unsafe for health. In another study Sharma *et al*. (2008) reported lead (Pb) concentration (1.56 µg/g) in cauliflower collected from different market sites of India. Present finding showed a higher concentration of lead (Pb) than those reported by (Zhou *et al*., 2007).

In vegetable samples, the maximum and the minimum value of the nickel (Ni) were 9.071 mg/Kg in cauliflower and 3.355 mg/Kg in carrot, respectively (Table 1). Nickel content in Multan sample was in the range of 4.07-7.90 mg/Kg (Table 2). Nickel content in all vegetable samples was below than the permissible limit of 10 mg/Kg set by joint FAO/WHO Codex (2001). In a previous study Naser *et al*. (2009) reported highest contents of nickel (Ni) in tomato ranged from (2.03-4.95µg/g) followed by cauliflower (1.69-4.44µg/g), respectively. Present result endorses the previous finding of Rehman *et al*. (2017) who reported nickel content in different vegetables ranging (1.83-7.69 mg/Kg). Present findings are also corresponding to the results of Yusuf *et al.* (2003).

The mean concentrations of manganese (Mn) ranged from (8.33-27.85 mg/Kg) in the Rawalpindi samples. Highest concentration was found in pea (27.85 mg/Kg) followed by cauliflower (24.69 mg/Kg), carrot (19.72 mg/Kg), tomato (18.15 mg/Kg), cucumber (16.31 mg/Kg), onion (15.52), and turnip (9.64 mg/Kg). The lowest concentrations were found in potatoes (8.33 mg/Kg). The highest and lowest concentrations were found in bitter gourd (45.56 mg/Kg) and brinjal (7.90 mg/Kg), An essential element is Manganese (Mn). Plant requires manganese to perform metabolic processes but their excessive accumulation can harm the consumer Sharma *et al*. (2006).

Iron (Fe) showed high concentration in vegetable samples. Among Rawalpindi samples, highest concentration was detected in onion (76.765 mg/Kg), while the least concentration was found in turnip 37.51 mg/Kg (Table 1). Vegetable samples from Multan showed higher concentration ranged from 46.758-156.784 mg/Kg (Table 2). Iron act as a micronutrients, if present in trace amount. Excess of iron associated with many health implications. In the literature, very high concentration of iron (364 µg/g) in different vegetables was reported by Ali and Al- Qahtani (2012). Similarly Khan and colleagues reported high iron

Table 2. Mean concentration (mg/Kg dw) and standard deviation of heavy metals in the vegetable samples collected from Multan region.

Vegetables	Heavy metal (mg/Kg)						
	Cd	Cr	Pb	Ni	Mn	Fe	Zn
Fruity(n=63)							
Cauliflower	0.1289±0.089	1.2088±0.476	1.8422±0.507	4.076±1.006	12.725±1.350	46.758±6.089	27.653±2.750
Tomato	0.1233±0.049	3.0533±0.369	1.9589±0.169	7.014±0.305	12.299±1.415	59.579±2.451	16.543±6.118
Cucumber	0.1356±0.077	5.6378±0.602	5.8422±1.356	6.984±2.387	31.036±21.078	91.253±24.010	28.535±3.811
Brinjal	0.3611±0.106	1.9556±0.417	1.1833±0.315	7.9045±.101	7.9045±.101	78.708±18.155	20.569±2.252
Round Gourd	0.3322±0.225	0.9556±0.201	6.9678±0.5271	6.0057±0.319	17.796±1.771	77.377±20.02	28.074±6.444
Bitter Gourd	0.7867±0.126	3.78±0.513	4.6189±0.431	7.7412±0.416	45.566±6.178	153.784±14.52	24.212±7.556
Okra	0.6789±0.087	1.6878±0.272	2.7911±0.303	4.1856±0.127	32.296±3.3094	121.298±7.211	23.797±5.706
Rooty(n=18)							
Onion	0.1267±0.04	1.9411±0.340	4.1656±0.411	7.2767±0.589	26.026±7.586	135.445±7.859	19.5±2.963
Potato	0.2356±0.067	2.7956±0.370	6.5211±0.464	4.2122±0.320	14.136±5.557	58.642±9.142	22.585±4.400
MRL							
FAO/WHO	0.05	2.3	0.1	10	-	465	60
SEPAC	0.2	0.5	-	10	-	-	100

MRL= Maximum Residual Limit ; dw = dry weight; n = number of samples; SEPAC = State Environmental protection Administration, China

Table 3. Estimated daily intake of metals (EDIM) through consumption of different vegetables grown in both regions.

Vegetables	Consumption g/day/person	Estimated daily intake of metals (mg/day)						
		Cd	Cr	Pb	Ni	Mn	Fe	Zn
Cauliflower(R)	120	7.514E-05	0.000191	0.000804	0.001458	0.00397	0.008412	0.0035248
Cauliflower(M)	120	2.071E-05	0.000195	0.000296	0.000655	0.002044	0.007511	0.0044418
Tomato (R)	130	0.0001827	0.000428	0.000576	0.001234	0.001859	0.009089	0.004512
Tomato(M)	130	2.146E-05	0.000532	0.000341	0.001221	0.001259	0.010368	0.0028786
Cucumber (R)	74	0.0001	0.000126	0.000421	0.000902	0.001616	0.007325	0.0028149
Cucumber (M)	74	0.0000	0.000559	0.000579	0.000692	0.003074	0.009040	0.0028265
Pea	120	0.0003	0.000170	0.000908	0.000588	0.004474	0.010373	0.0038665
Brinjil	110	0.0001	0.000289	0.000175	0.001168	0.001167	0.011621	0.0030369
Round gourd	118	5.248E-05	0.000151	0.001101	0.000949	0.002811	0.012222	0.0044343
Bitter gourd	104	0.0001096	0.000527	0.000644	0.001078	0.006343	0.021409	0.0033705
Okra	170	0.0001545	0.000385	0.000636	0.000953	0.007349	0.027603	0.0054152
Onion (R)	90	0.0001154	0.000300	0.000507	0.001117	0.00187	0.009249	0.0020048
Onion (M)	90	1.527E-05	0.000234	0.000502	0.000877	0.003135	0.016318	0.0023492
Potato (R)	86	0.0001280	0.000179	0.000751	0.000840	0.00097	0.004838	0.0023538
Potato (M)	86	2.713E-05	0.000322	0.000751	0.000485	0.001646	0.006751	0.0025999
~~Turnip~~	~~86~~	~~0.0001527~~	~~0.000189~~	~~0.000492~~	~~0.000609~~	~~0.00111~~	~~0.004319~~	~~0.0029736~~
Carrot	128	0.0001880	0.000337	0.000522	0.000575	0.00338	0.008068	0.0042534
EDIM from all vegetables		0.0017240	0.005107	0.009998	0.015393	0.0184507	0.184507	0.0576566
MTDI0.021			0.2	0.21	0.3	2-5	-	60

M = sample collected from Multan; R = Sample collected from Rawalpindi; MTDI = Maximum tolerable daily intake

contents (73-190 mg/Kg) in cauliflower and tomato, which is similar to the current finding of Khan *et al*. (2013). Farmer are not well trained in Pakistan and blindly use wastewater to irrigate vegetables and other crops without taking into account their consequences. Heavy metals accumulations is due to direct use of untreated wastewater. Furthermore, non-judicial applications, of agricultural practices imparts to food stuffs an alternative source of heavy metal.

Zinc (Zn) concentration in vegetable samples varied in the range of 16.64-28.41 mg/Kg with least concentration in onion and maximum concentration in cucumber (Table 1). Among Multan samples, highest concentration was observed in cucumber (28.53 mg/Kg), whereas lowest concentration was detected in tomato (16.54 mg/Kg) (Table 2). All the vegetable samples were within the maximum permissible limit of 60 mg/Kg set by FAO/WHO. Zinc is most important and a vital trace component for higher plants and animals and also play a role in energy metabolism, transcription and translation due to the variety of enzyme systems (Meunier *et al*., 2005). In some soil, the higher amount of zinc is associated to human activities and it is potentially dangerous. Excessive contents in soil results in phytotoxicity and eventually enter to the food chain. Results obtained from the present study were similar to those obtained by Mohammad *et al*. (2003) who found Zn contents in cucumber 32.3µg/g and 20.08 mg/Kg, respectively.

Estimated daily intake of heavy metals. Heavy metals are comon componeuts in the Earth's crust that are not degradable. There are several pathways of heavy metal exposure in our body. These enter our body through different routes like food, drinking water, and air and cause many serious effects even at very low concentration. The explantion behind the toxicity of heavy metals is that they are noncompetitive inhibitors for numerous enzymes Esposito *et al*. (2001). Table 3 summarizes the estimated daily intake of metals (EDIM) of seven metals (Cd, Cr, Pb, Ni, Mn, Fe, and Zn along with maximum tolerable daily intake (MTDI). EDIM were evaluated following the mean concentrations of each metal in each vegetable and the respective consumption rate among the masses. Iron (Fe) showed highest daily intake 0.185 followed by Zn (0.058), Mn (0.049), Ni (0.015), Pb (0.009), Cr (0.0051), and Cd (0.0018) mg/day, respectively. It is obvious from the finding that the daily intake of all the metals was less than the respective MTDI.

Table 4. Health risk assessment of heavy metals from consuming different vegetables grown in both regions.

Vegetables	Health risk index						
	Cd	Cr	Pb	Ni	Zn	Fe	Mn
Cauliflower(R)	1.074E-05	1.274E-07	3.214E-05	7.286E-05	1.175E-05	1.019E-06	2.835E-05
Cauliflower (M)	2.958E-06	1.295E-07	1.184E-05	3.273E-05	1.481E-05	9.104E-07	1.459E-05
Tomato (R)	2.611E-05	2.853E-07	2.304E-05	6.166E-05	1.5041E-05	1.102E-06	1.327E-05
Tomato(M)	3.066E-06	3.543E-07	1.364E-05	6.103E-05	9.596E-06	1.257E-06	8.992E-06
Cucumber (R)	1.643E-05	8.460E-08	1.682E-05	4.510E-05	9.384E-06	8.878E-07	1.153E-05
Cucumber (M)	1.919E-06	3.724E-07	2.315E-05	3.9E-05	9.422E-06	1.096E-06	2.195E-05
Pea	4.282E-05	1.127E-07	3.629E-05	2.938E-05	1.289E-05	1.258E-06	3.195E-05
Brinjil	7.596E-06	1.925E-07	6.989E-06	5.836E-05	1.013E-05	1.409E-06	8.336E-06
Round gourd	7.496E-06	1.007E-07	4.403E-05	4.744E-05	1.479E-05	1.482E-06	2.007E-05
Bitter gourd	1.565E-05	3.509E-07	2.573E-05	5.389E-05	1.124E-05	2.595E-06	4.530E-05
Okra	2.207E-05	2.561E-07	2.545E-05	4.763E-05	1.806E-05	3.346E-06	5.249E-05
Onion (R)	1.649E-05	1.994E-07	2.025E-05	5.582E-05	6.683E-06	1.121E-06	1.336E-05
Onion (M)	2.181E-06	1.559E-07	2.008E-05	4.389E-05	7.831E-06	1.978E-06	2.239E-05
Potato (R)	1.828E-05	1.190E-07	3.003E-05	4.197E-05	7.846E-06	5.864E-07	6.931E-06
Potato (M)	3.875E-06	2.146E-07	3.003E-05	2.425E-05	8.667E-06	8.183E-07	1.176E-05
Turnip	2.181E-05	1.254E-07	1.965E-05	3.043E-05	9.913E-06	5.235E-07	7.927E-06
Carrot	2.685E-05	2.247E-07	2.087E-05	2.873E-05	1.418E-05	9.779E-07	2.414E-05
THRI	0.000247	3.405E-06	0.000399	0.000770	0.000193	2.237E-05	0.000344

M = sample collected from Multan; R = Sample collected from Rawalpindi; THRI = Total health risk index

Assessment of health risk index (HRI). Health risks from the mass consumption of contaminated vegetables is evaluated and summarised in the (Table 4). The health risk index < 1 considered as safe Zheng *et al*. (2007). Results showed that HRI of all the metals fell within the permissible limit (< 1) which indicates that exposed population due to the consumption of these vegetables. The following decreasing order was observed for heavy metals in all vegetable samples NI > Pb > Mn > Cd > Zn > Cr > Fe, respectively.

Conclusion

This study revealed the presence of heavy metals in selected vegetables grown in Peri-Urban areas of Punjab as well as estimated daily intake and the associated health risk by consuming these vegetables. Among both regions, a wide range of variation for different heavy metals in different vegetables were observed. Results revealed that cadmium (Cd), and lead (Pb) content was exceeding their maximum residual limits (MRLs) set by FAO/WHO. From the consumption perspective, EDIM and HRI of all metals were below than the permissible limit hence it is concluded that consumption of these vegetables poses no significant threat to the local population.

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