HEAVY METAL TOXICITY AND HUMAN HEALTH RISK SURVEILLANCES OF WASTEWATER IRRIGATED VEGETABLES IN LAHORE DISTRICT, PAKISTAN

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Abstract: The concentration levels of cadmium (Cd), chromium (Cr) and lead (Pb) in wastewater drains (Gulshan Ravi, Shadbagh and Outfall), soil and wastewater irrigated vegetables (*Brassica campestris* L. *Brassica oleracea capitata, Brassica rapa* L. *Solanum tuberosum* L.) from Lahore District, Pakistan were assessed using atomic absorption spectrophotometer. The general trend for heavy metal level in soil samples was **Pb> Cd> Cr** and within the permissible limits described by European Union. The contamination status of three drains was found high and not considered good for irrigation purpose. The Pb and Cd concentration was higher than the limits (0.1mg/kg and 0.05mg/kg) set by FAO (Food and Agriculture Organization) and WHO (World Health Organization) in all vegetable samples and maximum Pb was in leafy vegetable (*Brassica campestris* L.) found higher than the Indian standards. Maximum metal transfer factor (MTF) was recorded for Cd in *Brassica rapa* L. (0.947). Daily intake metal for Pb was maximum and above the WHO permissible limits by the consumption of *Brassica campestris* L. and *Solanum tuberosum* L. Health risk assessment of Cd, Cr and Pb by the consumption of wastewater irrigated vegetables revealed least health risk (≤ 1), except for Cd having (HRI ≥ 0.1) that could be the source of potential health risk for the consumers community.

Keywords; Heavy metals, Wastewater irrigation, Vegetables, Soil, Health risk assessment, Transfer factor, Daily intake, Health risk index.

1. INTRODUCTION

Water management is fundamental for the safe global food production and water scarcity now became a prime concern in many regions of the World (Rijsberman et al., 2006; Molden, 2007). Water scarcity is putting stress on agricultural practices because irrigation is the largest beneficiary of freshwater use (Khan et al., 2013a). Under the condition of increased freshwater scarcity, wastewater is now recognized as a potential source for irrigation (Ensink et al., 2002; Khan et al., 2013a). About 20 million hectares in 50 countries are irrigated with the urban wastewater and produced 40% of food worldwide (Scott et al., 2004). In developing countries, ineffective implementation of legislation makes the practice more ordinary. Pakistan is an agricultural country and most of its agricultural area situated in semi-arid and the arid climate zone (Butt et al., 2005). About 32,500 hectares land is presently irrigated with wastewater directly in Pakistan (Ensink et al., 2004).

The Lahore district is the second largest metropolitan city of Pakistan and has many clusters of ill-planned industries. These industries discharge their hazardous wastewater into twelve different drains managed by WASA (Water and Sanitation authority) and putting stress on the local environment (The Urban Gazette, 2013). After collecting a huge volume of municipal and industrial wastewater, all the drains carry wastewater through urban and sub urban area of Lahore and ultimately dispose it off into river Ravi (Saleemi, 1990). The vegetables cultivation by the wastewater of these drains in the corresponding peri-urban areas by poor farmers being a cheap source of irrigation water (Mapanda et al., 2007). It is estimated that about 3,304 cubic feet per second (cusecs) of wastewater is being disposed of into the river Ravi from different drains coming from Lahore district (JICA, 2010; Hassan et al., 2016) and approximately 1000 hectares of agricultural land is being irrigated by this untreated wastewater. These toxic heavy metals are accumulating in vegetables through absorption from soil (WWF, 2006). Globally, the heavy metal pollution problem is of great concern due to its negative impacts on environment and human health (Chen et al., 2005; Khan et al., 2011). Toxic heavy metals accumulate in non-edible and edible parts of vegetables cultivated in wastewater-irrigated soil (Perveen et al., 2012). On consumption, these metals may accumulate in human body leading to serious health risks including cancer, anemia, liver, kidney, nervous system, respiratory and metabolic disorders (Khan et al., 2011). In the recent decades, studies on the soils contamination by heavy metals due to wastewater irrigation have been done by various investigators worldwide (Markus & Mcbratney, 1996; Manta et al., 2002; Mico et al., 2006; Shi et al., 2007; Peris et al., 2008; Gjoka et al., 2011; Qiao et al., 2011; Ikenaka et al., 2010; Škrbić, & Đurišić-Mladenović, 2013). In Pakistan, some studies have also been conducted on the wastewater irrigation (Yamin & Ahmad, 2007; Alam et al., 2015; Butt et al., 2005; Mahmood & Malik, 2014; Batool et al., 2016) and health risk assessment associated with it (Jan et al., 2010; Khan et al., 2010; Jamali et al., 2009; Akbar et al., 2009; Mahmood & Malik, 2014; Rehman et al., 2016; Muhmood et al., 2015). However, a lot of research work is yet to be done on the negative impacts of wastewater irrigation on human food and human health with the help of different health risk assessment tools as food safety is gaining importance among public health issues (Khan et al., 2014). Keeping in view the concern about heavy metal contamination of food, the present study was conducted with special emphasis on assessment of selected metals (Cd, Cr and Pb) in some vegetables grown by wastewater irrigation and evaluation of human health risk through daily intake of heavy metals through consumption of vegetables.

2. MATERIAL & METHODS

Lahore (31.34^0 N and 74.22^0 E) is the second largest metropolitan, consisting of about 1121 ill-planned industries, was selected as study area (Mahmood & Malik, 2014). Three sampling sites were selected along the three different drains (Gulshan Ravi drain, Outfall drain and Shadbagh drain) in peri-urban areas of Lahore, where wastewater irrigation was the common practice. Random Sampling was done of drain wastewater, soil and the vegetable samples during winter season from the above mentioned areas irrigated by the wastewater (Fig. 1).

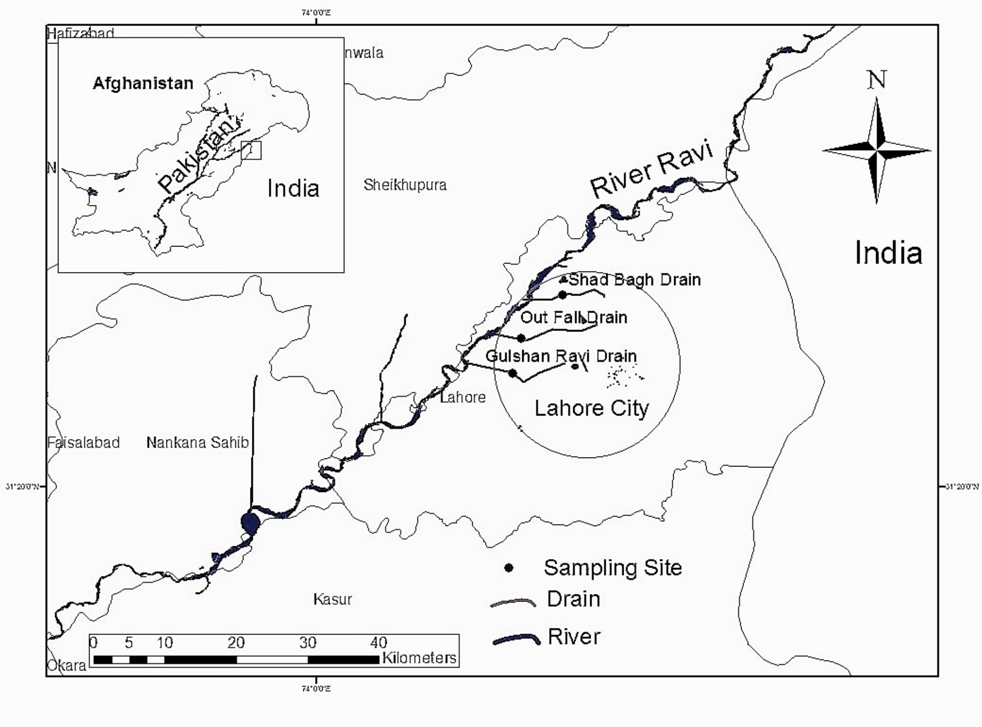

Figure 1. Study area showing sampling locations in vicinities of Lahore, Pakistan.

2.1. Sampling Strategies

Pre-cleaned HDPE (high density polyethylene) plastic bottles were used to collect wastewater samples from different depths to obtain composite sample. A metal-free soap was used to rinse the bottles and soaked overnight in 10 % HNO_3 followed by rinsing with deionized water (Chary et al., 2008; Mahmood & Malik, 2014). The collected samples were transferred to the Water Quality Laboratory of the College of Earth & Environmental Sciences, University of the Punjab, Lahore and stored at 4^0C temperature until analysis (US EPA, 1983). Triplicate samples were obtained by the interval of 3 days. Soil samples were collected from the agricultural land irrigated by the drain wastewater in the vicinity of Shadbagh Drain, Gulshan Ravi Drain and Main Outfall drain. The soil samples were obtained from rhizosphere zone (top 6 inches) in close to the sampled vegetables with the help of plastic scooper in clean polyethylene labeled sampling bags. Stones, gravels and wooden materials were removed from the soil samples, followed by oven drying for 24h at 105^0C to remove the moisture content. The dried samples were then sieved by using 2mm sieve and stored in the polyethylene sampling bags at 4^oC until analysis (Lu, 2000). Fresh vegetable samples viz; Brassica (*Brassica campestris* L), Cabbage (*Brassica oleracea capitata*), Potato (*Solanum tuberosum* L.) and Turnip (*Brassica rapa* L.) irrigated by the drain wastewater in the study area were collected randomly in 3-5 replicates in labeled, clean polyethylene bags. The vegetable samples were transferred to the Laboratory of the College of Earth and Environmental Sciences, University of the Punjab Lahore, Pakistan. In order to remove the air borne particles and any deposition from the vegetables they were cleaned with deionized water and air dried for 24 hours followed by oven drying at 70 – 80^0C for 24 hours to remove the moisture content. The dried samples were then ground into powder form using pestle and mortal to facilitate sample preparation (Wu et al., 2010).

2.2. Sample Preparation and Digestion Protocols

About 50ml drain wastewater samples were digested with the help of 10 ml conc. HNO_3 on hot plate at 80^0C, until the solution appeared transparent. The sample was then cooled at room temperature and filtered with Whatman filter paper No. 42. Volume of each sample was then maintained up to 50ml with deionized water and stored at 4^0C until metal analysis (APHA, 2005).

2.3. Heavy Metal Analysis and Quality Control

One gram (each for vegetable & soil samples) was digested with the 15 ml mixture of HNO_3, $HClO_4$ and H_2SO_4 (5:1:1) at 100^0C on hot plate until the solution appeared transparent. The liquid digested samples were then cooled and filtered using Whatman No. 42 filter paper. Volume of every digest was adjusted up to 50 ml with distilled water and stored at 4^0C until metal analysis (USEPA Method: 3005A). Heavy metal concentrations were determined using Atomic Absorption Spectrophotometer (Perkin Elmer 800) in the College of Earth and Environmental Sciences, University of the Punjab Lahore, Pakistan. Quality control procedures were strictly followed for the entire sample to ensure the quality of results. Analytical grade calibration standards were used for instrument calibration, purchased from Merck (Germany). Glassware, prior to use was double washed with deionized water, rinsed with 10% HNO_3 and baked at 450°C for more than 6 h. Standard of 5, 10, 20, 50, 100, and 200 μg/L were used to quantify the calibration curves.

2.4. Dietary Survey

A dietary survey was conducted for the potential risk assessment regarding wastewater irrigated vegetables consumption with the help of questionnaire containing questions about age, weight, family members, vegetable consumption and source of vegetables. A random selection was done for 150 healthy adults from the general population of Lahore district within study area limits, living at that place greater than 10 years (>10 Years). Dietary questionnaire consisted 4 vegetable items (Brassica, Potato, Turnip, and Cabbage) to have their estimates in Kg / Person/day by using one week recall method technique. Information was obtained about the frequency of consumption and quantity of consumption for selected vegetables. Response rate of participants (male and female) was found 80% with age limit of 19 – 55 Years (Jiang et al., 2005).

2.5. Data Analysis

2.5.1. Transfer Factor (TF)

Transfer of metals from soil to vegetables was evaluated as transfer factor (TF) and calculated by following equation (Khan et al., 2010).

$$\mathbf{MTF} = C_{plant} / C_{soil} \quad \text{……….} \quad (1)$$

Where C_{plant} indicate metal concentration in the plants and C_{soil} is the concentration of metal in soil samples.

2.5.2. Daily Intake of Metals (DIM)

DIM through contaminated vegetables intake in adult was evaluated by data obtained from the survey with the help of a questionnaire. DIM for each vegetable and metal was calculated by the following equation (Chary et al., 2008).

$$\mathbf{DIM} = C_{metal} \times C_{factor} \times D_{food\ intake} / B_{av.\ weight} \ldots .(2)$$

C_{metal} is the metal concentration in plant (mg/Kg). C_{factor} conversion factor (0.085), $D_{food\ intake}$ is the daily vegetables intake; and $B_{av.\ weight}$ represents the average bodyweight, respectively. The average vegetable intake and the average bogy weight outcomes taken from the dietary survey.

2.5.3. Health Risk Index of Metals (HRI)

HRI was calculated by using US EPA method. Value of health risk index depends upon DIM and RfD_{oral} reference dose. Rfd is a measure of per day human body metal exposure without hazardous impacts during the whole life (US-EPA IRIS, 2006; Jan et al., 2010)

$$\mathbf{HRI} = DIM / Rfd \ldots\ldots\ldots\ldots\ldots (3)$$

Rfd values in (mg/kg bw/day) are as described by (US-EPA IRIS, 2006); Cr (1.5), Ni (0.02), Cu (0.04), Pb (0.004), and Cd (0.001).

2.6. Statistical Analysis

Descriptive statistical analysis was done with IBM SPSS (Statistical Package for the social sciences). Whereas, Graph pad prism 6.07 was used for graphs.

3. RESULTS & DISCUSSION

3.1. Concentration Profile of Selected Heavy Metals in Wastewater

Concentration of heavy metal in wastewater drains (Gulshan Ravi drain, Outfall drain and Shadbagh drain) along with National Environmental Quality Standards (NEQS) limits (MOE, 2000) and Irrigation water quality guidelines (WWF, 2007) are presented in Table 1. The decreasing trend for reported concentration of Pb was, Gulshan Ravi drain (0.633mg/L) > Outfall drain (0.393 mg/L) > Shadbagh drains (0.261mg/L) and higher than Cd and Cr in comparison with NEQS limits (MOE, 2000). Order of metal concentration was Pb > Cd > Cr in Gulshan Ravi drain and Shadbagh drain, and Pb > Cr > Cd in Outfall drain. Maximum concentration of Cd (0.168 mg/L) was in Shadbagh drain and the maximum concentration of Cr (0.22 mg/L) reported in Outfall drain. The Cd concentration in Gulshan Ravi drain, and Shadbagh drain and Pb concentration in Gulshan Ravi drain found beyond the permissible limits and only Cr found within the permissible limits (MOE, 2000). In comparison with irrigation water quality guidelines (WWF, 2007), these three drains observed not fit for the irrigation purpose.

Discharge of municipal and industrial sewage is the major source of heavy metals in wastewater drains of Lahore city and high Pb concentration might be due to the number of paint industries, textile industries, leather industries, iron and steel foundries, brick kilns, discharge of hospital waste containing batteries, thermometers, etc. (Mahmood & Malik, 2014) and usage of leaded gasoline nearby these drains. Pb concentration in current study was found higher and Cr and Cd were lower by previously reported from Lahore studies (Mehmood & Malik, 2014; Kashif et al., 2009). However, similar trend of Pb> Cd > Cr was observed by (Iqbal et al., 2015). In comparison with Indian and China studies, relative lower values were found in present study than studies from India (Tiwari et al., 2011) while higher Pb and Cd than those reported from China (Wantong et al., 2014). Detailed comparison of heavy metals in present study wastewater with the some previous studies from the region is given in Table 2.

3.2. Metal Concentration in Soil and Vegetables

Descriptive statistics for the heavy metal concentration in soil and vegetables given in Table 3. Maximum Pb concentration (5.278 mg/kg) was found in rhizosphere soil of *Brassica rapa* L. followed by order *Brassica campestris* L. soil (2.792mg/kg) > *Solanum tuberosum* L. soil (2.463mg/kg) > *Brassica oleracea capitata* (2.117mg/kg) soil. Decreasing trend for concentration of Cd was *Solanum tuberosum* L. soil (0.854 mg/kg) > *Brassica campestris* L. soil (0.725mg/kg) > *Brassica oleracea capitata* soil (0.667mg/kg) > *Brassica rapa* L. soil (0.628mg/kg). Whereas, Cr concentration was observed in order *Brassica oleracea capitata* (0.693 mg/kg) followed by *Brassica campestris* L. soil (0.683mg/kg) > *Brassica rapa* L. soil (0.662mg/kg) > *Solanum tuberosum* L. soil (0.490mg/kg). The Pb, Cd and Cr concentrations were within the Indian permissible limits (Awasthi, 2000) and EU standards (European Commission standards, 2006). Present study soil Cd value found greater than the majority of the Pakistan (Khan et al., 2015; Yousaf et al., 2016; Alam et al., 2015; Khan et al., 2013c) and world average values (Alloway, 1995; Lacatusu, 1995) and less than the Indian study by (Singh et al., 2010a) while Cr and Pb recorded less than the world average values (Alloway, 1995; Lacatusu, 1995). Alam et al., (2015) also found Pb concentration in Lahore city soil which was 32 times higher than allowable toxic limits. Detailed comparison of soil heavy metals concentration from present study with some previous studies is given in Table 4. Different metal concentrations in the rhizosphere of vegetables in same area might be due to the difference in amount of heavy metals in wastewater at that zone or the different removal capacity of vegetables for each metal. Among vegetable samples, the maximum Pb concentration was found in *Brassica campestris* L. (2.766 mg/kg) followed by *Solanum tuberosum* L. (2.166mg/kg) > *Brassica oleracea capitata* (1.576mg/kg) > *Brassica rapa* L. (1.42mg/kg).

Table 1. Descriptive statistics of selected heavy metals in wastewater drains from Lahore, Pakistan.

Sampling Site	Cd (mg/L)		Cr (mg/L)		Pb (mg/L)	
	Mean ± SD	Range	Mean + SD	Range	Mean + SD	Range
Gulshan Ravi drain	0.125±0.003	0.122-0.129	0.111±0.003	0.108-0.114	0.633±0.30	0.43-0.97
Outfall drain	0.076±0.06	0.012-0.115	0.22±0.006	0.213-0.224	0.393±0.12	0.267-0.5
Shadbagh drain	0.168±0.05	0.115-0.197	0.091±0.001	0.09-0.092	0.261±0.05	0.205-0.29
[a]NEQS	0.1	-	1.0	-	0.5	-
[b]Irrigation water quality guidelines	0.01	-	0.01	-	0.1	-

[a] NEQS – National Environmental Quality Standards for Industrial Effluent Discharge (MOE, 2000)
[b]Irrigation Water Quality Guidelines for Pakistan (WWF, 2007)

Table 2. Comparison of mean heavy metal concentration (mg/L) in wastewater of present study with previous studies from the region

Heavy metal	Present Study			Pakistan						India			China
	G.R	O.F	S.B	a	b	c	d	e	f	g	h	i	j
Pb	0.633	0.393	0.261	0.43	0.03	8.208	0.61	0.34	0.920	4.86	0.090	0.34	4.48
Cd	0.125	0.076	0.168	0.19	0.18	8.797	0.23	0.10	0.730	4.31	0.016	1.22	<0.10
Cr	0.111	0.22	0.091	0.33	0.07	9.430	-	-	0.120	4.57	0.053	-	-

G.R - Gulshan Ravi Drain, O.F - Outfall Drain, S.B - Shadbagh Drain
[a]Mehmood & Malik et al., (2014), [b]Kashif et al., (2009), [c]Akhtar et al., (2014)
[d]Randhawa et al., (2014), [e]Khan et al., (2013b), [f]Iqbal et al., (2015), [g]Tiwari et al., (2011),
[h]Singh et al., (2010b), [i]Chandra et al., (2009), [j]Wantong et al., (2014)

Table 3. Descriptive statistics of selected heavy metals in soil & vegetables samples of wastewater irrigated farmlands of Lahore, Pakistan.

Vegetable type	Sample	Cd (mg/kg)		Cr (mg/kg)		Pb (mg/kg)	
		Mean ± SD	Range	Mean ± SD	Range	Mean + SD	Range
Brassica campestris L.	Soil	0.725 ±0.03	0.698-0.756	0.683±0.09	0.593-0.769	2.792±0.26	2.5-3
	Vegetable	0.671 ±0.05	0.614-0.711	0.549±0.05	0.491-0.583	2.766±0.25	2.5-3
Brassica oleracea capitata	Soil	0.667±0.02	0.645-0.683	0.693±0.08	0.647-0.783	2.117±0.19	2-2.341
	Vegetable	0.516±0.10	0.445-0.632	0.454±0.02	0.438-0.478	1.576±0.07	1.5-1.64
Brassica rapa L.	Soil	0.628±0.04	0.578-0.661	0.662±0.02	0.644-0.689	5.278±0.28	5-5.565
	Vegetable	0.595±0.00	0.587-0.6	0.60±0.140	0.468-0.746	1.42±0.1	1.32-1.52
Solanum tuberosum L.	Soil	0.854±0.06	0.789-0.896	0.490±0.01	0.48-0.502	2.463±0.03	2.432-2.5
	Vegetable	0.648±0.07	0.6-0.732	0.374±0.01	0.363-0.383	2.166±0.85	1.3-3
Permissible Limits							
EU[a]	Soil	3	-	100	-	100	-
Indian[b]		3-6	-	NA[d]	-	250-500	-
FAO/WHO[c]	Vegetable	0.05	-	2.3	-	0.1	-
Indian[b]		1.5	-	20	-	2.5	-

[a] EU – European Union (European Commission Standards, 2006 (EC No. 1881/2006))
[b]Heavy metals permissible limits in soil by Prevention of Food Adulteration Act,1954 (Awasthi, 2000)
[e] FAO – Food and Agriculture Organization & WHO – World Health Organization (FAO / WHO, 2011 (Food CF/5 INF/1))
[d]NA – Not Available

Table 4. Comparison of mean heavy metal concentration in soil samples from present study with some previous studies

Heavy metal	Present study (mg/kg)	Pakistan					India	Nigeria	China	[i]World Average values (ug/g)
		a (mg/kg)	b (mg/kg)	c (mg/kg)	d (ug/g)	e (mg/kg)	f (ug/g)	g (mg/kg)	h (mg/kg)	
Cd	0.719	0.12	11.0	0.31	0.47	0.08	3.12	0.6	0.17	0.06
Cr	0.632	0.42	0.1	8.64	11.44	0.37	19.21	-	46.7	100
Pb	3.163	0.92	39.7	5.25	112.70	-	21.95	-	42.5	10
[a]Khan et al., (2015), [b]Ahmad et al., (2015), [c]Yousaf et al., (2016), [d]Alam et al., (2015), [e]Khan et al., (2013c), [f]Singh et al., (2010a), [g]Obiora et al., (2016), [h]Chang et al., (2013), [i]Alloway (1995) & Lacatusu (1995)										

The Cd level was found in order *Brassica campestris* L. (0.671 mg/kg) > *Solanum tuberosum* L. (0.648mg/kg) > *Brassica rapa* L. (0.595mg/kg) > *Brassica oleracea capitata* (0.516mg/kg). Maximum concentration of Cr was recorded in order *Brassica rapa* L. (0.60 mg/kg) > *Brassica campestris* L. (0.549mg/kg) > *Brassica oleracea capitata* (0.454mg/kg) > *Solanum tuberosum* (0.374mg/kg). Heavy metal concentration of Pb and Cd exceed the FAO/WHO limits (FAO/WHO, 2011)in all vegetables and only Pb in *Brassica campestris* L. was found beyond the Indian standards (Awasthi, 2000) and (FAO/WHO, 2011). High concentration of Pb and Cd in leafy vegetables might be due to the fast transpiration rate and ambient drift into the lenticels and stomata openings after uptake of metals from soil (Iqbal et al., 2015; Luo et al., 2011). Moreover, in Lahore city thousands of tons of Pb and Cd coated broken ships' steel are recycled by many steel rolling mills and iron and steel foundries, from where wastewater is being discharged untreated or partially treated into drains (Mehmood & Malik, 2014). The wastewater irrigation practice might be the reason for high concentration of Pb and Cd in many vegetables and soil samples. High concentration of Cr in tuber vegetables could be due to the single source of wastewater irrigated soil for metal uptake not from atmosphere. Concentration of heavy metals in cabbage sample of present study found higher than Zhou et al., (2016) and lower than Qadir et al., (2015).

3.3. Transfer Factor (TF)

Soil to plant metal transfer factor (TF) is the key module of heavy metal exposure to human through food chain and important to measure the HRI (health risk index) (Cui et al., 2004). Range of TF was recorded in following order Cd (0.947-0.759) > Cr (0.906-0.655) > Pb (0.390-0.289) for the study area. Highest TF for Cd was observed for *Brassica rapa* L. (0.947) followed by the order *Brassica campestris* L. (0.926) > *Brassica oleracea capitata* (0.774) > *Solanum tuberosum* L. (0.759). Maximum TF of Cr was also observed in *Brassica rapa* L (0.906) > *Brassica campestris* L. (0.804) > *Solanum tuberosum* L. (0.763) > *Brassica oleracea capitata* (0.655). Whereas for Pb, the highest TF was observed in order *Brassica oleracea capitata* (0.390) > *Brassica campestris* L. (0.334) > *Brassica rapa* L. (0.327) > *Solanum tuberosum* L. (0.289). Overall trend of transfer factor of metals was found Cd > Cr > Pb. High TF of Cd in both leafy and tuber vegetables might be due to its less strong retention capacity for soil and high mobile nature in comparison with other metals (Lokeshwari & Chandrappa, 2006). Moreover, the higher transpiration rate and moisture content in leafy vegetables to sustain the growth in plant might be the reason of higher metal uptake in them (Iqbal et al., 2015). On comparison with some previous studies, the TF for Cd, Cr and Pb in current study was found higher than those from Lahore city (Mehmood & Malik, 2014) and Peshawar (Jan et al., 2010). Higher TF for Cr and Cd than Pakistan studies (Khan et al., 2013c) (Khan et al., 2010), Nigeria study (Obiora et al., 2016) as well as lower TF for Cd than recorded by (Khan et al., 2013c), lower Cd TF by *Brassica oleraces capitata* in comparison with Indian study. Detailed comparison of TF calculated from current study with some previous studies of different countries is given in Table 5.

3.4. DIM & HRI

DIM (Daily intake metal) of Cr for adults via the ingestion of wastewater cultivated vegetables was within the range of permissible limits by WHO (1996). However, for Pb, the ingestion of *Brassica campestris* L. (0.0007) and *Solanum tuberosum* L. (0.0006) may cause severe health problems as its DIM exceeds the permissible limits (WHO, 1996) and higher than (Khan et al., 2013c) while Pb and Cd intake recorded beyond the safe limits by WHO (1996) and within the (US-EPA IRIS, 2006) by the intake of vegetables collectively.

Table 5. Comparison of transfer factor (TF), daily intake metal (DIM) & health risk index (HRI) from present study with some previous studies

Heavy metal	Parameter	*Brassica campestris* L.	*Brassica oleracea capitata*	*Brassica rapa* L.	*Solanum tuberosum* L.
Cd	DIM	0.0003[P] 0.00025[b] 0.00113[d]	0.00008[P] 0.00028[d] 9.30×10−5[f] 0.000681[h]	0.00009[P] 0.000144[a] 0.00038[d]	0.0001[P] 0.000234[a] 0.000036[c] 0.00022[d] 0.000015[e] 0.000073[g]
	HRI	0.3[P] 0.25[b] 0.73[d]	0.08[P] 0.75[d] 0.681[h]	0.09[P] 0.0028[a] 0.20[d]	0.1[P] 0.00468[a] 0.13[d] 0.072[c] 0.07[g]
	TF	0.926[P] 0.87[b] 0.340[d]	0.774[P] 0.08[d] 0.47-4.69[f] 2.959[i]	0.947[P] 0.113[d]	0.759[P] 0.96[c] 0.066[d] 0.128[g]
Cr	DIM	0.00008[P] 0.0028[d]	0.00007[P] 0.0032[d] 4.70×10^{-4}[f] 0.00210[h]	0.00009[P] 0.000560[a] 0.0015[d]	0.00006[P] 0.000756[a] 0.000044[c] 0.0017[d] 0.0006[e] 0.00082[g]
	HRI	0.000053[P] 0.0018[d]	0.000047[P] 0.0021[d] 0.014[h] 0.0002[i]	0.00006[P] 0.016[a] 0.001[d]	0.00004[P] 0.0216[a] 0.00003[c] 0.0012[d] 0.00055[g]
	TF	0.804[P] 0.13[d]	0.655[P] 0.14[d] 0.02-0.06[f] 0.175[i]	0.906[P] 0.07[d]	0.763[P] 0.23[c] 0.07[d] 0.036[g]
Pb	DIM	0.0007[P] 0.0066[b] 0.0029[d]	0.00009[P] 0.003[d] 2.80×10−4[f] 0.00194[h]	0.00007[P] 0.000244[a] 0.0008[d]	0.0006[P] 0.000140[a] 0.0005[d] 0.0000082[e] 0.0021[g]
	HRI	0.18[P] 1.9[b] 1.13[d]	0.023[P] 0.28[d] 0.554[h]	0.018[P] 0.00488[a] 0.38[d]	0.15[P] 0.00279[a] 0.22[d] 0.52[g]
	TF	0.334[P] 0.42[b] 0.180[d]	0.390[P] 0.187[d] 0.07- 0.29[f] 0.460[i]	0.327[P] 0.05[d]	0.289[P] 0.032[d] 0.016[g]

P (Present study) [a]Yousaf et al., (2016), [b]Khan et al., (2010), [c]Khan et al., (2013c), [d]Mahmood & Malik (2014) [e]Shaheen et al., (2016), [f]Wang et al., (2012), [g]Obiora et al., (2016), [h]Chauhan & Chuahan (2014) [i]Singh et al., (2010b)

Comparison of current study's DIM with some past studies revealed that the DIM was found higher than those reported by northern Pakistan study (Khan et al., 2013c) and by (Mahmood & Malik, 2014) except Pb and Cd in *Solanum tuberosum* L. higher Cd in *Solanum tuberosum* L. than those reported by Bangladesh study (Shaheen et al., 2016) and lower than those reported from Pakistan study (Yousaf et al., 2016), China study (Wang et al., 2012) Indian studies (Chauhan & Chuahan, 2014; Singh et al., 2010b). The HRI of heavy metals in current study found below than the safe limits (HRI <1) suggest that study area has no health risk. However, the HRI for Cd was relatively high (0.3) for the consumption of *Brassica campestris* L. that might pose higher public health risk. On comparison with some local studies from Pakistan, the DIM calculated for current study was found lower than those reported from Lahore (Mahmood & Malik, 2014) and for only Cr and Cd by the consumption of *Solanum tuberosum* L, higher than from Peshawar study (Khan et al., 2013c). Detailed comparison of present study DIM and HRI values with some previous studies is presented in Table 5.

4. CONCLUSION

This study clearly indicates that heavy metal pollution is of concern at Lahore district due to the wastewater irrigation. Heavy metal concentrations in Gulshan Ravi, Shadbagh and Outfall drains were higher than the NEQS and WWF irrigation water quality guidelines. All soil samples irrigated by above mentioned drains were also higher in metal concentration (Pb> Cd> Cr) than vegetables except *Brassica campestris* L. but reported within the permissible limits (Awasthi, 2000; European Commission Standards, 2006)**.** The Cd and Pb concentration in all the vegetables were higher than FAO/WHO limits, particularly in leafy vegetable. However, health risk assessment outcomes revealed that least health risk is calculated for Pb and Cr at the present in the study area but Cd has HRI (0.3) that might lead to potential health risk to consumers in near future. The process of metals accumulation in soil is going on due to wastewater irrigation practices without any treatment. If the situation remains unchanged it can trigger early metal toxicity. Therefore, Industrial effluent shall be treated prior to disposal into drains to comply with the NEQS.

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