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SURVEILLANCE OF HEAVY METALS IN MAIZE GROWN WITH WASTEWATER AND THEIR IMPACTS ON ANIMAL HEALTH IN PERI-URBAN AREAS OF MULTAN, PAKISTAN

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The study was conducted in peri-urban areas of Multan, Pakistan for the assessment of heavy metals risk on animal health by the consumption of maize as fodder grown with different types of wastewater/water and its source apportionment. Total 120 samples (wastewater, soil, raw milk, and maize plants) from six sites were collected and analyzed for cadmium, chromium, copper, manganese, nickel and lead contents by inductively coupled plasma-optical emission spectrometry (ICP-OES). The maize plants grown with industrial effluents were highly contaminated and exhibited the highest carcinogenic health risk and the lowest at the canal water irrigation site. The Total Target Health Quotient (TTHQ) values ranged between 27.44 and 80.34 at wastewater, 2.32 and 5.0 at canal water and 3.68 and 7.5 at tube well water irrigation site. The animal population at all studied sites were found expose to carcinogenic health risks. The multivariate statistical analysis indicated that the wastewater/water containing heavy metals and contaminated soil were common sources of maize plants contamination. The consumption of contaminated maize as fodder by lactating animals resulted in milk contamination which indicated that the application of wastewater/water containing heavy metals was causing food chain contamination. The untreated wastewater is not suitable to grow maize to use as fodder for animals.
Keywords: Fodder, health risk, irrigation, maize plants, TTHQ, wastewater

INTRODUCTION

Food safety is a matter of general public health concern in the world and the demand of food safety has diverted the attention of researchers to assess the health risks associated with contaminated foodstuffs by heavy metals, pesticides, and toxins (Khan *et al*., 2016). The heavy metals are not degraded biologically and have the potential to cause serious health implications in the human body (Nwude *et al*., 2011). The soils under wastewater irrigation have exhibited the risk of accumulation of heavy metals (Khan *et al*., 2015; Ahmad *et al*., 2016). Wastewater is a combination of effluents from domestic, commercial establishments including hospitals and institutions, industries, stormwater, urban runoff and agricultural activities (Ahmad *et al*., 2016). Wastewater irrigation is common practice in urban and peri-urban areas of almost all cities in the world and it is rapidly increasing in developing countries facing water scarcity. Twenty million hectares, 7% of world land is under wastewater irrigation in over 50 countries and the unreported area maybe even more as no legal harmonized system is available at a global and national level for the systematic collection of the data. Such practice is likely to increase to meet the increasing food needs as the urban population is projected to be double by 2050 (Water, 2014). The annual generation of wastewater in Pakistan is about 4.3 BCM (billion cubic meters) out of which 1.37 BCM is industrial and 3.06 BCM is municipal wastewater (PCRWR, 2006). In Pakistan, major cities like Karachi, Lahore, Faisalabad, Rawalpindi, Multan, Peshawar, Hyderabad, Quetta, Gujranwala and Sargodha are discharging untreated wastewater into surface water bodies and the same is used to irrigate food crops (PCRWR, 2006). Approximately 26% of vegetables are grown with wastewater in the urban and sub-urban agricultural areas of all cities. The practice of direct use of wastewater for irrigation seems will increase in Pakistan in the future (Ensink *et al*., 2004).

Maize is cultivated worldwide as cereals and major energy source is human food. The maize plant is also used as a fodder for animals (Prasanna *et al*., 2001). Through supplements, hazardous elements are joining the foodstuff chain in such farming in a direct proportionate manner (Khan *et al*., 2016). The toxic metals such as Cd and Pb accumulate in different parts of plants without any role (Kabata-Pendias, 2001) while certain elements such as Mn, Cu, Fe, and Zn are considered essential metals for photosynthesis and metabolic activities in plants.

The plants grown with wastewater may absorb and accumulate toxic elements in a concentration exceeding permissible limits and may pose a severe threat to the health of the exposed population (Khan *et al*., 2016). Therefore it is necessary to assess the health risk of heavy metals in plants to ensure food safety for the protection of the health of consumers (Keser, 2013).

The soil, an integral part of ecosystem and source of major plant nutrients and water to meet food demands of humans and animals, is a sink of metals because of disposal of metal-containing substances (Alloway, 1995). Heavy metals like Cd, Cr and Pb have a wide range of toxicity, accumulate easily in soil, and pose a serious threat to human and animal health via skin contact, dust digestion and food chain contamination (Sun *et al*., 2016). The researchers have a special focus on soil contamination and its resulting food chain contamination in recent years (Tedoldi *et al*., 2017). Keeping in view the multifarious environmental problems of Multan City, it has been selected as a study area. Health risk assessment of metals in contaminated crops and vegetables is conducted regularly to monitor quality in developed countries (Milacic and Kralj, 2003) but very little research has been carried out in developing countries(Mahmood and Malik, 2014). It was hypothesized that application of wastewater to grow maize plants will contaminate it with heavy metals. Therefore, this study was conducted to (i) investigate the concentration of Cd, Cr, Cu, Mn, Ni and Pb in maize plants grown at six sites using different qualities of wastewater in irrigation, (ii) assess the health risk index and total target health quotient of heavy metals in maize plants for consumption of animals, and (iii) identify the sources of heavy metal contamination in maize plants using appropriate statistical analysis.

MATERIALS AND METHODS

***Study area*:** The city of Multan is the 5th largest populous city of the Punjab province of Pakistan. It is one of the oldest city of Pakistan and the main industrial city of South Punjab (NESPAK, 2017). It is located at 30.2° North, 71.4° East and is 710 ft above mean sea level. This city lies on the east bank of the Chenab River in the geographic center of Pakistan. The untreated wastewater of Multan industrial estate is being used to irrigate the agricultural lands. The wastewater of the industrial units located in the city area is being discharged into WASA Sewerage System which is being either disposed of in water bodies or used to irrigate agricultural lands as per the general practice of other cities and towns of Pakistan (Ensink *et al*., 2004). Therefore the finding of this study may be replicated in other cities of Pakistan.

***The climate of the study area*:** The Multan city lies in the warm composite zone, where the climate is dry hot in summer and cold in winter. The maximum and the minimum mean temperature in summer is 42°C and 29°C whereas in winter it is 21°C and 4.5°C, respectively. The average annual rainfall is about 186 mm most of which falls during the monsoon from July-September (Abbas, 2013; Abbas *et al*., 2014).

***Six selected sites under varying quality wastewater irrigation*:** Six irrigation sites were selected in peri-urban areas of Multan city which are the main producer of agricultural produce like vegetables, wheat, fruits, fodder (maize plants and brassica), milk and meat etc. which is supplied to the public in the study area and adjoining districts. One site under untreated industrial effluents irrigation, two sites under untreated urban wastewater irrigation, one site under mixed water (canal water + urban untreated wastewater) irrigation, one site under canal water and one site under tube well water irrigation were selected (Table 1). Keeping in view the importance of public health, six main irrigation sites were selected as representative sites.

Table 1. Description of selected sites and maize plants samples across six irrigations sites in peri-urban areas of Multan City.

Sr.	Name of Site	No of maize plants samples
1	Site-A (Basti Valvit) (Untreated industrial effluents)	5
2	Site-B (Chah Bahadarwala) (Untreated urban wastewater)	5
3	Site-C (Mouza Kayianpur) (Canal water mixed with urban wastewater)	5
4	Site-D (Binda Sandeela Surajmyni) (Untreated urban wastewater)	5
5	Site-E (Qadirpur Ranwaan) (Canal water, control area)	5
6	Site-F (Mouza Binda Mallana) (Tube well water)	5
	Total samples	30

***Sampling of maize plants*:** Thirty samples of maize plants grown across six sites were collected to examine the contamination of heavy metals. The soil samples and maize plants were collected from the same place to determine the co-relation of their contaminants. The sampled pants (stems and leaves) were matured and exposed to full sunlight and were collected from 6 sites randomly. Each sample was homogenized by mixing five samples to make one sample. Five homogeneous samples of the plant were taken from each site. Moderate samples of good appearance and size were taken. Samples were washed with distilled water and placed in paper bags. Each sample was assigned identity and inventory of samples was prepared (Jones Jr, 2001).

***Analysis of samples*:** The samples of wastewater, soil, raw milk and maize plants were analyzed in the Center for Environmental Protection Studies (CEPS), Laboratories Complex, Lahore, accredited for ISO/IEC 17025 using ICP-OES Perkin Elmer, USA, Optima DV 5300 for heavy metals

Pb, Cu, Cd, Cr, Mn and Ni using standard methods and guidelines.

Assessment of health risk exposure**:** Several interactive and iterative steps are required for complete assessment of health risk to the animal population exposed to heavy metals pollution. Determination or estimation of the level of exposure is one of the basic steps for risk assessment of any chemical (Weber *et al*., 2006). The assessment of exposure indicates the pathways, magnitude, duration, and frequency of toxicants to which animal are potentially exposed (Lee *et al*., 2005). In wastewater irrigation, four major pathways of exposure are anticipated (Qishlaqi *et al*., 2008). However, in this study, the only intake of maize plant has been considered for assessment of health risk for animals.

Assessment of animal health risk**:** The DIM (daily intake metals) and HRI (health risk index) of heavy metals for animals were calculated for maize plants feeding at study area according to the method described for humans. The standard weight of animals and average fodder intake (Table 2) were used to calculate DIM, HRI and TTHQ values of heavy metals in maize plants for animals.

Table 2. Average body weight of animals and daily fodder intake.

Animals	Live body weight (adult) kg	Daily fodder intake (winter) kg
Buffalo	500	80
Cow (Sahiwal)	400	60
Holsten Frisian Cow	500	80

Source: Shah (1994)

Daily intake of metals (DIM)**:** The DIM was calculated using the equation by Balkhair and Ashraf (2015) and WHO (1996).

$$\mathrm{DIM} = \frac{\mathrm{mc} \times \mathrm{cf} \times \mathrm{di}}{bw}$$

Where *mc* is the concentration of heavy metals in maize plants (mg/kg) on a dry weight basis, *cf* is conversion factor (fresh weight to dry weight) and its value is taken as 0.085, *di* is daily intake of maize plants. The average weight of maize plants for different animals and their body weights were taken as given in Table 2.

Health risk index (HRI)**:** HRI is defined as the ratio of daily intake of metals in the food crop to an Oral Reference Dose (RfD) and was calculated with the equation (Balkhair and Ashraf, 2015).

$$\mathrm{HRI} = \frac{\mathrm{DIM}}{RfD}$$

An HRI > 1.0 for any single metal indicates that the health of the consumer population is at risk and value of HRI <1.0 indicates that the metal is risk-free. The RfD is an estimated daily oral reference dose prescribed by USEPA and is considered safe and free of the risk of adverse health effects during a lifetime (Balkhair & Ashraf, 2015). The oral reference dose (RfD) values for selected metals were taken from Integrated Risk Information System (IRIS US EPA) as 0.001 (Cd), 0.003 (Cr), 0.04 (Cu), 0.014 (Mn), 0.02 (Ni), 0.0035 (Pb) mg/kg body weight per day, respectively (Randhawa *et al*., 2014).

Total target health quotient (TTHQ)**:** The consumption or intake of two or more contaminants via single foodstuff may result in a negative effect on the health of the exposed population. TTHQ was used to assess the overall non-carcinogenic and carcinogenic impacts of single or individual foodstuff containing multiple heavy metals (USEPA 1986; Yu *et al*. 2015) and was computed as:

$$TTHQ = \sum_{i=1}^{n} \mathrm{HRIi}$$

Where HRIi is the HRI value of element i.

If the sum of calculated (∑ HRIi) is less than 1.0, the foodstuff is considered as non-carcinogenic or its impact on health is negligible. In the case of TTHQ is more than 1.0, the foodstuff is considered as carcinogenic or harmful for consumer health (Lee *et al*., 2005). The TTHQ was calculated and used to estimate the total non-carcinogenic and carcinogenic health risk caused by multiple heavy metals intake via single foodstuff by a specific receptor(USEPA, 1986).

Statistical analysis**:** Descriptive analysis included mean, the minimum, and the maximum values, standard deviation (SD), and coefficient of variation were made by using Microsoft Excel 2010. The statistical analysis was conducted to examine the source of the heavy metals in maize plants. SPSS 21 and Minitab 16 statistical software were used for required statistical analysis.

RESULTS

Heavy metal analysis of maize plants across six sites**:** The maize plants were treated as fodder for animals and the mean contents of heavy metals examined in the maize plants across six sites were compared with (WHO, 1996) permissible limits prescribed for maize plants as fodder for animals. The results are presented in Table 3.

Cadmium level in maize plants across six sites**:** The mean contents of Cd in maize (mg/kg) were 0.485, 0.332, 0.318, 0.422, 0.0208 and 0.0106 were observed in maize plants at the sites A, B, C, D, E, and F, respectively (Table 3). The mean contents of Cd were below the WHO permissible limits (0.5 mg/kg) across six sites. However, the Cd contents in maize plants were higher by 23, 16, 15, 21 times sites A, B, C, and D, respectively when compared with site E, *i.e.* control area. The Cd contents were lowest at site-F. The order of Cd across six sites was as: site-A > site-D > site-B > site-C > site-E > site-F. The maize plants were found more contaminated with Cd at wastewater irrigation sites (Figure 1a).

Table 3. Mean concentration of heavy metals (mg/kg) in maize plants (fodder) grown at six irrigation sites in peri-urban areas of Multan city.

Name of site	Cd		Cr		Cr		Mn		Ni		Pb		Total metals
	Mean	± SD	Mean	± SD	Mean	± SD	Mean	± SD	Mean	± SD	Mean	± SD	
Site-A													59.91
Site-B	0.3320	0.0228	6.120	0.2280	16.420	0.3194	16.56	0.2608	0.314	0.0167	0.864	0.1135	40.61
Site-C	0.3180	0.0148	7.504	0.0740	9.540	0.2966	16.72	0.2280	0.272	0.0228	0.770	0.0346	35.12
Site-D	0.4220	0.0286	2.426	0.0488	12.760	0.1817	18.72	0.2280	0.300	0.0316	1.144	0.0297	35.77
Site-E	0.0208	0.0023	0.272	0.0228	0.098	0.0148	2.72	0.2280	0.100	0.0316	0.208	0.0228	3.42
Site-F	0.0106	0.0037	0.400	0.0316	0.0094	0.0040	3.72	0.2387	0.344	0.0297	0.022	0.0032	4.51
PML[a]	0.5		50		20		30		2		0.5		103.00

a WHO (1996), Masona *et al*. (2011)

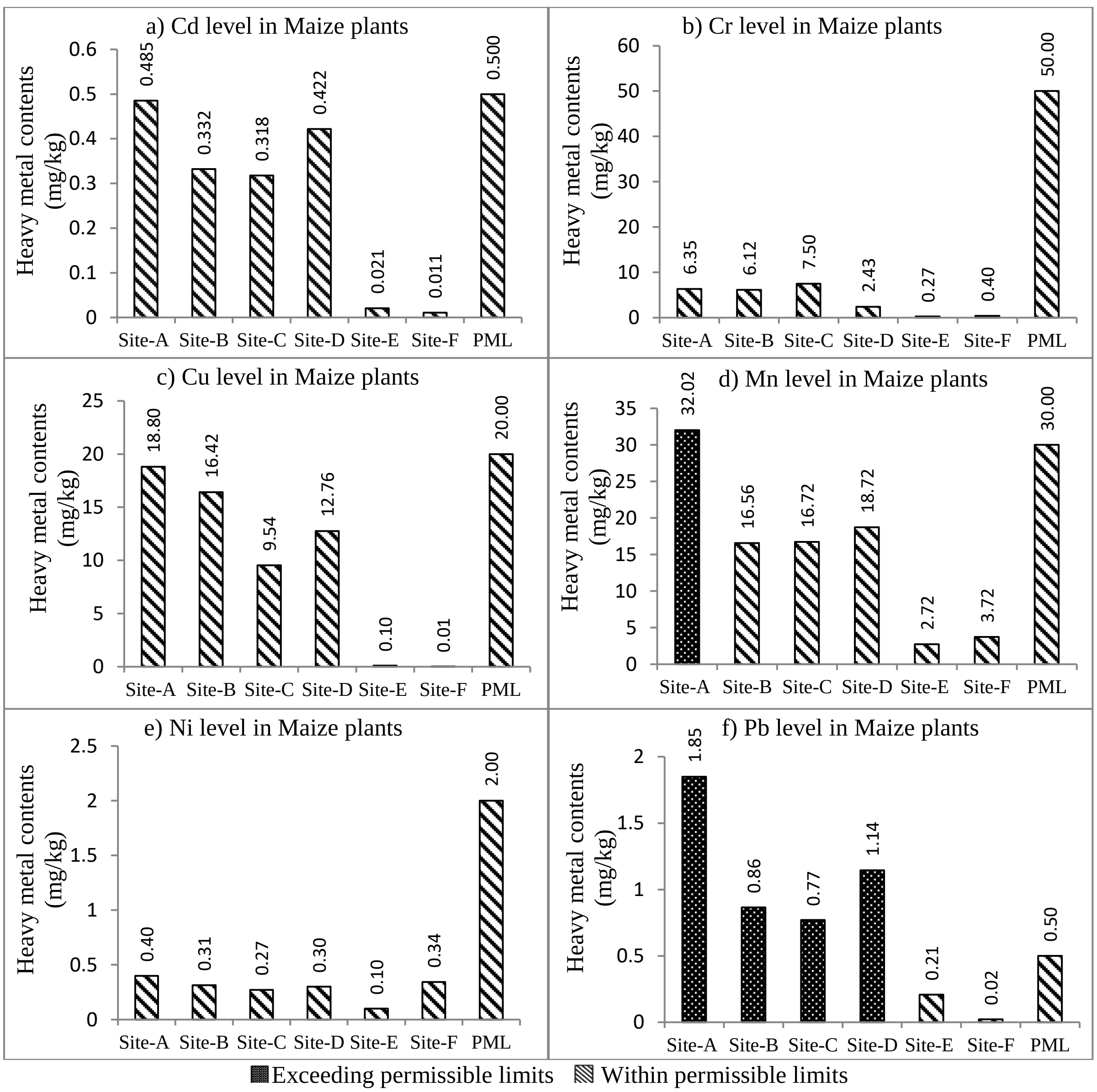

Figure 1. Site wise comparison of heavy metal concentration in maize plants (fodder) grown at six irrigation sites in peri-urban areas of Multan city.

***Chromium level in maize plants across six sites*:** The mean contents of Cr in maize (mg/kg) were 6.35, 6.12, 7.5, 2.426, 0.272 and 0.4 at site A, B, C, D, E, and F, respectively (Table 3). The mean contents of Cr were below the WHO permissible limits (50 mg/kg) across six sites. The Cr contents in maize plants were found higher when compared with the control area. The Cr contents were lowest at site-E (control area). Cr contents at site-F were more than site-E. It may be due to the application of treated wastewater since June 2016 at site-F. The order of Cr across six sites was as: site-C > site-A > site-B > site-D > site-F > site-E. The maize plants were found more contaminated with Cr at wastewater irrigation sites (Figure 1b).

***The copper level in maize plants across six sites*:** The mean contents of Cu in maize plants (mg/kg) were 18.8, 16.42, 9.54, 12.76, 0.098 and 0.0094 at site A, B, C, D, E, and F respectively (Table 3). The mean contents of Cu were below the WHO permissible limits (20 mg/kg) across six sites. Cu contents were lowest at site-F. The mean Cu contents in maize plants were found 192 times, 168 times, 97 times and 130 times higher at site-A, B, C and site-D respectively than that at site-E. The order of Cu across six sites was as: site-A > site-B > site-D > site-C > site-E > site-F. The maize plants were found more contaminated with Cu at wastewater irrigation sites (Figure 1c).

***Manganese level in maize plants across six sites*:** The mean contents of Mn in maize plants were 32.02, 16.56, 16.72, 18.72, 2.72 and 3.72 (mg/kg) at site A, B, C, D, E and F, respectively (Table 3). The mean contents of Mn were below the WHO permissible limits (30 mg/kg) across six sites except site-A exceeding permissible limits. Mn contents were lowest at site-E (control area). The mean Mn contents in maize plants were also found to be higher when compared to control area than site E. The order of Mn across six sites was as: site-A > site-D > site-C > site-B > site-F > site-E. The maize plants were found more contaminated with Mn at wastewater irrigation sites (Figure 1d).

***Nickel level in maize plants across six sites*:** The mean contents of Ni in maize plants were 0.4, 0.314, 0.272, 0.3, 0.1 and 0.344 (mg/kg) at site A, B, C, D, E and F, respectively (Table 3). These values were also below the WHO permissible limits (2 mg/kg) across the six sites. The Ni contents were lowest at the site E. The mean Ni contents in maize plants were found 4 times, 3 times, 3 times and 3 times higher at site-A, B, C and site-D than that at site-E. The order of Ni across six sites was as: site-A > site-F > site-B > site-D > site-C > site-E. The maize plants were found more contaminated with Ni at wastewater irrigation sites (Figure 1e).

***Lead level in maize plants across six sites*:** The mean contents of Pb in maize plants were recorded 1.85, 0.864, 0.77, 1.144, 0.208 and 0.022 (mg/kg) at site A, B, C, D, E and F, respectively. The mean contents of Pb exceeded the WHO permissible limits (0.5 mg/kg) at site-A, B, C and site-D respectively. Pb contents were lower at site-E and site-F than permissible limits and were lowest at site-F. The mean Pb contents in maize plants were found 9 times, 4 times, 3.7 times and 5.5 times higher at site-A, B, C and site-D respectively than that at site-E. The order of Pb across six sites was as: site-A > site-D > site-B > site-C > site-E > site-F. The maize plants were found more contaminated with Pb at wastewater irrigation sites (Figure 1f).

***Site wise comparison of total metals concentration in maize plants*:** The total metals concentration in maize plants given in Table 3 indicated the site wise order in maize as: site-A (59.91 mg/kg) > site-B (40.61 mg/kg) > site-D (25.77 mg/kg) > site-C (35.12 mg/kg) > site-F (4.51 mg/kg) > site-E (3.42 mg/kg) (Figure 2). The comparison of total metals concentration in maize plant with that at site-E indicated that maize plant was 18 times, 12 times, 10 times, 10 times more contaminated with heavy metals at wastewater irrigation sites. The total metal contents at site-F higher than site-E may be due to the application of treated wastewater six month ago of study period which might raise the contamination level at the tube well water irrigated site.

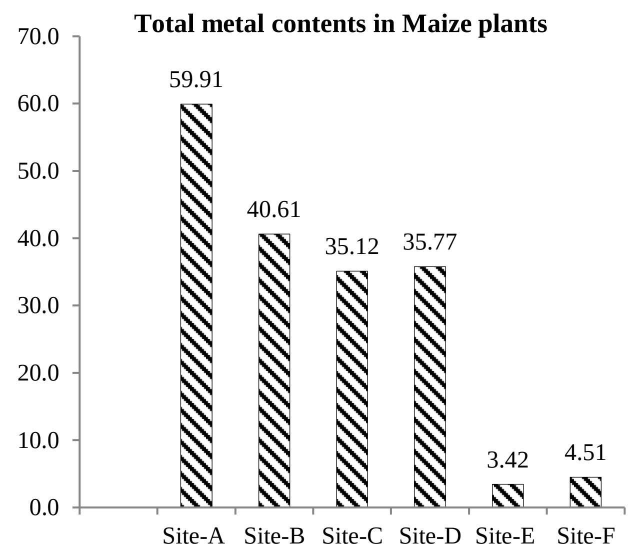

Figure 2. Site wise comparison of total heavy metals concentration in maize plants grown at six irrigation sites in peri-urban areas of Multan city.

***Assessment of health risk*:** The summary of computed DIM, HRI and TTHQ values of heavy metals in maize plants for four animals are given in Figure 3. The comparison of TTHQ values of maize plants is shown in Figure 3. The Figure 3 indicated the TTHQ values of maize plants at site-A were revealed as 80.34, 75.32, 80.34 and 50.21, at site-B were 57.5, 53.9, 57.5 and 45.036, at site-C were 61.005, 57.2, 61.005 and 39.522, at site-D were 43.90, 41.16, 43.9 and 27.44, at site-E were 5.06, 4.75, 5.06 and 3.16, at site-F were 5.89, 5.52, 5.89 and 3.68. The data depicted that maize plants grown at wastewater irrigation sites (A, B, C, D) yielded very high TTHQ values indicating very high carcinogenic health risk to exposed animals and that at site-E and site-F yielded very low TTHQ values indicating a low carcinogenic health risk. However, maize plants across six sites exhibited carcinogenic health risk to exposed animals. The TTHQ values of maize plants at site-F were slightly higher than that of maize plants for selected animals at site-E.

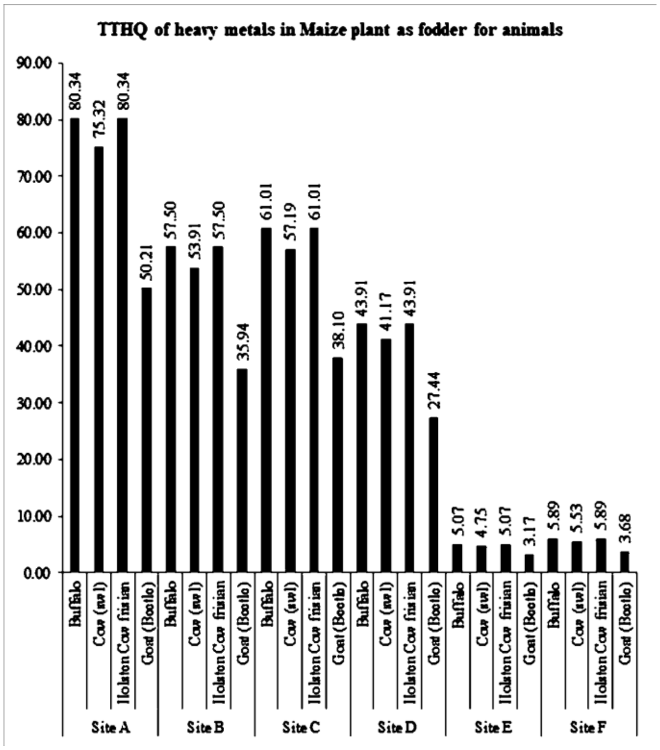

Figure 3. Site wise comparison of TTHQ of heavy metals in maize plants for animals across six sites.

DISCUSSION

Groundwater and soil contamination at an Industrial site irrigated with effluents in Multan and concluded that large fertile agricultural areas have become nonproductive due to heavy metal contamination (Tariq *et al*., 2010). The present findings are in line with these conclusions because the maize plants have been contaminated to the extent that it exhibited health risks for animals. On the other hand, Randhawa *et al*. (2014) conducted another study in Multan city (study area) to examine the metals concentration in soil, vegetables and irrigation water and reported the concentration of Pb and Cd in vegetables were above the WHO guidelines. They further concluded that the presence of metals in vegetables is due to the presence of metals in irrigation water/wastewater irrigating the land and is the main factor for contamination of vegetables and to make vegetables unfit for human consumption. The results of this study are also supported by the conclusion of Randhawa *et al*. (2014). In another study by Ismail *et al*. (2014) soil and vegetables grown with canal water were found contaminated with higher concentrations of metals than irrigated with tube-well water (Khan *et al*., 2015; Ahmad *et al*., 2016).

PCRWR (2006) conducted a similar study in Faisalabad, Pakistan for assessment of impacts of industrial and sewage effluents on vegetables and crops, and reported that the vegetables and crops grown with industrial wastewater were found more contaminated with heavy metals than that grown with sewage. The industrial effluents mixed with urban sewage contained heavy metals like chromium, cadmium, nickel, manganese, lead and zinc etc. in concentration excessive to permissible limits and joined food chain causing toxic to plants and humans. Bakhsh *et al*. (2005) reported that the soils irrigated with wastewater and vegetables grown on such soil were contaminated with heavy metals above permissible limits and regular intake of vegetables grown with untreated wastewater may accumulate the heavy metals Pb, Cu, Zn and Fe in the human body to the toxic level. Mahmood and Malik (2014) reported the HRI for Brassica as 2.42 and 2.22, respectively grown with wastewater for Cd and Mn in Lahore, Pakistan posing a health risk to the health of consumers. Khan *et al*. (2016) reported the vegetables high enriched with heavy metals grown with wastewater in Rawalpindi, Pakistan. Raja *et al*. (2015) reported the vegetables irrigated with wastewater as unhealthy for human consumption due to high contents of heavy metals. Singh *et al*. (2010) and Qishlaqi *et al*. (2008) reported higher health risk of heavy metals in vegetables grown with treated or untreated wastewater. Perveen *et al*. (2012) reported the higher contents of Pb, Cr, Cd and Ni in vegetables above WHO permissible limits in Peshawar City, Pakistan and concluded that the vegetables should not be grown with wastewater containing heavy metals and such vegetables can cause abnormalities in humans and animals.

Balkhair and Ashraf (2015) reported high HRI for Cd, Pb and Cr in vegetables grown with wastewater. Hamid *et al*. (2016) reported higher values of HRI > 1.0 of heavy metals in wastewater irrigated vegetables near Lahore city, Pakistan. Khan *et al*. (2015) reported the HRI for Mn, Pb, Ni, Cd, and Cu more than 1.0 in vegetables. Olu *et al*. (2013) reported the mean contents of Pb as 150 mg/kg in maize plants grown in industrial area higher than observed in this study (1.85 mg/kg) and contents of Cu (10.7 mg/kg) lower than observed in this study (18.8 mg/kg), the contents of Ni (4.77 mg/kg) higher than observed in this study (0.4 mg/kg). The results of this study are in line with the results of Olu *et al*. (2013). Lu *et al*. (2015) reported Cr contents (9.22-15.63 mg/kg), Pb (1.25-3.57mg/kg), Ni (1.61-1.40 mg/kg) and Zn (2.11-3.98 mg/kg) in stems and leaves of maize plants grown with wastewater and these results are with the findings of Lu *et al*. (2015). The mean contents of metals observed in this study are lower than the results reported by Khan *et al*. (2015). It might be due to the reason that site-F remained under tube well water irrigation and treated wastewater was applied since six months ago to irrigate land and crops at site-F which might raise the contamination level of maize plants higher than that grown at canal water irrigation site-E.

Khan *et al*. (2016) reported the TTHQ value of heavy metals in Brassica in Khushab city, Pakistan as 93.55 grown at wastewater, 82.05 at canal water and 65.64 at tube well water irrigated sites for humans. The TTHQ values observed in this study ranged from 27.44 to 80.45 at wastewater, 3.17 to 5.07 at canal water and 3.68 to 5.89 at tube well water irrigation site. Khan *et al*. (2016) reported higher contents of Cd and Ni in *Brassica campestris* irrigated with urban sewage in Sargodha city Pakistan. The above results are in agreement with the results of and conclusion of this study.

***Conclusions*:** The maize plants as fodder for animals (Buffalo, Cow, Goat) yielded the TTHQ values in the range 3.2 to 80.3 across six sites higher than safe limit 1.0 exhibiting "carcinogenic health risk" to exposed animals. The TTHQ values were highest (27.4 to 80.2) at wastewater irrigation sites and were lowest (3.2 to 5.1) at canal water irrigation site. The maize plants grown at wastewater irrigation sites yielded the highest carcinogenic health risk to animals. The maize plants grown with canal water exhibited carcinogenic health risk to exposed animals which is an indicator of heavy metal contamination in canal water irrigation system which is largest in Pakistan among the world. It invites immediate attention of Government for remediation. The multivariate statistical analysis indicated that the wastewater/water containing heavy metals and contaminated soil are common sources of contamination of maize plants.

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