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Health Risk Assessment from Wastewater Irrigated Vegetables

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Abstract: Consumption of heavy metals contaminated vegetables is a main food chain channel for exposure of human. This study was conducted to evaluate the adverse effects of heavy metals via contaminated vegetables receiving waste water irrigation. It was found from the obtained results that the waste water irrigated soils and vegetables collected from Multan, Pakistan have considerable amount of heavy metals. Ni, Cd, Cr and Cu concentration in wastewater and Cd, Zn, Cu and Fe contents in soil were above the safe limits. The heavy metals concentration in vegetables was greater than the permissible limits of WHO (World Health Organization). It was also found that both children and adults ingest considerable amount of the heavy metals by consuming wastewater irrigated vegetables. Hazard Quotient of cadmium was more than 1 which indicated potential health risk from cadmium while for Zn, Cu, Fe, Mn, Pb, Ni and Cr have hazard quotient value of less than 1 which showed that no potential health risk would occur from these heavy metals with the consumption of vegetables contaminated with the said heavy metals.

Key words: Heavy metal · Waste water · Vegetables · Hazard quotient · Pollution index

INTRODUCTION

Scarcity of irrigation water has affected human health and economic development. Increasing industrialization and urbanization resulted in discharge of huge amount of wastewater which is used for growing vegetables especially in urban and peri-urban areas due to declining availability of canal water/ irrigation water. Wastewater contains various heavy metals including Pb, Ni, Cd, Zn, Cu and Cr, which are found in waste water depending upon the nature of industry discharging this wastewater. Long term use of waste water for irrigation may result in heavy metal build up in soils and vegetables [1, 2, 3]. In periurban areas wastewater is used frequently for irrigating crops specially vegetables because of fresh water scarcity, easy availability and disposal problems. Wastewater contributes significantly to the build-up of heavy metals in soil [4] which act as a substrate for heavy metal accumulation in vegetables. Health problems in human and animals occur by the consumption of vegetables grown with the application of wastewater because vegetables have the ability to take up and accumulate heavy metals in different parts of their body [5]. Human health problems like depletion of essential nutrients which ultimately resulted in impairment of psyco-social behaviour, upper gastrointestinal cancer and intrauterine growth retardation. Heavy metals are persistent and non-biodegradable in nature; therefore they mostly accumulated in human body organs like bones, kidneys and liver [6]. Heavy metals like arsenic, mercury, zinc, copper, aluminium. Individual metals exhibit specific signs of their toxicity. Diseases like diarrhoea, stomatitis, gastrointestinal (GI) disorders, tremor, ataxia, vomiting, paralysis, depression, pneumonia and convulsion are caused by poisoning of arsenic, mercury, zinc, copper, aluminium and lead [7]. The adverse effects of heavy metals can be toxic (chronic, sub chronic and acute), carcinogenic, mutagenic or tetragenic and neurotoxin [8]. Keeping in view the above mentioned facts this study was therefore mainly conducted to evaluate soil and vegetable heavy metal contents in peri-urban areas of Multan irrigated with wastewater. The assessment of health risk from the consumption of wastewater irrigated vegetables was also evaluated.

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MATERIALS AND METHODS

History of Study Area: Multan city is surrounded by open and covered channels, which carry untreated city effluent. These channels pass through agricultural land from where farmers divert the effluent for irrigating vegetables. A number of farmers' fields were selected in the vicinity of Haji Block Industrial Estate, Shair Shah, Wal Watt Mor and Khaji Wala Kho regions of Multan. In these areas farmers are using industrial water from Nawab Sadiq drain and Gajju Wala drain for growing their vegetables. Farmers are practising this activity for more than ten years.

Collection of Soil, Water and Vegetable Samples: The sampling of wastewater was done from water courses of the fields from where the soil and vegetable samples were collected so that the quality of irrigation water may be monitored which was being applied to the field rather than at drains/outlets of pumping stations. Samples were collected in plastic bottles containing 2 mL concentrated hydrochloric acid to avoid microbial activity during storage.

Soil samples were collected by using spiral auger of 2.5 cm diameter from two depths (0-15 cm and 15-30 cm). Soil samples were randomly collected and bulked together to form a composite sample and transported to the laboratory. Samples were air-dried, crushed, passed through 2 mm mesh sieve and stored in plastic jars.

From the same fields vegetables (onion, *Allium cepa;* round gourd, *Citrullus fistulosus* brinjal*, (Solanum melongena)* and tomato, (*Lycopersicon esculentum) samples were* collected randomly. In laboratory, vegetables were washed with distilled water to remove soil particles, air dried, crushed, oven dried and ground for heavy metals determination. 50 wastewater, 200 soil and 100 vegetable samples were collected for heavy metal determination.

Soil, Water and Plant Analysis: The analysis of collected samples was conducted at Institute of Soil Chemistry and Environmental Sciences, Ayub Agriculture Research Institute, Faisalabad, Pakistan. For the determination of heavy metals concentration in soil, 25 g dried soil sample was mixed with 50 mL of DTPA (diethylene triamine penta acetic acid) extracting solution at pH 7.3 and kept on a reciprocal shaker at 120 rpm for 2 h. The aliquot was centrifuged at 5000 rpm for 5 min and supernatants were collected for heavy metal determination [9].

Heavy metal concentrations in vegetable samples were estimated by digesting with di-acid mixture (HNO_3 + $HClO_4$) [10]. The digested samples were then cooled and filtered through Whatman No.42 filter paper and volumes were made up to 100 ml using distilled water. Wastewater samples were analysed by method of AOAC [10]. Heavy metal *viz.* Zn, Cu, Fe, Mn, Pb, Ni and Cd concentrations in wastewater, soil and vegetable samples were estimated on Atomic Absorption Spectrophotometer (*Shimadzu-AA-7000*, Japan) by using respective hallow cathode lamp.

Quality Control Analysis: Chemicals used for the preparation of wastewater, soil and vegetable samples were purchased from MERCK Chemicals Germany. The glassware used in the analysis was washed with 10% HNO_3 and for solution preparation double deionized water was used. In order to calibrate the instrument for each metal using standards prepared from their stock solution. To check the precision and accuracy of analysis, the analysis was repeated against NIST standard reference material RM 1643E for water, SRM 1515 for soil and 1570A for vegetables, for heavy metals.

Calculations

Metal Pollution Index (MPI): To examine the overall heavy metal concentrations in wastewater irrigated vegetables, metal pollution index (MPI) was computed. This index was obtained by calculating the geometrical mean of concentrations of all the metals in the vegetables [11].

$$\text{MPI } (\mu g\ g^{-1}) = (Cf_1 \times Cf_2 \times \ldots\ldots\ldots\ldots \times Cf_n)^{1/n}$$

where Cf_n = concentration of metal ‘n’ in the sample.

Daily Intake of Metals: The daily intake of metals (DIM) was calculated by the following equation:

$$DIM = M \times K \times I / W$$

where,

M = Heavy metal concentrations in plants (mg/kg)
K = Conversion factor
I = Daily intake of vegetables
W = Average body weight

The conversion factor used to convert fresh green vegetable weight to dry weight was 0.085, as described by

Rattan *et al*. [12]. The average adult and child body weights were considered to be 55.9 and 32.7 kg, respectively, while average daily vegetable intakes for adults and children were considered to be 0.345 and 0.232 kg/ person/day, respectively [13].

Risk Assessment: Risk of intake of metal contaminated vegetables to human health was characterized by Hazard Quotient (HQ). This is a ratio of determined dose to the reference dose (RD). The population will pose no risk if the ratio is less than 1 and if the ratio is equal or greater than 1 then population will experience health risk [13, 14]. The following equation was used;

$$HQ = W \times M / R_fD \times B$$

where

W = Dry weight of contaminated plant material consumed (mg d^{-1}),

M = Concentration of metal in vegetables (mg kg^{-1}),

R_fD = Food reference dose for the metal (mg d^{-1}) and

B = Body mass (kg).

The values of R_fD for heavy metals were taken from USEPA, [15] and DEFRA, [16].

RESULTS

Heavy Metal Concentration in Wastewater: The concentration of different heavy metals in wastewater samples is given in Table 1. The concentration of lead in wastewater samples taken from different locations of Multan ranged from 0.02-0.98 mg L^{-1}. The maximum mean lead concentration (0.48 mg L^{-1}) was observed in samples which were taken from Khaji Wala Kho area while minimum lead concentration (0.25 mg L^{-1}) was in samples taken from Haji Block Industrial Estate. The order of lead contents in all location was Khaji Wala Kho > Wal Watt Mor > Shair Shah > Haji Block Industrial Estate. Lead concentration in all water samples was below the permissible limits of both WHO and WWF. The concentration of nickel in water samples of all locations was in the range of 0.01-0.35 mg L^{-1}. Water samples from Shair Shah area have maximum nickel concentration while samples taken from Wal Watt area have minimum nickel concentration. About 45% samples from Shair Shah, 40% samples from Haji Block Industrial Estate, 40% samples from Khaji Wala Kho and 30% samples from Wal Watt Mor area were above the permissible limits of both WHO and WWF. The order of all locations with respect to nickel contents was Shair Shah > Khaji Wala Kho > Haji Block Industrial Estate > Wal Watt Mor. The highest cadmium concentration (0.04 mg L^{-1}) was observed in water samples taken from Shair Shah while the lowest cadmium concentration (0.001 mg L^{-1}) was obtained from samples of Haji Block Industrial Estate and Wal Watt Mor. For cadmium the order of different locations was Shair Shah = Wal Watt Mor > Haji Industrial Estate > Khaji Wala Kho. The percentage of samples above the permissible limit was 30, 50, 60 and 30% for Haji Block Industrial Estate, Wal Watt Mor, Shair Shah and Khaji Wala Kho respectively. The zinc concentration in

Table 1: Heavy metal contents in wastewater in different locations of Multan

		Pb	Ni	Cd	Zn	Cu	Fe	Mn
Location					-mg L^{-1}-			
Haji Block Industrial Estate	Range	0.02-0.79	0.02-0.33	0.001-0.03	0.11-0.30	0. 02-0.32	1.6-5.9	0.01-0.41
	Mean	0.25	0.14	0.009	0.19	0.12	2.54	0.07
	STDV	0.26	0.13	0.01	0.06	0.11	1.69	0.12
Wal Wat Morr								
	Range	0.14-0.94	0.05-0.31	0.001-0.02	0.02-0.29	0.02-0.34	1.4-6.1	0.001-0.06
	Mean	0.44	0.13	0.01	0.14	0.12	2.84	0.03
	STDV	0.24	0.09	0.007	0.08	0.09	2.01	0.02
Shair Shah								
	Range	0.06-0.98	0.01-0.42	0.001-0.04	0.02-0.25	0.05-0.32	1.16-7.13	0.002-0.09
	Mean	0.48	0.16	0.01	0.12	0.09	2.76	0.04
	STDV	0.29	0.12	0.01	0.08	0.13	2.26	0.02
Khaji Wala Kho								
	Range	0.06-0.76	0.06-0.32	0.001-0.02	0.02-0.19	0.01-0.13	1.26-6.13	0.007-0.09
	Mean	0.43	0.15	0.008	0.13	0.11	3.0	0.05
	STDV	0.25	0.11	0.008	0.07	0.14	2.28	0.04
Permissible limits	5.0*	0.2*	0.01*	2.0*	0.2*	5.0*	-	
Permissible limits	5.0**	0.2**	0.01**	2.0**	0.2**	5.0**	-	

*Critical limits as described by WHO, (2007), ** Critical limits as described by WWF, (2007) for Pakistan

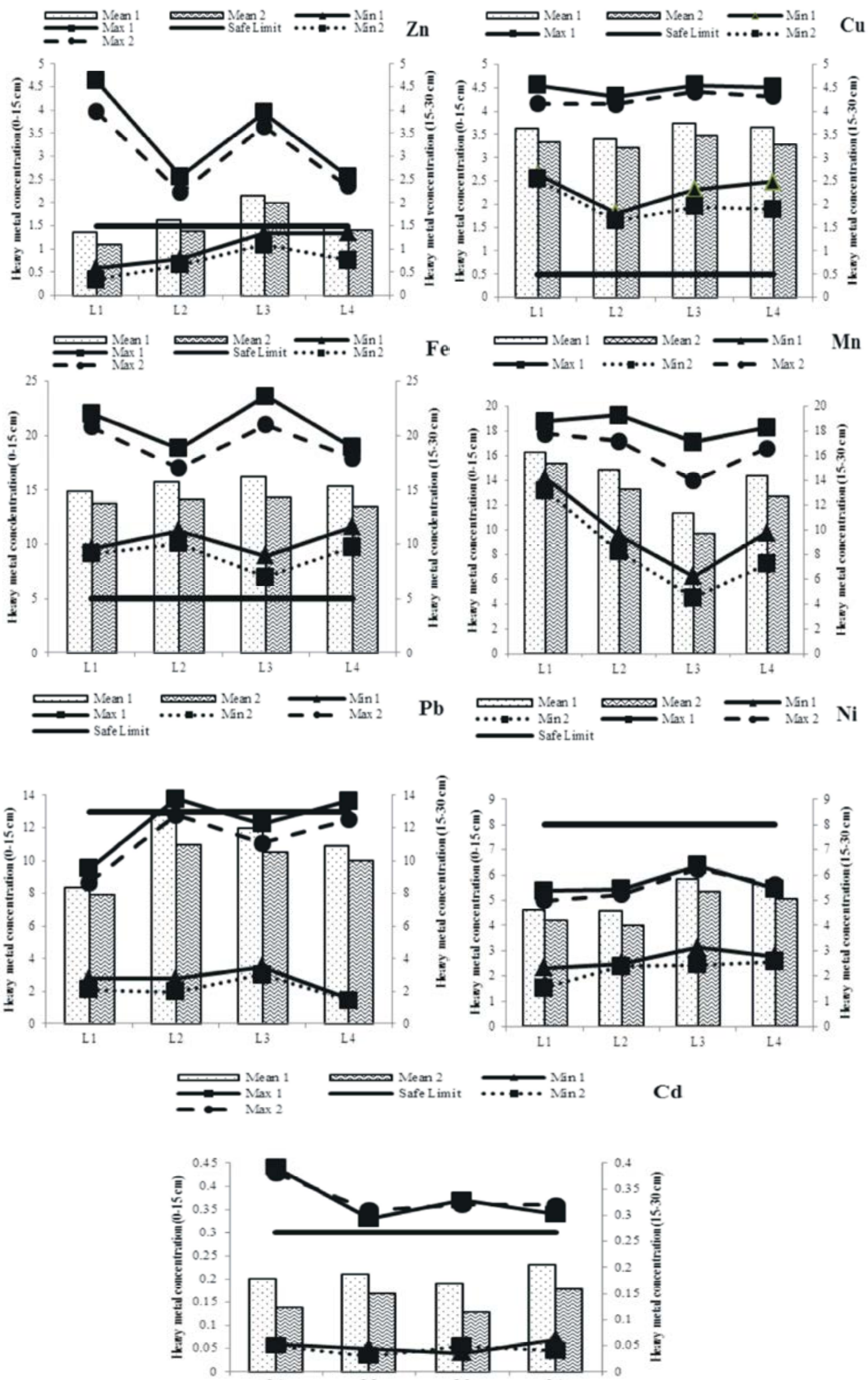

Fig. 1: Heavy metal content (mg kg^{-1}) in wastewater irrigated soils

Mean 1, Min 1, Maxi 1= Mean, mninimum and maximum values of heavy metal in upper (0-15 cm) soil depth, Mean 2, Min 2, Maxi 2 = Mean, mninimum and maximum values of heavy metal in lower (15-30 cm) soil depth, L_1= Haji Block industrial Estate, L_2 = Wal Watt Mor, L_3= Shair Shah, L_4 = Khaji Wala Kho wastewater samples ranged from 0.02-0.30 mg L^{-1} with a mean value of 0.15 mg L^{-1}. The water samples taken from Haji Industrial Estate have maximum mean zinc concentration while Shair Shah has minimum average zinc concentration. The concentration of copper in waste water samples ranged from 0.01-0.34 mg L^{-1}. The order of locations with respect to copper contents was Haji Industrial Estate = Wal Watt Mor > Khaji Wala Kho > Shair Shah. 30, 30, 25 and 20% samples for Haji Industrial Estate, Wal Watt Mor, Shair Shah and Khaji Wala Kho respectively were above the safe limits. The concentration of iron and manganese ranged from 1.16-7.13 and 0.001-0.41 mg L^{-1} respectively. Khaji wala Kho have the highest iron and Haji Industrial Estate have highest manganese concentration.

Heavy Metal Content of Wastewater Irrigated Soils: The DTPA extractable content of different heavy metals is presented in Fig. 1. The content of DTPA extractable zinc in upper and lower soil depth ranged from 0.58-4.63 mg kg^{-1} and 0.34-3.97 mg kg^{-1} in all locations, respectively. The maximum zinc content in both soil layers was obtained in soil samples from Haji Block Industrial Estate followed by Shair Shah region. The sequence of different locations regarding zinc content in soil was Haji Industrial Estate > Shair Shah > Khaji Wala Kho > Wal Watt Mor. About 15% soil samples from Haji Industrial Estate, 60% from Wal Watt Mor, 78% from Shair Shah and 45% samples from Khaji Wala Kho were above the permissible limits [17]. The content of copper in soil samples taken from different location ranged from 1.84 – 4.56 mg kg^{-1} in upper soil layer and 1.64- 4.42 mg kg^{-1} in lower layer of soil. Soil samples taken from Shair Shah region have maximum mean copper content while minimum mean copper content were obtained in soils of Wal Watt Mor. Copper content in all soil samples analysed were more than the permissible values. The iron content in Haji Block Industrial Estate ranged from 9.14 - 22.0 mg kg^{-1} with a mean value of 14.35 mg kg^{-1}, in Wal Watt Mor from 1.64 - 4.32 mg kg^{-1} with mean value of 15.0 mg kg^{-1}, in Shair Shah from 6.98- 23.6 mg kg^{-1} with mean value of 15.35 mg kg^{-1} and in Khaji Wala Kho from 9.76- 18.3 mg kg^{-1} with mean value of 14.45 mg kg^{-1}. The soils of all locations have iron content higher than the safe limits. The content of manganese in all locations ranged from 4.52-9.78 mg kg^{-1} in both soil layers. The order of locations for manganese was Haji Industrial Estate > Wal Watt Mor > Khaji Wala Kho > Shair Shah. The lead contents in both upper and lower layer in different locations ranged from 2.11-9.52, 1.96-13.78, 3.02-12.2 and 1.43-13.67 mg kg^{-1} in Haji Industrial Estate, Wal Watt Mor, Shair Shah and Khaji Wala Kho respectively. About 2% samples from Wal Watt Mor and 3% samples from Khaji Wala Kho were above the permissible limits. The average content of nickel in upper and lower soil depth were (4.62, 4.19), (4.59, 3.98), (5.85, 5.34) and (5.64, 5.07) mg kg^{-1} for Haji Block Industrial Estate, Wal Watt Mor, Shair Shah and Khaji Wala Kho respectively. The sequence of all locations regarding nickel content was Shair Shah > Khaji Wala Kho > Haji Block Industrial Estate > Wal Watt Mor. The content of nickel in all samples were within the safe values. The cadmium content in upper and lower soil layers ranged 0.02- 0.44 mg kg^{-1}. The highest cadmium content (0.44 mg kg^{-1}) was observed in soil sample taken from Haji Block Industrial Estate while minimum cadmium was obtained in soil of Shair Shah. 15, 9, 6 and 16% soil samples of Haji Block Industrial Estate, Wal Watt Mor, Shair Shah and Khaji Wala Kho were more than the permissible values.

Heavy Metal Concentration in Wastewater Irrigated Vegetables: The concentrations of heavy metals (Pb, Ni, Cd, Zn, Cu, Fe and Mn) in edible parts of vegetables are shown in the Fig. 2. The concentration of zinc in different vegetables ranged from 30.8-105 ppm with an average value of 65.5 ppm. Among all vegetables tomato contained maximum mean value of zinc (87.4 ppm), while onion has minimum (47.6 ppm) for the same. The order of vegetable regarding zinc concentration was tomato > round gourd > brinjal > onion. About 80% onion and 100% samples of tomato, round gourd and brinjal were above the safe limits. The mean concentration of copper was 25.6, 30.8, 33.4 and 37.9 ppm for onion, round gourd, brinjal and tomato, respectively. About 55% samples of onion, 60% samples of round gourd, 70% samples of brinjal and 85% samples of tomato have copper concentration higher than the WHO safe values. Iron concentration in different vegetables ranged from 428- 953 ppm. Highest iron concentration (953 ppm) was recorded in tomato and lowest concentration was observed in onion. The sequence of vegetables with respect to iron was tomato > brinjal > round gourd > onion. Samples of all vegetables have iron concentration more the recommended tolerable level. The maximum manganese concentration was obtained in brinjal followed by round gourd while minimum concentration of manganese was recorded in tomato. The concentration of lead and nickel ranged from 3.4- 6.9 and 7.8- 22.6 ppm respectively.

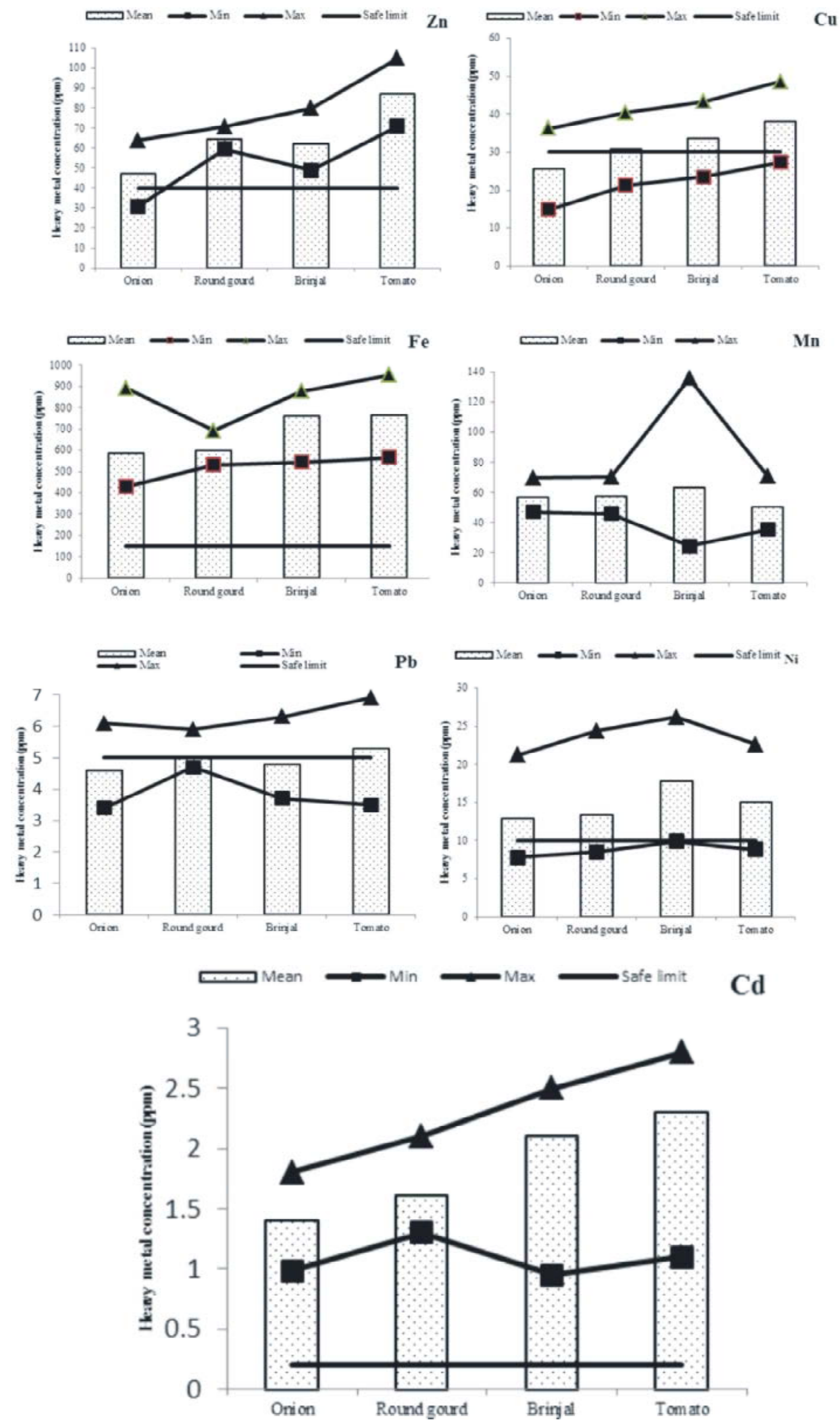

Fig. 2: Heavy metal concentration in edible portion of different vegetables
Mean, Min, Maxi = Mean, minimum and maximum values of heavy metal in vegetables

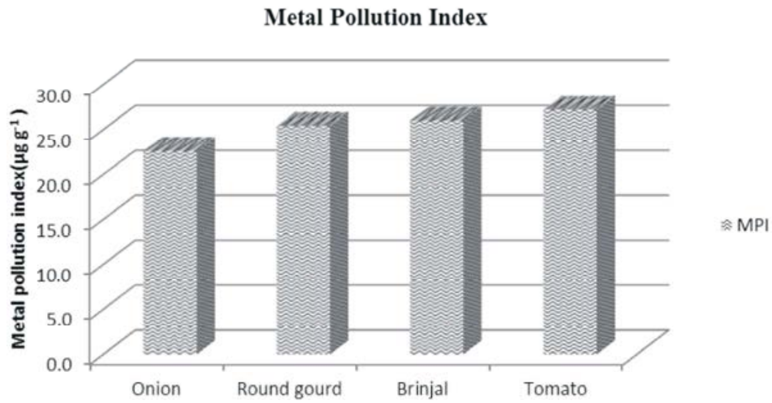

Fig. 3: Metal pollution index (µg g^{-1}).

Table 2: Daily intake of metal (DIM) for children and adults

	Onion		Round gourd		Brinjal		Tomato	
	Child	Adult	Child	Adult	Child	Adult	Child	Adult
Metal	mg kg^{-1} $person^{-1}$ day^{-1}							
Zn	0.029	0.025	0.039	0.034	0.038	0.033	0.053	0.046
Cu	0.009	0.007	0.008	0.007	0.012	0.011	0.016	0.014
Fe	0.354	0.308	0.360	0.313	0.458	0.399	0.461	0.401
Mn	0.031	0.027	0.035	0.030	0.035	0.030	0.035	0.031
Pb	0.003	0.002	0.003	0.002	0.003	0.003	0.003	0.003
Ni	0.009	0.008	0.010	0.009	0.011	0.009	0.014	0.012
Cd	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

Table 3: Hazard quotient (HQ) of different metals.

Metal	Onion	Round gourd	Brinjal	Tomato
Zn	0.08	0.11	0.11	0.15
Cu	0.19	0.18	0.27	0.35
Fe	0.03	0.03	0.04	0.04
Mn	0.05	0.06	0.06	0.06
Pb	0.60	0.62	0.63	0.65
Ni	0.40	0.43	0.47	0.61
Cd	0.94	1.00	1.09	1.10
Cr	0.10	0.09	0.09	0.09

Tomato has highest lead concentration while brinjal was found to contain maximum nickel concentration. The order of different vegetables for lead and nickel was tomato > round gourd > brinjal > onion and brinjal > tomato > round gourd > onion respectively. In case of lead 30, 50, 40 and 60% samples of onion, round gourd, brinjal and tomato respectively were above the permissible values while for nickel 65, 80, 85 and 90% samples of onion, round gourd, brinjal and tomato were above safe limits. The mean concentration of cadmium was 1.4, 1.6, 2.1 and 2.3 ppm for onion, round gourd, brinjal and tomato respectively. All vegetables have concentration of cadmium higher than the permissible value.

Vegetable Contamination and the Implications for Human Health: For monitoring metal pollution of wastewater irrigated areas metal pollution index (Fig. 3) is considered to be a trustworthy and precise method [11]. The maximum metal pollution index was obtained for tomato followed by brinjal. The minimum metal pollution index was recorded for onion. Higher metal pollution index of tomato and brinjal suggested that these vegetables may cause more human health risk due to higher accumulation of heavy metals in their edible portion.

Daily Intake of Metals and Hazard Quotient (HQ): It is very important to estimate the level of exposure in order to observe the health risk of any pollutant. Food chain is the most important pathway among several possible pathways of exposure to humans. The highest intakes (Table 2) of Zn, Cu, Fe, Mn and Ni were from the consumption of tomato while lowest intake of these metals was from the consumption of onion for both adults and children. The data regarding hazard quotient is given in the Table 3. The maximum HQ was obtained in case of cadmium (1.00, 1.09 and 1.10) from the consumption of waste water irrigated round gourd, brinjal and tomato respectively. Hazard quotient ≥ 1 is considered unacceptable so consumption of round gourd, brinjal and tomato would adversely affect human health.

DISCUSSION

The areas where water for irrigation is becoming scarce, people are using industrial wastewater for irrigation. The toxic heavy metals entering the ecosystem through waste water irrigation may lead to their geoaccumulation and bioaccumulation. Continuous irrigation with wastewater altered the soil physicochemical properties which ultimately resulted in heavy metal uptake by food crops specially vegetables. Heavy metals bioavailability is greatly affected by their form, phase and oxidation state [19, 20]. In the present study Zn, Pb and Fe concentration in wastewater was in the range of WHO and WWF Pakistan permissible limits [21, 22] while 37% and 26 samples had higher concentration of Ni, Cu and Cd respectively (Table 1). In the Multan city about 832 million litters wastewater is generated per day that drains into the river through the city drainages, managed by WASA, Multan. The main channel of heavy metal accumulation in wastewater is the industrial and municipal sewage of city that is discharged into these drains [23]. Irrigation of agricultural land with the waste water resulted in the accumulation of heavy metals in soil [24]. The results of this study are in accordance with Mushtaq and Khan [25] who took water samples from Adiala, Pirwadhai, Taxilla and Wah factory areas of Rawalpindi district and found that concentration Zn, Cu, Fe, Cd, Ni and Cr were above the permissible limits. Khan *et al*. [26] found higher concentration of Cu, Mn and Cd in waste water samples of peri-urban regions of Lahore as found in this study. In the present study all soil samples (Fig. 2) have contents of bioavailable Fe and Cu higher than the permissible limits described by Maclean et al. [18] and Soltanpour, [17]. About 49, 12 and 3% for Zn, Cd and Pb were also above the permissible limits. Heavy metals leaching into the deeper layers of soils and their removal by vegetables may be a reason of low concentration of heavy metals than the permissible limits [27]. Similar findings were obtained by Mahallapa *et al*. [28] who took soil samples from waste water irrigated areas around Solapur city, India and they found that DTPA extractable contents of Zn, Cu, Pb, Ni, Cd and Cr were more than the permissible values. Like this study Hussain *et al*. [29] found higher concentration of Zn, Cu, Fe and Cd in soil samples taken from areas around Faisalabad city. The main sources of heavy metals to vegetables are their growth media especially drain water if used for irrigation. In the present study 100% vegetable samples for Cd and Fe, 90, 67, 45 and 70% samples for Zn, Cu, Pb and Ni respectively were above the critical limits of WHO [22]. The morphology and physiology of vegetables for heavy metal uptake, exclusion, accumulation and retention is different which ultimately led to variations in heavy metals concentration in different vegetables [30, 31]. The variations among vegetables regarding concentration of heavy metal may also be due to the variable factors like heavy metal concentration in soil wastewater used for irrigation and atmospheric deposition along with the plant's capability to uptake and accumulate the heavy metals [32]. Wastewater when used for irrigating vegetable may become a channel for the uptake of heavy metals from roots to the edible parts of the vegetables. Burning of fossil, sewage water, paints/pigments, industrial and traffic emission, discharge of lead storage batteries, fuel and textile mills may be the main sources of heavy metals in waste water of Multan. In the human body cadmium caused toxic effects on kidney, liver, testis, ovaries, nervous system, cardiovascular system and induces gastrointestinal problems [33]. Lead causes neurological, gastrointestinal, haematological, carcinogenic effects, renal failure and physiological disorders [34]. The findings of the present are also inline with the findings of various other researchers [24, 35, 36]. DIM for adults and children through consumption of contaminated vegetables may cause severe health risks by ingestion of heavy metals grown with waste water. Human risk assessment quantification from wastewater irrigated vegetables consumption is of prime importance in countries like Pakistan, where wastewater irrigation practice is still unchecked. There are several exposure pathways which mainly depend on contaminated sources of air, water, soil, food and consuming population [37] but the routes of exposure via food chain is one of the key pathways of heavy metals exposure to human [38]. For identifying adverse effects of heavy metals on human health metal pollution index was estimated. Tomato was found to have highest pollution index which showed greater health risk from the intake of tomato as compared to other vegetables. The contamination of vegetables with harmful metals could have a direct impact on the health of nearby inhabitants, because vegetables produced from periurban areas are mostly consumed locally. Therefore, the contamination of vegetables could be a matter of great concern for local residents. Daily intake of metals was highest in case of tomato in present study. Similar results were obtaied by Arora *et al*., [39] who found highest Zn, Cu, Fe and Mn intakes from the consumption of waste water irrigated spinach, carrot, methi and mint respectively. Khan *et al*., [40] also found maximum intakes of Zn, Cu, Ni, Pb, Cd and Cr from of *Lactuca sativa* L, *Raphanus sativus* L, *Brassica napus* L, *Lactuca sativa* L. and *Spinacia oleracea* L. consumption for adults and children. The maximum hazard quotient was obtained cadmium from the consumption of round gourd, brinjal and tomato. The results regarding hazard quotient are in accordance with those obtained by Khan *et al*., [40] who studied health risk index of Zn, Cu, Ni, Pb and Cd from of *Lactuca sativa* L, *Raphanus sativus* L, *Brassica napus* L, *Lactuca sativa* L and *Spinacia oleracea* L. and found that HQ was less than one. Similarly Zhuang *et al*. [41] have also reported HRI for Cd and Pb above the permissible limits in vegetables and cereals.

CONCLUSIONS

The continuous use of wastewater irrigation has led to contamination of soils and vegetables in the study areas. It was concluded that the wastewater-irrigated vegetables were contaminated with heavy metals and exceeded the WHO permissible limits. Hazard quotient of the studied metals was <1 except for cadmium, indicating that there is a relative absence of health risks associated with the ingestion of contaminated vegetables.

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REFERENCES

1. Marshall, F.M., J. Holden, V. Ghose, V. Chisala, E. Kapungwe, J. Volk, M. Agrawal, R. Agrawal, R.K. Sharma and R.P. Singh, 2007. Contaminated Irrigation Water and Food Safety for the Urban and Periurban Poor: Appropriate Measures for Monitoring and Control from Field Research in India and Zambia. Incpetion Report DFID Enkar R8160, SPRU, University of Sussex. www. Pollution and food. net.
2. Sharma, R.K., M. Agarwal and F.M. Marshall, 2007. Heavy metals contamination of soil and vegetables in suburban areas of Varanasi, India. Ecotoxicol. & Environ. Safety, 66: 258-266.
3. Singh, K.P., D. Mohon, S. Sinha and R. Dalwani, 2004. Impact assessment of treated/untreated waste water toxicants discharge by sewage treatment plants on health, agricultural and environmental quality in waste water disposal area. Chemo., 55: 227- 255.
4. Chen, Y., C. Wang and Z. Wang, 2005. Residues and source identification of persistent organic pollutants in farmland soils irrigated by effluents from biological treatment plants. Environ. Int., 31: 778-783.
5. Alam, M.G.M., E. T. Snow and A. Tanaka, 2003. Arsenic and heavy metal contamination of vegetables grown in Santa village, Bangladesh. Sci. Tot. Environ., 308: 83-96.
6. Duruibe, J.O., M.D.C. Ogwuegbu and J.N. Egwurugwu, 2007. Heavy metal pollution and human biotoxic effects. Int. J. Phys. Sci., 2: 112-118.
7. McCluggage, D., 1991. Heavy Metal Poisoning, NCS Magazine. The Bird Hospital, CO, USA. <www.cockatiels.org/articles/Diseases/metals.html>.
8. European Union. 2002. Heavy Metals in Wastes, European Commission on Environment (http: //ec.europa.eu/environment/waste/studies/pdf/heavy metals report.pdf).
9. Lindsay, W.L and, W.A. Norvell, 1978. Development of a DTPA soil test for Zn, Fe, Mn and Cu. S. Sci. Soc. Am. J., 42: 421-428.
10. AOAC. 2000. Official methods of analysis. Association of Official Analytical Chemists International. Maryland, USA.
11. Ureso, J., E.G. Regalado and I. Gracia, 1997. Trace elements in bivalve mollusks Ruditapes decussates and Ruditapes phillippinarum from Atlantic Coast of Southern Spain. Environ. Int., 23(3): 291 298.

12. Rattan, R.K., S.P. Dutta, P.K. Chhonkar, K. Suribabu and A.K. Singh, 2005. Long-term impact of irrigation with sewage effluents on heavy metal content in soil crops and ground water - a case study. Agric. Ecosys. & Environ., 109: 310-322.
13. Wang, X., T. Sato, B. Xing and S. Tao, 2005. Health risks of heavy metals to the general public in Tianjin, China via consumption of vegetables and fish. Sci. Tot. Environ., 350: 28-37.
14. Chien, L.C., T.C. Hung, K.Y. Chaong, C.Y. Yeh, P.J. Meng and Shieh. 2002. Daily intake of TBT, Cu, Zn, Cd and As for fishermen in Taiwan. Sci. Tot. Environ., 285: 177-185.
15. US Environmental Protection Agency (USEPA). 2002. Region 9, Preliminary Remidation Goals. http://www.epa.Gov/region09/waste/sfund/prg.
16. DEFRA (Department of Environment, Food and Rural Affairs). 1999. Total diet study aluminium, arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, tin and zinc. The Stationery Office, London.
17. Soltanpour, P.N., 1985. Use of ammonium bicarbonate- DTPA soil test to evaluate elemental availability and toxicity. J. Plant Nutr., 8: 323-338.
18. Maclean, K.S., A.R. Robinson and H.M. MacConnel. 1987. The effect of heavy metal and sewage sludge on the heavy metal contents of soil and plant tissues. Commun. Soil Sci. & Plant Anal., 18: 1303- 1316.
19. Bi, X., X. Feng, Y. Xeng, G. Qin, F. Li, T. Liu, Z. Fu and Z. Jing, 2006. Environmental contamination of heavy metals from zinc smelting area in Hezhang country, Western Guizhou. China Environ. Int., 32: 883-890.
20. Lei, M., B. Liao, Q. Zeng, P. Qin and S. Khan, 2008. Fraction distribution of lead, cadmium, copper and zinc in metal contaminated soil before and after extraction with disodium ethylene diamine tetra acetic acid. Commun. Soil Sci. & Plant Anal., 39: 1963-1978.
21. WWF, 2007. Report on National Surface Water Classification Criteria, Irrigation water Quality Guidelines for Pakistan, February- 2007. Waste Water Forum Pakistan.
22. WHO, 2007. WHO Expert standards program codex Alimentation Commission. Geneva, Switzerland. Available online http://www.who.int [Accessed 10/09/2012].
23. Wozniak, D.J and J.Y.C. Huang, 1982. Variable affecting removing metals removal from sludge. J. Water Pollut. Cont. Fed., 54: 1574-1580.
24. Jan, F.A., M. Ishaq, S. Khan, I. Ihsanullah, I. Ahmad and M. Shakirullah, 2010. A comparative study of human health risks via consumption of food crops grown on wastewater irrigated soil (Peshawar) and relatively clean water irrigated soil (lower Dir). J. Hazard. Mater., 179: 612-621.
25. Mushtaq, N. and K.S. Khan, 2010. Heavy metals contamination of soils in response to wastewater irrigation in Rawalpindi region. Pak. J. Agri. Sci., 47(3): 215-224.
26. Khan, A., S. Javid, A. Muhmood, T. Majeed, A. Niaz and A. Majeed, 2013. Heavy metal status of soil and vegetables grown on peri-urban area of Lahore district. Soil Environ., 32(1): 49-54.
27. Singh, A., R.K. Sharma, M. Agrawa and F.M. Marshall, 2010. Health risk assessment of heavy metals via dietary intake of foodstuffs from the wastewater irrigated site of a dry tropical area of India. Food Chem. Toxicol., 48: 611-619.
28. Mohallapa, N.J., M.V. Kulkarni and P.R. Purranik, 2010. Flux of heavy metals in soils irrigated with urban waste waters. American-Eurasian J. Agric. & Environ. Sci., 8(5): 487- 493.
29. Hussain, S.I., A. Ghafoor, S. Ahmad, G. Murtaza and M. Sabir, 2006. Irrigation of crops with raw sewage: hazard assessment of effluent, soil and vegetables. Pak. J Agri Sci., 43(3-4): 97-102.
30. Carlton, S.C.H and V. Davis, 1983. Comparative uptake of heavy metals by forage crops grown on sludge treated soils. In: Proceedings of International conference on Heavy metals in the environment. CEP Consultants Ltd., Edinburgh, UK, pp: 3933-3940.
31. Kumar, A., I.K. Sharma, S. Varshney and P.S. Verma, 2009. Heavy metals contamination of vegetable foodstuffs in Jaipur (India). Electronic J. Environ. Agri. Food Chem., 8(2): 96-101.
32. Pandey, R., K. Shubhashish and J. Pandey, 2012. Dietary intake of pollutant aerosols via vegetables influenced by atmospheric deposition and wastewater irrigation. Ecotoxicol. Environ. Safety, 76: 200-208.
33. Cooke, J.A. and M.S. Johnson, 1996. Cadmium in mammals. In: Beyer, W.N., Heinz, G., Redmon-Norwood, A.W. (Eds.), Environmental Contaminants in Wildlife. SETAC special publication series, Boca Raton, FL, Lewis, pp: 377-388.
34. ATSDR. 2007. Toxicological profile for lead. <http://www.atsdr. cdc.gov/csem/lead/pblead2>.

35. Akbar, F., M. Ishaq, I. Ihsanullah and S.M. Asim, 2009. Multivariate statistical analysis of heavy metals pollution in industrial area and its comparison with relatively less polluted area: a case study from the City of Peshawar and District Dir Lower. J. Hazard Mater., 176: 609-616.
36. Khan, S., S. Rehman, A.Z. Khan, M.A. Khan and T. Shah, 2010. Soil and vegetables enrichment with heavy metals from geological sources in Gilgit, northern Pakistan. Ecotoxicol. Environ. Safety, 73: 1820-1827.
37. Caussy, D., M. Gochfeld and E. Gurzan, 2003. Lessons from case studies of metals investigating exposure, bioavailability and risk. Ecotoxicol. Environ. Safety, 56: 45-51.
38. Muchuweti, M., J.W. Birkett, E. Chinyanga, R. Zvauya, M.D. Scrimshaw and J.N. Lester, 2006. Heavy metal content of vegetables irrigated with mixture of wastewater and sewage sludge in Zimbabwe: implications for human health. Agric. Ecosys. & Environ., 112: 41-48.
39. Arora, M., K. Bala, S. Rani, A. Rani, B. Kaur and N. Mittal, 2008. Heavy metal accumulation in vegetables irrigated with different water sources. Food Chemis., 111: 811-815.
40. Khan, S., Q. Cao, Y.M. Zheng, Y.Z. Huang and Y.G. Zhu, 2008. Health risks of heavy metals in contaminated soils and food crops irrigated with wastewater in Beijing, China. Environ. Pollut., 152: 686-692.
41. Zhuang, P., N.Y. Zou and Z.A. Li, 2009. Heavy metal contamination in soils and food crops around Dabaoshan mine in Guangdong, China: implication for human health. Environ. Geochem. Health. doi:10.1007/s10653-009-9248-3.