HEAVY METAL CONTAMINATION IN CHICKEN FEEDING AT WASTEWATER IRRIGATED AGRICULTURAL FARMS IN PERI URBAN AREAS OF MULTAN CITY, PAKISTAN: A HEALTH RISK ASSESSMENT

Z. Iqbal[a], F. Abbas[b], M. Raza[c], M. Gul[d] and R. Haider[e*]

[a] Environmental Protection Agency Punjab, Feroze Pur Road Lahore, Pakistan. E-mail: zafardoe@gmail.com ORCID ID 0000-0002-9094-1626

[b]Faculty of Sustainable Design, Engineering University of Prince Edward Island, Charlottetown, PE, Canada **E-mail:** fabbas@upei.ca

[c]Muhammad Nawaz Shareef University of Agriculture Multan Email: mohsinji774@gmail.com

[d] School Education Department, Punjab, Pakistan. E-mail: tem.multan@gmail.com

[e*]Corresponding author E-mail:rizwanchemist@gmail.com

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ABSTRACT: The nourishing of domestic chicken is source of livelihood in suburb of all cities and is favorite food of public in urban areas in Pakistan. The study assessed the heavy metal pollution in chicken's liver and total target health quotient (TTHQ). From six agricultural farms (4 under wastewater, 1 tube-well and 1 under canal water irrigation), liver samples (n=30)were analyzed for cadmium (Cd), chromium (Cr), copper (Cu), manganese (Mn), nickel (Ni) and lead (Pb) by inductivity coupled plasma-optical emission spectrometry (ICP- OES), Perkin Elmer USA. Samples of wastewater/water used for irrigation and soils from respective sites were analyzed for same metals for source apportionment. The mean contents of Cd, Cr, Cu, Mn and Ni in livers were within safe limits prescribed by World Health Organization (WHO) across all sites and that of Pb exceeded safe limit at wastewater irrigated sites. TTHQ ranged 0.01to 0.16 < 1.0 across all farms showing non carcinogenic health risk to humans. TTHQ values were 5 to 12 times higher at wastewater irrigated farms than that at tube-well and canal water farms. Multivariate statistical analysis indicated that wastewater used for irrigation and contaminated soils are common sources contributing the heavy metal contamination in livers. Tube-well and canal water irrigated fields are better places for nourishing the domestic chicken than wastewater irrigated fields to safeguard the public health.

Keywords: Domestic chicken; health risk index; total target health quotient; wastewater irrigated agricultural fields.

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INTRODUCTION

The meat of chicken is considered as important for human nourishment and contamination with toxic elements like Cd and Pb may influence its quality (Abdolgader *et al*. 2013). The metals may be present in chicken meat from soil from where they pick plants or feed and drink water (Damin *et al*. 2007). There is strong relationship between the cadmium in plants and cadmium in chicken meat and other organs typically kidney and liver (JICA-EPA 2000). The intake of contaminated diet is major source of Cd and Pb intake in humans (Ciobanu *et al*. 2012). The Cd and Pb accumulation in kidneys and livers of poultry has been remained in focus due to their key function in the body (Kalisińska and Salicki 2010). Elements like Pb, Cd and Cr are known carcinogenic due to their high toxicity range, easily rack up in soil and exert sever threats to exposed animals and humans via dust inhalation and intake of contaminated food(Sun *et al*. 2016; ATSDR,2017). Intake of contaminated food for long term can cause accumulation of toxic elements in human organs like kidneys and livers and result in disorder of human nervous system (WHO 2006).Forage grown with industrial and urban wastewater cause health risks to animal due to accumulation of toxic elements(Awasthi *et al*. 2012; Iqbal *et al*. 2019) and intake of meat of such animals for long term is main source of transmission and accumulation of heavy metals to human's organs causing serious health risks implications(Kar *et al*. 2015).

The preceding scenario reflects the significance of investigating the heavy metal contents in chicken meat raised at wastewater irrigated fields for information of general public and regulatory controlling agencies. There are rare studies to estimate the carcinogenic health risk of metals in domestic chicken meat which is favorite food in rural and urban areas in Pakistan. The domestic chickens are raised in wastewater irrigated agricultural farms in peri urban areas of all cities in Pakistan and supplied in urban markets. This is the first study in Pakistan which has provided comprehensive information and baseline data to decision makers and planners to formulate policies and standards for heavy metals in chicken meat and establishment of monitoring system for protection of public health. Therefore, this study was aimed to (i) investigate the concentration of Cd, Cr, Copper, Manganese, Nickel and Lead in domestic chicken liver raised at agricultural farms being irrigated with different qualities of wastewater, tube-well and canal water(i) assess the human health risk index (HRI) and total target health quotient (TTHQ) of heavy metals (ii) identify the sources of heavy metal contamination in domestic chicken liver using multivariate statistical analysis.

MATERIALS AND METHODS

Study area: Multan is the 6th main and centralcity of Pakistan (30.2^{o} north, 71.4 ^{o} east).The average annual rainfall is 186 millimeters mostly in monsoon season(Abbas *et al*. 2014).

Six main agricultural farms in suburb of Multan City were selected as representative farms where domestic chicken are raised in bulk. Four farms (S1, S2, S3, S4) were under wastewater irrigation, one was being irrigated with canal water (S5) and one was under tube-well water irrigation (S6).

Table 1. Description of study area.

Farm	Name of agricultural Farm
S1	Bastee Walvit (untreated industrial effluents)
S2	Chahh Bahadurvala (Untreated urban wastewater)
S3	Moza Kaianpur (canal water + urban untreated wastewater)
S4	Sooruj Miyaani (untreated urban wastewater)
S5	Qader Poor Ranwann (canal water irrigation)
S6	Muaza Mallanna (tube-well water)

Sampling and analytical methodology

Hens (n=30) (female age18-24 months) were purchased from selected sites from the local residents of the respective sites (5 from each site). The hens were slaughtered with standard protocol and procedure. Samples of hen's liver from each site were placed in ice boxes and freezed till analyses. Proper identity and inventory of the samples was prepared.

Composite samples of wastewater/water and surface soil from respective sites were collected according to standard methods to use the data for statistical analyses for source apportionment of toxicity. (data not shown).

Samples were analyzed in Center for Environmental Protection Studies lab, Pakistan Council of Scientific and Industrial Research Lahore, accredited for ISO/IEC 17025 using ICP-OES Perkin Elmer, USA, Optima DV 5300 for the heavy metals according to standard guidelines and methods (ASTM, 2007; APHA 2005; AOAC, 2012).

Human health risk assessment: The daily intake of metals (DIM) was calculated taking average body weight (Table 2) byequation (1)(Balkhair and Ashraf 2015).

$$DIM = \frac{Mc \times \mathrm{Cf} \times \mathrm{Di}}{\mathrm{B}} \quad (1)$$

Mc = mean contents (mg/kg) of element in liver, C_f is conversion factor (fresh weight to dry weight) and it is 0.085, Di is consumption of liver per day (kg), B is average weight of body (kg).

HRI was computed by equation (2)(Balkhair and Ashraf 2015)

$$\mathrm{HRI} = \frac{\mathrm{DIM}}{RfD} \quad (2)$$

HRI > 1.0 indicates the metal is risk full. RfD issafe daily intake dose and for Cd, Cr, Cu, Mn, Ni, Pb were 0.001, 0.003, 0.04, 0.014, 0.02, 0.0035 mg/kg per day per body weight respectively(Iqbal *et al*. 2020).

TTHQ was calculated by equation (3) (US EPA 1986; Iqbal *et al*. 2020)

$$TTHQ = \sum \mathrm{HRIs} \quad (3)$$

TTHQ > 1.0 is indicator of carcinogenic risk food.

Multivariate statistical analyses (MSA), including Pearson correlation matrix (PCM), principal component analyses (PCA), hierarchical cluster analyses (HCA), was conducted for source apportionment using SPSS 21 and Minitab 16 software.

Table 2 Average body weight of children and adults and average weight of liver intake per day.

Age group (years)	*Group*	*Average body weight (kg)*	*Average liver intake kg/day*
4-10	Child	18	0.1
10-15	Children	30	0.2
20-60 and above	Adult	60	0.45

RESULTS AND DISCUSSION

The concentrations of the metals in wastewater/water and soil across all sites were tabulated to use the data for MSA (data not shown). The mean concentrations of the metals in livers of chicken (Table 3) indicated that the contents of Pb exceeded the WHO safe limit at farms S1, S2, S3, S4 and contents of the remaining metals were within safe limits across all farms. Safe limit for Ni was not available in published literature. The data revealed that mean contents of Cd in livers were 25 to 45, Cr were 2 to 10, Cu were 2 to 3.5, Mn were 2 to 6, Ni were 21 to 85 and Pb were 53 to 80 times higher at farms S1, S2, S3, S4 than that at S5.The results indicated that livers of chicken feeding at wastewater irrigated sites contained many times higher contents of the heavy metals than that at tube- well and canal water irrigated sites.

Table 3 Mean contents of heavy metals (mg/kg) in livers of domestic chicken across all farms

Farms		***Cd***	***Cr***	***Cu***	***Mn***	***Ni***	***Pb***	***Total contents***
S1	Mean	0.09	0.05	0.0318	1.36	0.03	0.16	1.722
	± SD	0.0255	0.0141	0.0032	0.0374	0.0045	0.0316	
S2	Mean	0.06	0.02	0.024	0.36	0.0248	0.122	0.611
	± SD	0.0127	0.0055	0.0007	0.0316	0.0033	0.0286	
S3	Mean	0.05	0.008	0.016	0.31	0.0312	0.106	0.521
	± SD	0.0076	0.0007	0.0032	0.0071	0.0057	0.0241	
S4	Mean	0.084	0.011	0.028	0.395	0.103	0.14	0.761
	± SD	0.0167	0.0020	0.0014	0.0036	0.0022	0.0141	
S5	Mean	0.002	0.005	0.0094	0.22	0.0012	0.002	0.24
	± SD	0.0006	0.0020	0.0030	0.0283	0.0004	0.0003	
S6	Mean	0.001	0.002	0.003	0.18	0.001	0.00244	
	± SD	0.0002	0.0004	0.0005	0.0374	0.0003	0.0031	0.189
Mean		0.0478	0.0160	0.0187	0.4708	0.0319	0.0887	
MRL (mg/kg)		0.5[a]	0.1[b]	1[a]	2.9[c]	Not available	0.1[a]	

a (Zhuang *et al*. 2014; FAO/WHO 2002), b Ubwa *et al*. (2017), c Hussain *et al*. (2012)

Figure 1 showed the total contents of the metals (mg/kg) in livers at farm S1, S2, S3, S4, S5 and S6 as 1.72, 0.61, 0.52, 0.76, 0.24 and 0.19 respectively. The order of total contents of the metals was: S1 > S4>S2 > S3 > S5>S6. Total contents of the metals were 2.2 to 7.2 times higher in livers at farm S1, S2, S3, S4, S5 than S6 and were lower at S6 than that at S5. The data revealed that the livers at farm (S1) under industrial effluents irrigation were highest contaminated and lowest contamination in livers was at tube-well water irrigated farm (S6). It might be due to availability of higher concentration of the heavy metals in wastewater and soil which provided more opportunity to heavy metals to transmit the in chicken's liver through different pathways from where they pick food items.

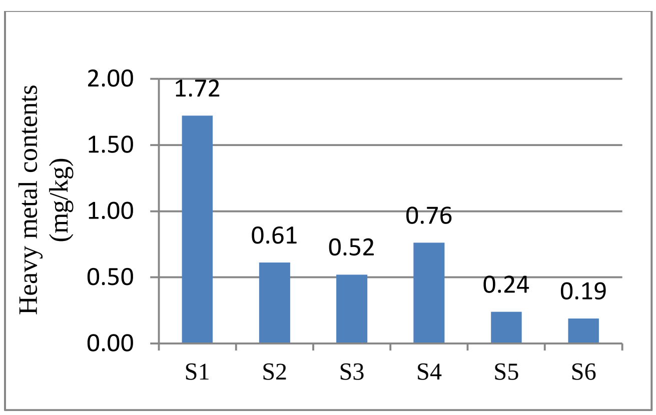

Figure 1. Total contents of heavy metals in chicken liver across all farms

Human health risk assessment: DIM, HRI and TTHQ values across all farms for children and adults are given in Table 3 and site wise comparison of TTHQ is shown in Figure 2.

The HRI < 1.0 of all the metals across all farms indicated that all the metals were risk free for all age groups of humans.TTHQ ranged0.01 to 0.16 < 1.0 across all sites showing the chicken liver health risk free for consumption of humans. However the TTHQwere 5.3 to 12.5 times higher at farms S1, S2, S3, S4 than that at farm S5. The results revealed that the chicken feeding at wastewater irrigated sites yielded higher TTHQ due to higher contamination with the metals than that at tube-well and canal water irrigated sites. The tube well water irrigation site yielded lower TTHQ than that at canal water irrigation site which revealed that chicken raised at tube- well water irrigation site were less contaminated with heavy metals than that at canal water irrigation site. The results showed that tube-well and canal water irrigation sites are better safe places for nourishing the domestic chicken for safe food produce for human consumption than wastewater irrigated fields to protect public health.

Table 4. DIM, HRI and TTHQ of heavy metals via intake of chicken liver for children and adults

Farm	*Group years*	*Body weight kg*	*Liver intake kg/day*	*DIM HRI*	*Cd*	*Cr*	*Cu*	*Mn*	*Ni*	*Pb*	*TTHQ*
	Child	18	0.1	Mean	0.09	0.05	0.0318	1.36	0.03	0.16	
	4-10			DIM	4E-05	2E-05	1E-05	0.0006	1.4E-05	8E-05	0.12
				HRI	0.0423	0.0078	0.0004	0.0457	0.00071	0.021	
S1	Child	30	0.2	DIM	5E-05	3E-05	2E-05	0.0008	1.7E-05	9E-05	0.14
	10-15			HRI	0.0504	0.0093	0.0004	0.0544	0.00084	0.0256	
	Adult	60	0.45	DIM	6E-05	3E-05	2E-05	0.0009	1.9E-05	1E-04	0.16
	20-60			HRI	0.0576	0.0107	0.0005	0.0622	0.00096	0.029	
	Child	18	0.1	Mean	0.06	0.02	0.024	0.36	0.0248	0.122	
	4-10			DIM	3E-05	9E-06	1E-05	0.0002	1.2E-05	6E-05	0.06
				HRI	0.0282	0.0031	0.0003	0.0121	0.00058	0.016	
S2	Child	30	0.2	DIM	3E-05	1E-05	1E-05	0.0002	1.4E-05	7E-05	0.07
	10-15			HRI	0.0336	0.0037	0.0003	0.0144	0.000694	0.0195	
	Adult	60	0.45	DIM	4E-05	1E-05	2E-05	0.0002	1.6E-05	8E-05	0.08
	20-60			HRI	0.0384	0.0043	0.0004	0.0165	0.00079	0.022	
	Child	18	0.1	Mean	0.05	0.008	0.016	0.31	0.0312	0.106	
	4-10			DIM	2E-05	4E-06	8E-06	0.0001	1.5E-05	5E-05	0.05
				HRI	0.0235	0.0013	0.0002	0.0104	0.00073	0.014	
S3	Child	30	0.2	DIM	3E-05	4E-06	9E-06	0.0002	1.7E-05	6E-05	0.06
	10-15			HRI	0.028	0.0015	0.0002	0.0124	0.000874	0.017	
	Adult	60	0.45	DIM	3E-05	5E-06	1E-05	0.0002	2E-05	7E-05	0.07
	20-60			HRI	0.032	0.0017	0.0003	0.0142	0.001	0.019	
	Child	18	0.1	Mean	0.084	0.011	0.028	0.395	0.103	0.14	
	4-10			DIM	4E-05	5E-06	1E-05	0.0002	4.8E-05	7E-05	0.08
				HRI	0.0395	0.0017	0.0003	0.0133	0.00242	0.019	
S4	Child	30	0.2	DIM	5E-05	6E-06	2E-05	0.0002	5.8E-05	8E-05	0.09
	10-15			HRI	0.04704	0.0021	0.0004	0.0158	0.002884	0.0224	
	Adult	60	0.45	DIM	5E-05	7E-06	2E-05	0.0003	6.6E-05	9E-05	0.10
	20-60			HRI	0.0538	0.0023	0.0004	0.0181	0.0033	0.026	
	Child	18	0.1	Mean	0.002	0.005	0.0094	0.22	0.0012	0.002	
	4-10			DIM	9E-07	2E-06	4E-06	0.0001	5.6E-07	9E-07	0.01
				HRI	0.0009	0.0008	0.0001	0.0074	2.8E-05	3E-04	
S5	Child	30	0.2	DIM	1E-06	3E-06	5E-06	0.0001	6.7E-07	1E-06	0.01
	10-15			HRI	0.00112	0.0009	0.0001	0.0088	3.36E-05	0.0003	
	Adult	60	0.45	DIM	1E-06	3E-06	6E-06	0.0001	7.7E-07	1E-06	0.01
	20-60			HRI	0.0013	0.0011	0.0002	0.0101	3.8E-05	4E-04	
	Child	18	0.1	Mean	0.001	0.002	0.003	0.18	0.001	0.002	
	4-10			DIM	5E-07	9E-07	1E-06	8E-05	4.7E-07	1E-06	0.01
				HRI	0.0005	0.0003	4E-05	0.006	2.4E-05	3E-04	
S6	Child	30	0.2	DIM	6E-07	1E-06	2E-06	0.0001	5.6E-07	1E-06	0.01
	10-15			HRI	0.00056	0.0004	4E-05	0.0072	0.000028	0.0004	
	Adult	60	0.45	DIM	6E-07	1E-06	2E-06	0.0001	6.4E-07	2E-06	0.01
	20-60			HRI	0.0006	0.0004	5E-05	0.0082	3.2E-05	4E-04	
RfD[a] values mg/kg.bw/day					0.001	0.003	0.04	0.014	0.02	0.004	

a US EPA (2005)

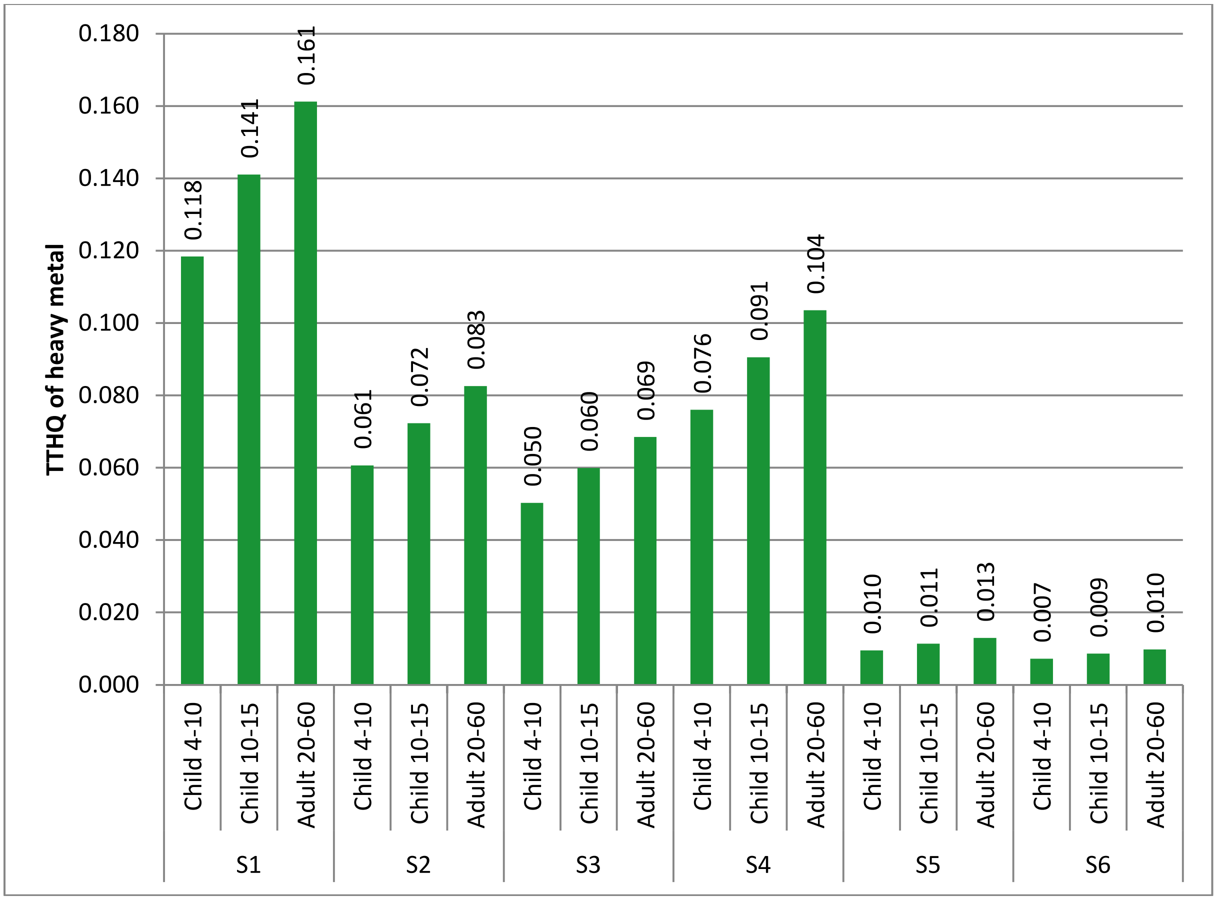

Figure 2. TTHQ of heavy metals in chicken liver across all farms

Source apportionment: Correlation analysis is an effective tool to show the relationships between elements. The elements originating from same source indicate significant correlation (Jiang *et al*. 2014). Hence, Pearson's coefficients of correlation of elements were computed. The group formation of elements imparting from same or similar source is shown byHCA.PCA shows the relationship and group formation among the elements. Positive loadings of elements on principal components (PC) point out the anthropogenic sources and negative loadings indicate towards natural sources of contamination (Rodriguez *et al*. 2008). PCA and HCA are often applied together for confirmation of results (Soliman *et al*. 2015).Hence PCA and HCA were performed.

PCM (Table4) showed that allmetal pairs have high significant positive correlation within liver at0.01 indicating same source disseminating the contamination in chicken liver across all sites. The metals in livers showed high significant positive correlation with the metals in wastewater (Table 4) and with the metals in soil(Table 5)at 0.01indicating both soil and wastewater were common sources contributing the contamination in livers across all sites.

The dendogram (Figure 2) in HCA showed the group formation. The metals Cd, Pb, Cu and Ni framed group 1and Cr and Mn framed group 2.

Table 4 PCM between heavy metals within chicken liver and metals of wastewater.

	Cd	*Cr*	*Cu*	*Mn*	*Ni*	*Pb*	*wwCd*	*wwCr*	*wwCu*	*wwMn*	*wwNi*	*wwPb*
Cd	1	**0.607****	**0.889****	**0.638****	**0.683****	**0.968****	**0.680****	0.154	**0.649****	**0.656****	**0.522****	**0.519****
Cr		1	**0.704****	**0.915****	**0.098**	**0.599****	**0.566****	-0.115	**0.518****	**0.760****	**0.610****	**0.913****
Cu			1	**0.702****	**0.636****	**0.906****	**0.676****	0.064	**0.631****	**0.671****	**0.571****	**0.596****
Mn				1	0.124	**0.624****	**0.454***	-0.034	**0.439***	**0.757****	**0.575****	**0.979****
Ni					1	**0.625****	0.356	**0.548****	0.21	0.277	**0.488****	**-0.056**
Pb						1	**0.731****	0.058	**0.750****	**0.646****	**0.490****	**0.519****

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tail

Table 5 PCM between heavy metals within chicken liver and metals of surface soil

	Cd	*Cr*	*Cu*	*Mn*	*Ni*	*Pb*	*ssCd*	*ssCr*	*ssCu*	*ssMn*	*ssNi*	*ssPb*
Cd	1	**0.607****	**0.889****	**0.638****	**0.683****	**0.968****	**0.509****	**0.523****	**0.717****	-0.153	0.165	**0.536****
Cr		1	**0.704****	**0.915****	**0.098**	**0.599****	**0.888****	**0.885****	0.642**	**-0.517****	-0.288	**0.896****
Cu			1	**0.702****	**0.636****	**0.906****	**0.572****	**0.579****	**0.640****	-0.194	0.249	**0.597****
Mn				1	0.124	**0.624****	**0.983****	**0.983****	**0.638****	**-0.712****	**-0.387***	**0.988****
Ni					1	**0.625****	-0.027	0.026	0.321	0.074	**0.594****	0.001
Pb						1	**0.493****	**0.498****	**0.770****	-0.09	0.128	**0.522****

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tail

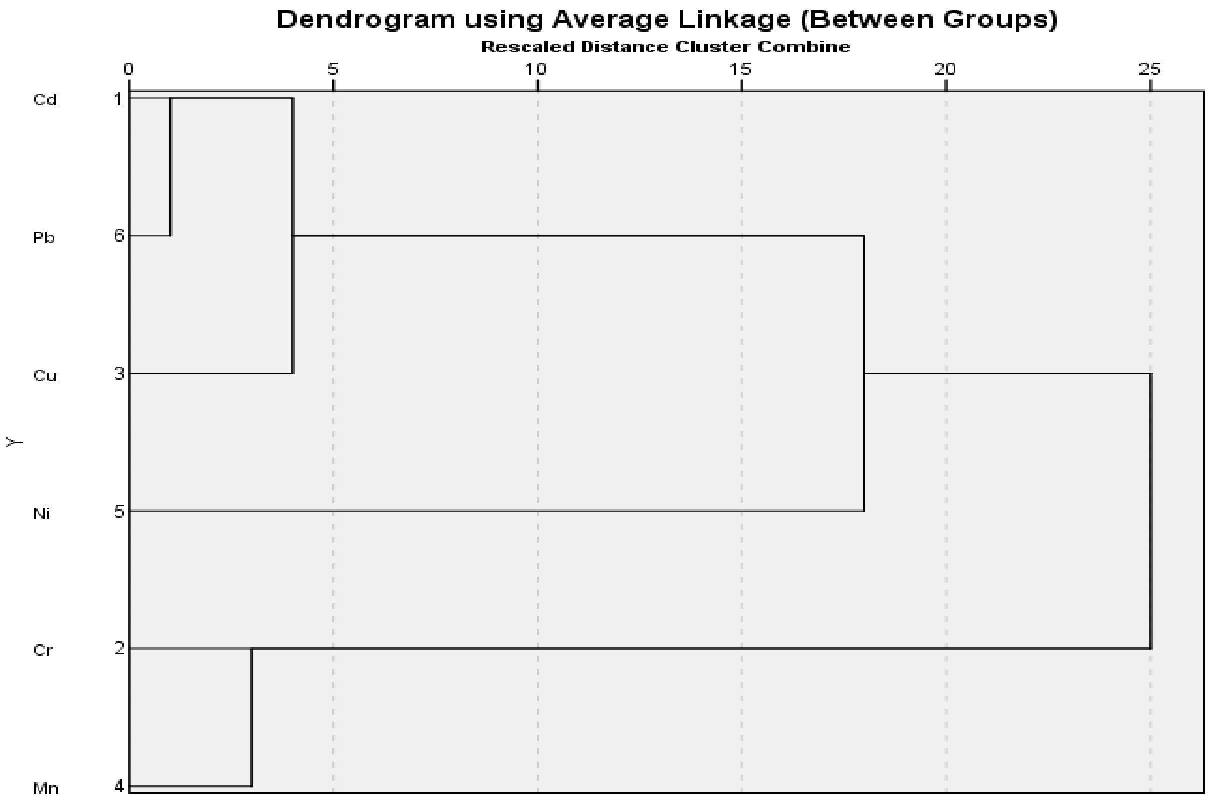

Figure 2 HCA of heavy metals in chicken liver across six irrigation sites

For PCA, two PCs showing Eigenvalues > 1.0 were extracted (Table 6). The PC 1 (Eigenvalue 4.33) explained 72.2 % and PC 2 (Eigenvalue 1.24) explained 20.7 % of total variance in the analyzed data. The PC 1 exhibited high positive loadings ofPb, Cu and Cd, and PC 2 exhibited high positive loadings of Cr and Mn. The positive loadings pointed out theanthropogenic activities like urban sewage, industrial effluents, sludge (Ali *et al*. 2019). PCA biplot(Figure 3) indicated the formation of two groups of the metals of same composition as illustrated by HCA dendogram (Figure 2) which confirmed the results of PCA. The domestic chicken pick food items from fields irrigated with wastewater and thus take contaminated food.

Table 6 PC loadings of the elements in livers of domestic chicken across all farms

	Chicken liver	
	PC1	***PC2***
Eigenvalues	4.33	1.24
% Total Variance	72.2	20.7
% Cumulative Variance	72.2	92.9
Cd	0.457	-0.182
Cr	0.376	0.514
Cu	0.461	-0.074
Mn	0.384	0.491
Ni	0.292	-0.656
Pb	0.453	-0.161

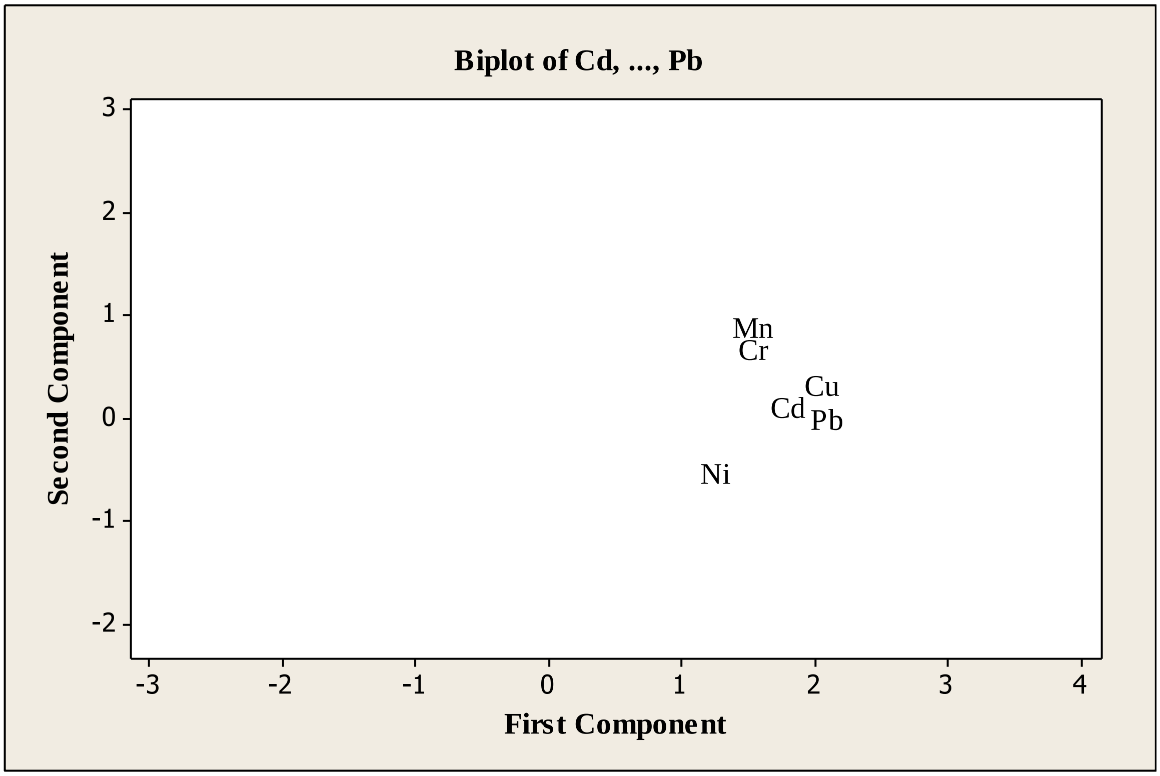

Figure 3 PCA biplot of heavy metals in chicken liver across all farms

Multivariate statistical analyses evidenced that waste water and soils were adding the metal contamination in domestic chicken liver across all sites. The farm S1was being irrigated by combined industrial effluents (14 cusec) discharged by Multan industrial estate (MIE) having more than 300 industrial units including phosphate fertilizer, edible oils, smelting plants, auto parts manufacturing and repairing, textile dyeing, pesticide formulation, electroplating are functional and similar units are operational in urban area discharging wastewater in sewerage system which is used to irrigate the S2, S3 and S4 sites (Tariq *et al*. 2010; Iqbal 2018) and these units disseminate the heavy metals in their processed wastewater (Ali *et al*. 2019) which is source of metal contamination in soil and food stuff grown in study area (Randhawa *et al*. 2014, Ismail *et al*. 2015, Iqbal *et al*. 2019; Iqbal *et al*. 2020).

The results of this study are supported by the results of previous studies (Abdolgader *et al*. 2013 ; Ismail and Abolghait, 2013;Hussain *et al*. 2012;Aljaff *et al*. 2014;Akan *et al*. 2010;Zhuang *et al*. 2014;Rehman *et al*. 2013) (Table 7). In previous studies only contents of selected metals were observed and compared with allowable limits but in this study carcinogenic health risk of metals in form of TTHQ was computed and TTHQ values of domestic chicken feeding in six different environments were also compared to identify the best environment for nourishing the domestic chicken. Total contents of the metals in livers of domestic chicken were 2.2 to 7.2times higher feeding at four wastewater irrigated fields than that at canal water irrigation field and were lowest at tube-well water irrigated fields. TTHQ ranged 0.01 to 0.16 < 1.0 across six sites showing health risk free for exposed population. TTHQ were 5.3 to 12.4 times higher at wastewater irrigated fields than that at canal water field. The chicken raised at tube- well water irrigation site yielded lower TTHQ than that at canal water irrigation site.The higher contamination of chicken liver at wastewater irrigated fields is also indicating that other organs of domestic chicken like tissues may also become contaminated. Continuous consumption of domestic chicken raised at wastewater irrigated fields may cause serious health implications due to intake of heavy metals and their accumulation in different organs of the human body. Iqbal *et al*.(2019) reported that maize plants grown with wastewater (in study area) posed high carcinogenic risk to animals feeding these plants due to accumulation of heavy metals. The domestic chicken pick food items from fields irrigated with wastewater and thus take contaminated food. The results showed that tube-well water and canal water irrigation sites are best places for nourishing the domestic chicken while wastewater irrigated fields are sources of heavy metal contamination in the organs of domestic chicken.

Table 7 Comparison of results of heavy metal contents (mg/kg) in livers of domestic chicken in this study with the other studies

Location	***Chicken organs***	***Cd***	***Cr***	***Cu***	***Mn***	***Ni***	***Pb***	***Reference***
Libya	Liver G1	0.085[**]	-	-	-	-	0.23[**]	(Abdolgader *et al*. (2013)
	Liver G2	0.079[**]	-	-	-	-	0.199[**]	
	Liver G3	0.036[*]	-	-	-	-	0.213[**]	
	Liver G4	0.04[*]	-	-	-	-	0.222[**]	
	Liver G5	0.06[**]	-	-	-	-	0.215[**]	
Egypt	Liver	0.04[*]	-	-	-	-	0.87[**]	Ismail and Abolghait. (2013)
Iraq	Liver of local chicken	0.124[**]	-	-	-	-	3.269[**]	Hussain *et al*. (2012)
	Liver of branded chicken	0.078[**]	-	-	-	-	2.577[**]	
Iraq	Liver	0.005[*]	0.086[**]	0.158[**]	0.09[*]	0.09[**]	-	Aljaff *et al*. (2014)
Nigeria	Liver	0.27[**]	0.651[**]	1.44[**]	4.11[**]	1.09[**]	0.22[**]	Akan *et al*. (2010)
China	Liver	9.36[**]	-	5.18[**]	-	-	0.73[**]	Zhuang *et al*. (2014a)
	Kidney	4.64[**]	-	1.31[**]	-	-	1[**]	
Pakistan (Kohat)	Liver G1	-	-	9.18[**]	3.84[**]	-	-	Rehman *et al*. (2013)
	Kidney G1	0.01[*]	-	3.82[**]	1.18[**]	-	13.09[**]	
	Liver G2	1.09[**]	-	8.89[**]	3.94[**]	-	-	
	Kidney G2	-	-	4[**]	-	-	0.04[**]	
	Liver G3	-	-	10.07[**]	4.32[**]	-	7.56[**]	
	Kidney G3	-	-	1.9[**]	1.08[**]	-	1.52[**]	
	Liver G4	-	-	7.28[**]	0.24[*]	-	-	
	Kidney G4	-	-	-	-	-	2.16[**]	
Pakistan (Multan city)	Liver (mean)	0.047	0.016	0.018	0.47	0.03	0.08	This study

[*] Concentration lower than the concentration measured in this study, [**] Concentration higher than the concentration measured in this study

Conclusions: The TTHQ values of chicken liver were less than 1.0 across six sites exhibiting "non-carcinogenichealth risk"and the livers of domestic chicken were "health risk free" to exposed population of all age groups.

The TTHQ values of heavy metals in domestic chicken liver were 5 to 12 times higher feeding at wastewater irrigation sites than that at canal water and tube-well water irrigated siteswhich indicated that the domestic chicken feeding at wastewater irrigation sites were more contaminated with heavy metals than that feeding at canal water and tube-well water irrigated fields.The domestic chicken pick food items from fields irrigated with wastewater and thus take contaminated food. The multivariate statistical analysis indicated that the wastewater used for irrigation and contaminated soil are common sources contributing the heavy metal contamination in domestic chicken liver. Therefore wastewater irrigated agricultural fields are not suitable for nourishing the domestic chicken to avoid the intake of heavy metals to human body through this food chain to save public from health risk implications

The canal water and tubewell water irrigated fields are best places for nourishing the domestic chicken

Conflict of Interest: The authors declare that they have no conflict of interest

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