

Research Article



Effect of Different Irrigation Sources on Proximate Composition and Heavy Metals Uptake in Some Selected Vegetables

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Abstract | Polluted soils due to prolonged irrigated by f waste water are a reason of accumulation of heavy metals leads to the production of contaminated food which exerts serious health risks to the humans. In the present study, edible portions of five vegetables viz., okra, tomato, spinach, carrot and cauliflower, grown with canal, tubewell and sewage irrigation water, were assessed for their proximate (moisture, ash, protein and fiber) and heavy metal (Pb, Ni, Cu, Cd, Fe and Cr) contents. Significant differences were found for proximate composition of canal, tubewell and sewage water irrigated vegetables. The vegetables grown with tubewell water had higher moisture, ash and fiber contents compared with those grown with canal and sewage water; whereas protein content detected was higher in okra, tomato and spinach irrigated with sewage water and in carrot and cauliflower grown with tubewell water. Significant variations were also recorded in heavy metal (Pb, Ni, Cu, Cd, Fe and Cr) contents of these vegetables grown with different sources of irrigation water. The vegetables irrigated with sewage water had greater concentrations of these metals, which were higher than the safe limits recommended by WHO (1996). All the vegetables grown with tubewell water had significantly lower heavy metal contents, well below the critical limits. The concentration of Pb in tomato and cauliflower, Cd in tomato and spinach, and Fe in spinach irrigated with canal water were also detected beyond the safe limits. The study concludes that the continuous use of sewage water deteriorates or lowers the quality and increases heavy metal contents of vegetables.

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Introduction

Most of agricultural lands especially near urban areas are irrigated by city or municipal waste water due to insufficient availability of fresh water, undemanding accessibility and discarding problems of waste water. Waste water is recognized markedly to add heavy metals into soils (Mapanda et al., 2005; Ahmad et al., 2015; Khan et al., 2016). Heavy metals are injurious to humans and animals

due to their solubility in water, non-biodegradable nature and their potential to build up in various body parts. These are even toxic and detrimental to humans at very low concentrations as there is no proper route for their removal from the body.

Waste water contains large quantity of noxious heavy metals such as lead (Pb), nickel (Ni), iron (Fe), copper (Cu), cadmium (Cd), chromium (Cr), zinc (Zn) etc. (), which affects plant growth (Nazir et al., 2015;

Munzuroglu and Geckil, 2002). These metals also exert various health risks (Singh et al., 2004; Chen et al., 2005; Murtaza et al., 2010) due to transfer of these contaminants into food chain (Jamal et al., 2013). The use of waste water and excessive use of agro-chemicals are the chief sources of poisonous heavy metals (Yusuf and Osibanjo, 2006). The agricultural soils irrigated with waste water contain large quantity of heavy metals that not only pollute the soil but also deteriorate food quality and safety when vegetables and other food crops are grown on these soils (Mapanda et al., 2005; Muchuweti et al., 2006; Bigdeli and Seilsepour, 2008; Zulfqar et al., 2012). Food security and health threats make heavy metals as one of the most severe environmental issue. The increase in heavy metal contents of agricultural soils is the result of enhanced anthropogenic activities (Sharma et al., 2007). On the other hand, soils irrigated with waste water are beneficial for farmers as these have enhanced organic matter content and essential plant nutrients such as available phosphorus, potassium, nitrogen and magnesium as compared to fresh water irrigated soils and impart to lessen the expenditures of fertilizers (Ramirez-Fuentes et al., 2002; Rusan et al., 2007; Qadir et al., 2010; Rai et al., 2011) mainly in soils situated near industries and peri-urban areas (Murtaza et al., 2010).

Vegetables are important part of human diet as they provide proteins, carbohydrates and fats, and are economical source of energy. The significance of these biochemical substances is well documented (Hussain et al., 2010). A proximate analysis and nutrient contents of some vegetables showed that they also contain appreciable quantities of minerals, vitamins, antioxidants and other biochemical constituents (Bolanle et al., 2014). Proximate and mineral compositions of vegetables have been found to be significantly affected by the soil (Hussain et al., 2011) and water quality used for irrigation, which ultimately affects human health (Singh et al., 2004; Tandi et al., 2004). Vegetables, when grown on polluted soils or through irrigation with waste water, accumulate higher quantity of heavy metals in their edible and non-edible parts (Bahemuka and Mubofu, 1999; Alam et al., 2003; Sharma et al., 2006; Perveen et al., 2012). Leafy vegetables tend to accumulate more heavy metals and render more environmental pollution due to their large surface area (Itanna, 2002) as compared to other fruit vegetables.

This issue needs special attention, when agricultural lands are continuously irrigated with untreated

sewage water for longer times to cultivate vegetables. Heavy metal bioaccumulation in the food chain can be highly dangerous to human health (Dadar, 2016). Ingestion of heavy metals by humans through various foods such as vegetables has been recorded (Muchuweti et al., 2006). Human body organs such as liver, bones and kidneys accumulate heavy metals which create various health hazards (Duruibe et al., 2007). Toxic effects of heavy metals include neurological damage, immune system suppression and fatal abnormalities in humans and animals. However, each metal shows its particular signs and symptoms of toxicity (Besser et al., 2007). Heavy metals in higher concentrations can affect liver, brain, lungs and bones (Jamal et al., 2013). Therefore, the present study was carried out with the intention to evaluate and compare the proximate composition and heavy metal accumulation of some vegetables irrigated with canal, tubewell and sewage water continuously for the last fifteen years.

Materials and Methods

Collection of samples

The mature edible parts of five vegetables (tomato, okra, cauliflower, carrot and spinach) were collected randomly from areas located in the vicinity of Multan irrigated with different sources of water such as canal, tubewell and sewage water continuously for the last fifteen years. The collected vegetable samples were brought to the laboratories of Department of Horticulture and Department of Food Science and Technology, Bahauddin Zakariya University, Multan for their analysis. The dust particles from collected vegetables were removed by washing with distilled water and air dried in shade for one hour.

Proximate analysis

Edible parts of above mentioned vegetables were analyzed for their following contents.

Moisture content

The vegetable samples were dried in an oven (Memmert, 100-Germany) at $105 \pm 2^\circ\text{C}$ for 24 hours and their moisture contents were estimated following the procedure of AOAC (1995).

Ash content

The ash contents of vegetables were measured by incineration at 550°C for 6 hours following the method 942.05 (AOAC, 1990).

Crude Protein

The nitrogen contents of the vegetable samples were determined by micro Kjeldahl (Glass Model Pyrex-1) (984.13) and crude protein content was estimated by multiplying nitrogen with factor 6.25 (AOAC, 1990).

Crude fiber

Standard procedure (962.09) of Anon (1990) was used to estimate the crude fiber contents.

Heavy metals analysis

For heavy metal extraction, vegetable samples were sliced into pieces and dried in an oven (Memmert-100, Germany) for 72 hours at 70 °C. then dried vegetable plant parts were ground with a pestle in a mortar to a fine powder and sieved through a muslin cloth. 0.5 g dried samples (three replicates for each vegetable) from each source of irrigation were digested in 15 ml of HNO₃ and 5ml HClO₄ mixture (3:1) on a hot plate (ARE, Velp Italy) at 80 °C until transparent solutions were obtained. These transparent solutions were filtered through Whatman # 42 filter paper and then diluted to 25 ml with deionized distilled water separately (Farooq et al., 2008; Hseu, 2004). The concentrations of heavy metals (Pb, Ni, Cu, Cd, Fe and Cr) in the filtrates were determined by using an Atomic Absorption Spectrophotometer (Perkin Elmer-100).

Statistical analysis

The recorded data were subjected to one way analysis of variance (ANOVA) as described by Steel et al. (1997). Least significance difference test was applied to assess significant differences between the means at 5% level of probability.

Results and Discussion

Proximate analysis

The results of moisture, ash, protein and fiber contents of edible parts of selected vegetables collected from areas continuously irrigated with different sources of irrigation water are presented in Table 1.

Moisture

Statistical analysis of the data showed significant differences in proximate composition of vegetables. Vegetables irrigated with tubewell water had significantly higher moisture content in their edible parts, followed by those irrigated with canal water. The minimum moisture content was recorded in vegetables irrigated with sewage water (Table 1).

Ash

Table 1 indicated that significantly higher ($p \geq 0.05$) ash content were measured in edible parts of the studied vegetables irrigated with tubewell water as compared to those irrigated with canal and sewage water.

Protein

The crude protein contents in edible parts of the vegetables grown in sewage, canal and tubewell water are presented in Table 1. Protein contents were significantly higher ($p \geq 0.05$) in okra, tomato and spinach when grown with sewage water, followed by those irrigated with canal water. Lower values for protein content were recorded in these vegetables grown with tubewell water. While, flower (cauliflower) and root (carrot) vegetables had higher protein content when grown with tubewell water, followed by when grown with canal water. Significantly lower protein content was recorded when these vegetables (cauliflower and carrot) were raised with sewage water.

Fiber

The crude fiber content of the vegetables grown with various sources of irrigation water is given in Table 1. All the vegetables studied had significantly higher ($p \geq 0.05$) fiber content when grown with tubewell as an irrigation source, followed by when irrigated with canal water. The minimum fiber content in these vegetables was observed when grown with sewage water.

Heavy metals

The concentrations of Pb, Ni, Cu, Cd, Fe and Cr in edible portions of five different vegetables grown with different water sources (tubewell, canal and sewage) are presented in Table 2.

Lead (Pb)

In edible parts of all the vegetables irrigated with sewage water, Pb content was significantly higher ($p \geq 0.05$) compared with those grown with canal or tubewell water (Table 2). Pb content of canal water grown carrot (1.83 mg kg⁻¹), spinach (1.70 mg kg⁻¹) and okra (1.36 mg kg⁻¹) were within the limits. The lowest Pb content was found in all the vegetables irrigated with tubewell water, which were within permissible limit. Spinach when raised with sewage water accumulated higher amounts of Pb in their leaves (38.43 mg kg⁻¹), followed by carrot roots (35.80 mg kg⁻¹) and cauliflower heads (27.73 mg kg⁻¹). The fruits of tomato and okra pods accumulated lower amounts of Pb (18.80 and 6.77 mg kg⁻¹, respectively) as compared to these vegetables when grown with sewage water.

Table 1: Proximate composition of edible parts of some vegetables grown with different types of irrigation water.

Vegetables	Treatments	Moisture content (%)	Ash content (%)	Protein (%)	Fiber (%)
Okra	Canal water	83.47 ± 0.15b	8.50 ± 0.10b	13.23 ± 0.06b	13.80 ± 0.10b
	Tubewell water	85.87 ± 0.15a	9.13 ± 0.06a	11.30 ± 0.10c	14.80 ± 0.10a
	Sewage water	81.50 ± 0.10c	6.80 ± 0.10c	14.50 ± 0.10a	13.00 ± 0.10c
	LSD _{0.05}	0.2746	0.1762	0.1762	0.1998
Tomato	Canal water	92.27 ± 0.15b	4.80 ± 0.10b	1.00 ± 0.10b	1.57 ± 0.06b
	Tubewell water	93.80 ± 0.10a	5.23 ± 0.15a	0.60 ± 0.10c	1.85 ± 0.05a
	Sewage water	89.10 ± 0.35c	3.50 ± 0.10c	1.05 ± 0.01a	1.27 ± 0.06c
	LSD _{0.05}	0.4517	0.2401	0.1635	0.1104
Spinach	Canal water	89.37 ± 0.15b	22.37 ± 0.06b	22.13 ± 0.21b	6.50 ± 0.10b
	Tubewell water	90.43 ± 0.15a	24.16 ± 0.29a	20.20 ± 0.10c	7.80 ± 0.10a
	Sewage water	86.53 ± 0.15c	20.53 ± 0.31c	23.60 ± 0.10a	5.70 ± 0.10c
	LSD _{0.05}	0.3052	0.4965	0.2903	0.1998
Carrot	Canal water	84.37 ± 0.21b	8.60 ± 0.10b	1.00 ± 0.006b	1.23 ± 0.06b
	Tubewell water	85.97 ± 0.21a	9.30 ± 0.10a	1.04 ± 0.010a	1.53 ± 0.07a
	Sewage water	80.40 ± 0.10c	7.10 ± 0.10c	0.70 ± 0.10c	0.93 ± 0.06c
	LSD _{0.05}	0.3586	0.1998	0.1161	0.1215
Cauliflower	Canal water	88.40 ± 0.10b	1.43 ± 0.06b	27.40 ± 0.10b	7.20 ± 0.10b
	Tubewell water	89.90 ± 0.20a	1.69 ± 0.010a	28.67 ± 0.15a	7.90 ± 0.10a
	Sewage water	84.20 ± 0.10c	1.13 ± 0.06c	26.00 ± 0.10c	5.50 ± 0.10c
	LSD _{0.05}	0.2825	0.949	0.2401	0.1998

Values are mean ± SD of three samples of edible portions of each vegetable; analyzed individually in triplicate. Mean values having the same letters are not significantly different ($p \geq 0.05$).

Nickel (Ni)

The vegetables irrigated with sewage water had significantly higher ($p \geq 0.05$) Ni content compared with those irrigated with canal and tubewell water (Table 2). The maximum Ni contents in sewage irrigated vegetables were recorded in spinach (27.57 mg kg⁻¹), followed by cauliflower (16.83 mg kg⁻¹), carrot (15.67 mg kg⁻¹), tomato (13.20 mg kg⁻¹) and okra (10.27 mg kg⁻¹). The Ni contents in all the vegetables irrigated with canal water ranged from 4.60 to 6.80 mg kg⁻¹, being low in tomato and high in spinach. Tubewell water irrigated vegetables had Ni contents ranging from 1.70 to 3.80 mg kg⁻¹, with lower value in cauliflower and higher one in okra. All the vegetables irrigated with sewage water contained Ni contents above the safe limits, whereas Ni contents in all those irrigated with canal and/or tubewell water were.

Copper (Cu)

Irrigation with sewage water resulted in significantly higher ($p \geq 0.05$) Cu content in all the vegetables as compared with other two sources of water. The maximum Cu content was found in spinach (38.10 mg kg⁻¹), followed by carrot (26.47 mg kg⁻¹), tomato

(15.80 mg kg⁻¹), cauliflower (15.60 mg kg⁻¹) and okra (10.90 mg kg⁻¹). The vegetables irrigated with canal water had Cu contents ranging from 4.10 to 8.60, being low in tomato and high in spinach. The vegetables irrigated with tubewell water showed lowest Cu contents i.e. 0.94 to 4.40 mg kg⁻¹ with lower value in okra and higher in spinach (Table 2).

Cadmium (Cd)

The maximum contents of Cd were recorded in all the five vegetables tested when irrigated with sewage water, which were significantly higher ($p \geq 0.05$) than those irrigated with other two sources of irrigation. The canal irrigated vegetables had intermediate levels of Cd (0.016 to 0.59 mg kg⁻¹), while the lowest Cd contents were detected in all the vegetables irrigated with tubewell water.

Iron (Fe)

The data regarding Fe contents in tested vegetables grown in sewage, canal and tubewell water are presented in Table 2. The results indicated that significantly higher ($p \geq 0.05$) Fe levels were recorded in all the vegetables raised with sewage water. In canal irrigated

Table 2: Heavy metal contents (mg kg⁻¹) of edible parts of some vegetables grown with different types of irrigation water.

Vegetables	Treatments	Lead (Pb)	Nickel (Ni)	Copper (Cu)	Cadmium (Cd)	Iron (Fe)	Chromium (Cr)
Okra	Canal water	1.36 ± 0.04b	5.40 ± 0.10b	5.34 ± 0.05b	0.02 ± 0.010b	122.57 ± 0.96b	0.71 ± 0.01b
	Tubewell water	0.94 ± 0.01c	3.80 ± 0.10c	0.94 ± 0.01c	0.01 ± 0.006b	58.43 ± 0.85c	0.33 ± 0.01c
	Sewage water	6.77 ± 0.06a	10.27 ± 0.32a	10.90 ± 0.40a	1.23 ± 0.058a	151.03 ± 0.38a	1.50 ± 0.10a
	LSD _{0.05}	0.0821	0.4051	0.4652	0.0679	1.5433	0.1165
Tomato	Canal water	4.40 ± 0.20b	4.60 ± 0.10b	4.10 ± 0.10b	0.59±0.01b	119.57 ± 0.91b	0.83 ± 0.01b
	Tubewell water	1.00 ± 0.10c	2.53 ± 0.05c	1.90 ± 0.10c	0.004±0.001c	76.43 ± 1.25c	0.30 ± 0.01c
	Sewage water	18.80 ± 0.10a	13.20 ± 0.30a	15.80 ± 0.10a	2.5±0.10a	153.43 ± 0.78a	1.23 ± 0.058a
	LSD _{0.05}	0.3708	0.3708	0.1998	0.1159	1.9946	0.0686
Spinach	Canal water	1.70 ± 0.20b	6.80 ± 0.10b	8.60 ± 0.10b	0.23 ± 0.058b	178.70 ± 1.808b	0.56 ± 0.051b
	Tubewell water	0.50 ± 0.10c	2.50 ± 0.10c	4.40 ± 0.10c	0.007 ± 0.001c	119.27 ± 2.417c	0.008 ± 0.001c
	Sewage water	38.43 ± 0.21a	27.57 ± 0.25a	38.10 ± 0.30a	5.53 ± 0.153a	259.43 ± 3.907a	3.60 ± 0.10a
	LSD _{0.05}	0.3542	0.333	0.3826	0.1884	5.6951	0.1297
Carrot	Canal water	1.83 ± 0.058b	6.47 ± 0.115b	6.93 ± 0.153b	0.016 ± 0.001b	135.67 ± 1.00b	0.64 ± 0.001b
	Tubewell water	0.14 ± 0.01c	2.53 ± 0.058c	2.83 ± 0.058c	0.006 ± 0.000b	92.00 ± 0.458c	0.014 ± 0.001c
	Sewage water	35.80±0.10a	15.67 ± 0.15a	26.47 ± 0.153a	4.216 ± 0.015a	197.97 ± 1.32a	1.18 ± 0.020a
	LSD _{0.05}	0.1337	0.2307	0.2579	0.0177	1.9834	0.0232
Cauliflower	Canal water	5.70 ± 0.10b	4.90 ± 0.10b	7.10 ± 0.20b	0.20 ± 0.006b	117 ± 2.98b	0.61 ± 0.01b
	Tubewell water	0.08 ± 0.01c	1.70 ± 0.10c	3.70 ± 0.10c	0.009 ± 0.001c	74.43 ± 1.10c	0.33 ± 0.01c
	Sewage water	27.73 ± 0.21a	16.83 ± 0.153a	15.60 ± 0.10a	6.20 ± 0.10a	137.70 ± 2.05a	1.70 ± 0.01a
	LSD _{0.05}	0.2666	0.2401	0.2825	0.1155	4.364	0.0200
Safe limits ^a		2.00	10.00	10.00	0.02	150	1.30

Values are mean ± SD of three samples of edible portions of each vegetable; analyzed individually in triplicate. Mean values having the same letters are not significantly different ($p \geq 0.05$) ^aSources: Asaolu (1995) and Anon., (1996).

vegetables, Fe contents varied from 117 mg kg⁻¹ in cauliflower to 178.70 mg kg⁻¹ in spinach. Lower levels of Fe accumulation were observed in vegetables grown in tubewell water.

Chromium (Cr)

The significant differences ($p \geq 0.05$) were observed among sewage, canal and tubewell irrigated vegetables for Cr contents. The sewage water grown vegetables such as spinach (3.60 mg kg⁻¹), cauliflower (1.70 mg kg⁻¹), okra (1.50 mg kg⁻¹) tomato (1.23 mg kg⁻¹) and carrot (1.18 mg kg⁻¹) showed more accumulation of Cr. While, lower Cr contents were recorded with canal and tubewell water irrigated vegetables ranging from 0.56 to 0.83 and 0.008 to 0.33 mg kg⁻¹, respectively (Table 2).

Higher moisture contents were recorded in tubewell water irrigated vegetables compared with canal and sewage water irrigated ones. Similar results were reported by Rehman et al. (2013), who recorded higher moisture content in edible parts of vegetables irrigated with fresh water than those irrigated with waste

water; whereas moisture content in the range of 77-95% was documented in edible vegetables by Hanif et al. (2006) and Rehman et al. (2013). The differences in moisture contents among the vegetables could possibly be due to different nature of edible parts and variation in their growing times. However, the differences in a single vegetable irrigated with different sources of water were possibly due to availability of moisture in the soil and its uptake along with nutrients and heavy metals.

Significantly greater ash contents were recorded in tubewell water irrigated vegetables while, lower contents were observed in canal and sewage water, respectively. These results are in close proximity to the findings reported by Rehman et al. (2013). They recorded maximum ash contents in vegetables grown in fresh water than sewage water irrigated vegetables. The ash content also varied among the vegetables studied, being the maximum in spinach (leafy vegetable), followed by carrot, okra and tomato and being the minimum in cauliflower. Rehman et al. (2013) also reported higher ash content in leafy veg-

etables as compared to non-leafy vegetables. Similar results were documented by [Dan et al. \(2013\)](#), who also found more ash contents in leafy vegetables. In fact, ash content is a quantity of nonvolatile inorganic components staying behind ashing. As spinach leaves are considered as a major source of minerals, therefore they have more ash content.

Okra, tomato and spinach when grown with sewage water contained greater values for protein, followed by those irrigated with canal water. While, tubewell water irrigated okra, tomato and spinach contained lower values for protein content. Tubewell water irrigated cauliflower and carrot had higher protein content, followed by when grown with canal water. Significantly lower protein content was recorded when these vegetables were grown with sewage water. [Rehman et al. \(2013\)](#) reported similar results in various vegetables and found higher protein content in fruit (green pepper, brinjal) and leafy portions of vegetables grown in sewage water compared with fresh water, possibly due to presence of more nitrogen content in waste water than in fresh water. They also recorded more protein content in fresh water grown cauliflower and onion compared with waste water grown, indicating a differential behavior of these vegetables. The results of present study are also in close conformity with the findings of [Effiong et al. \(2009\)](#) and [Hanif et al. \(2006\)](#) as they documented similar contents of protein in various vegetables. Spinach has higher protein content compared to okra and other vegetables ([Hanif et al., 2006](#); [Hussain et al., 2010](#)).

The crude fiber contents were significantly greater in all the vegetables grown with tubewell, followed by those irrigated with canal water. Lower fiber contents were recorded in these vegetables grown with sewage water. [Rehman et al. \(2013\)](#) also reported variations in fiber content of some vegetables grown in fresh and waste water. Fiber contents recorded were higher in some vegetables when irrigated with waste water while in others when irrigated with fresh water. In the present study, edible parts of the vegetables studied also differed in their fiber contents. Okra pods had higher fiber content, followed by spinach leaves and cauliflower heads, while carrot roots and tomato fruits had low quantities of fiber. Our results are partially in agreement with the findings of [Rehman et al. \(2013\)](#), who reported higher fiber content in leafy vegetables but in the present study more contents were recorded in okra pods followed by spinach leaves and cauliflow-

er heads. [Hanif et al. \(2006\)](#) also reported variations in fiber contents among various vegetables.

The Pb content in all the vegetables irrigated with different water sources followed the trend; sewage water > canal water > tubewell water. These results are in line with the findings of [Latif et al. \(2008\)](#), who stated that all the vegetables which were irrigated with waste water contained Pb contents above critical levels. Similar results were reported by various scientists in different vegetables grown with sewage or waste water ([Lone et al., 2003](#); [Butt et al., 2005](#); [Jagtap et al., 2010](#)). [Mahmood and Malik \(2014\)](#) also found greater Pb contents in vegetables grown with waste water which were higher than permissible levels and reported that the sources of Pb contamination were waste water, emission of traffic and industries, paint industries and storage batteries. The Pb contents in vegetables irrigated with waste water surpass the safe limits as illustrated by WHO standards ([WHO, 1996](#)) and continuous and longer use of waste water for irrigation results not only in accumulation of higher Pb content in the vegetables grown ([Muchuwiti et al., 2006](#)) but also accumulates in the soil ([Rusan et al., 2007](#)). In the present study, Pb contents in canal irrigated cauliflower (5.70 mg kg^{-1}) and tomato (4.40 mg kg^{-1}) were also higher than the safe limits, probably due to drain of some sewage or waste water in the canals. However, Pb content of canal water grown carrot, spinach and okra (contain Pb contents, which were within the limits. Whereas, tubewell water irrigated vegetables contained the lowest Pb content and found within permissible limit. Spinach grown with sewage water accumulated higher amounts of Pb in their leaves, followed by carrot roots and cauliflower curds. Lower amounts of Pb were accumulated in fruits of tomato and okra pods as compared to these vegetables when grown with sewage water. This indicates that the vegetables not only differ in their Pb uptake but their accumulation also varies in different parts of the plants. The present results are in line with those reported by [Kashif et al. \(2009\)](#), who found Pb content in waste water grown spinach much higher than safe limits.

All the vegetables irrigated with sewage water contained Ni contents above the safe limits (10 mg kg^{-1}), whereas Ni contents in all those irrigated with canal and/or tubewell water were below the safe limits as described by [Asaolu \(1995\)](#) and [WHO \(1996\)](#). The maximum uptake and accumulation of Ni was

recorded in spinach leaves when grown with sewage water. [Perveen et al. \(2012\)](#) also reported higher Ni contents in leafy vegetables as compared to other vegetables. Continuously irrigating vegetable fields with waste water for extended period may be responsible for accumulations of heavy metals to the lethal levels ([Kirkham, 1983](#)). Higher heavy metal content including Ni in waste water and the vegetables grown with this water were also reported by various Pakistani scientists in Attok ([Lone et al., 2003](#)), Rawalpindi ([Latif et al., 2008](#)) and Peshawar areas ([Perveen et al., 2012](#); [Ihsanullah et al., 2011](#)).

The higher Cu content was observed in all the vegetables grown with sewage irrigated which exceeded the permissible levels while the canal and tubewell irrigated vegetables were safe to eat as they contained Cu concentrations below the critical values described by [WHO \(1996\)](#). [Ihsanullah et al. \(2011\)](#) reported exceeded levels of Cu in sewage water grown leafy vegetables. Higher accumulations of Cu in different vegetables grown with sewage water were reported by various scientists ([Lone et al., 2003](#); [Latif et al., 2008](#)). Therefore, the results of the present study are in accordance with the findings of previous workers.

All tubewell water irrigated vegetables had Cd contents, which were well below the safe limits (0.03 mg kg^{-1}) ([Asaolu, 1995](#) and [WHO, 1996](#)). The vegetables grown with sewage and canal water showed more accumulation of Cd contents above the critical values except canal irrigated carrot, okra and cauliflower. [Kashif et al. \(2009\)](#) reported that Cd contents in all the vegetables grown with Hudaira drain water exceeded the safe levels. Our results are also supported by the findings of [Mahmood and Malik \(2014\)](#), who recorded higher Cd contents in vegetables irrigated with waste water, which were also greater than the safe limits described by European Union ([EU, 2002](#)). Elevated levels of Cd in sewage water were also analyzed by [Lone et al. \(2003\)](#), [Jagtap et al. \(2010\)](#), [Ihsanullah et al. \(2011\)](#) and [Balkhair and Ashraf \(2016\)](#).

All the edible parts of spinach, carrot, tomato and okra except cauliflower grown in sewage water contained Fe contents above the critical levels, while all the vegetables grown in canal and tubewell water contained Fe contents below safe limits except spinach grown in canal water had Fe contents above critical limits stated by [WHO \(1996\)](#). Greater Fe content in canal water irrigated vegetables might be due to that indus-

trial contaminated water is drained into canals which carry heavy metals with it. These results demonstrated that the vegetables tested differed in their uptake of Fe and its accumulation in different parts. [Kashif et al. \(2009\)](#) and [Ihsanullah et al. \(2011\)](#) concluded that waste water grown spinach contained Fe contents higher than stated standards.

Sewage water irrigated tomato and carrot had Cr content within the safe limits described by [WHO \(1996\)](#). While, sewage water grown vegetables (spinach, cauliflower and okra) showed more accumulation of Cr above the safe limits. Canal and tubewell water irrigated vegetables contained Cr contents which were also within the permissible limits. These results were closely related with the conclusions of [Ihsanullah et al. \(2011\)](#), [Jagtap et al. \(2010\)](#) and [Lone et al. \(2003\)](#), who found Cr levels in edible portions of some vegetables grown with sewage water higher than critical levels. The higher contents of heavy metals in vegetables irrigated with sewage water were also reported by several workers ([Liu et al., 2005](#); [Ihsanullah et al., 2011](#); [Perveen et al., 2012](#)). Waste water grown vegetables usually show higher accumulation of heavy metals than those grown with ground water ([Jan et al., 2009](#) and [2010](#); [Khan et al., 2010](#)). [Mahmood and Malik \(2014\)](#) also found Cr contents in vegetables irrigated with waste water higher than the permissible limits. They also reported that paint industries, textile factories, electroplating and tanneries ejected Cr in waste water. The variations in heavy metal contents in various plants may be due to several reasons like soil heavy metal contents, waste water for irrigation, plant's potential to absorb and uptake and atmospheric deposition of heavy metals ([Pandey et al., 2012](#)). The present results are in accordance with the conclusion of [Naz et al. \(2016\)](#), who also detected significantly higher heavy metals contents in spinach leaves when grown with sewage water as compared to canal and tubewell water, exceeding the maximum permissible limits (MPLs).

Conclusions

Edible parts of some selected vegetables collected from areas irrigated continuously with canal, tubewell and sewage water for the last fifteen years were analyzed for their proximate and heavy metal contents. The results indicated that proximate composition of the tested vegetables was significantly influenced by the irrigation source. The moisture, ash and fiber

contents were observed more in edible parts of the vegetables grown with tubewell water compared with canal and sewage water grown vegetables, whereas higher protein contents were detected in okra, tomato and spinach irrigated with sewage water. The accumulation of heavy metal contents (Pb, Ni, Cu, Cd, Fe and Cr) was higher in all the tested vegetables grown with sewage water than those grown with canal and tube water. All heavy metal contents in almost all the vegetables irrigated with sewage water were toxic and higher than the safe limits, while the tubewell irrigated vegetables contained heavy metals contents within the recommended levels described by WHO (1996). Leafy vegetable (spinach) irrigated with sewage water had more accumulation of all the heavy metals studied than fruit (okra and tomato) and root (carrot) vegetables. As decreased nutritional status and increased heavy metal accumulation in vegetables cause negative effects on human health, therefore proper techniques must be developed to diminish heavy metal pollution from soils, irrigation water and environment to save the consumers' health.

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Author's Contribution

Safina Naz, Muhammad Akbar Anjum and Saeed Akhtar conceived the idea. The experiments were performed and written by Safina Naz while SPSS analysis was performed by Syed Atif Hasan Naqvi and the reference section was compiled by Muhammad Asif Zulfiqar.

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