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Long term application of wastewater on trace elements accumulation in the soil and sugarcane

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Abstract

Wastewater is used as an alternate source of irrigation in densely populated areas all over the world. Unfortunately untreated wastewater when used to irrigate the crops becomes a source of trace elements contamination to soils and crops and can cause severe health effect on animals and humans. The present study was designed to evaluate the long term application of wastewater on trace elements (Cd, Co, Cr, Cu, and Zn) accumulation in soil and edible and non-edible parts of sugarcane. Samples of soil, sugarcane root, shoot and leaf irrigated with uncontaminated water (clean water) and untreated wastewater (industrial+municipal) were collected in triplicate and analyzed for total Cd, Cr, Co, Cu, and Zn content with ICP-MS and Atomic Absorption Spectrophotometer (AAS). The results of this study show that electrical conductivity (EC) and total dissolved solids (TDS) of uncontaminated water were 490µS/cm and 245ppm and wastewater ranged from 790 to 3550 µS/cm and 396-1775ppm. The salinity of wastewater ranged from 0.2 to 0.8. Cadmium and Co was present at very low concentration in uncontaminated and wastewater. Chromium, Cu and Zn in wastewater ranged from 1.07-4.62, 0.19-10 and 0.078-0.197 mL per L. Chromium and Cu exceed the safe limit in wastewater. The concentration of such elements in wastewater remained in the safe limit for crops. Soils irrigated with wastewater was likely to exceed the safe limits of Cr and Cu once irrigated with wastewater. Sugarcane root shows no accumulation of any of the trace elements. Bio-concentration factor or plant concentration factor (BCF or PCF) of Cd, Cr, Cu and Zn was less than 1 in all soils irrigated with wastewater. Whereas BCF and PCF of Co was more than 1 in soil irrigated with uncontaminated water (soil A) and soil irrigated with wastewater (soil B).

Keywords: Wastewater; Sugarcane; Irrigation; Accumulation; Elements.

1. Introduction

Water is the most precious natural resource and is under constant threat more likely because of increase in industrialization and urbanization (Bincy et al., 2015). Furthermore excessive use of water for irrigation and domestic purposes proceed towards water scarcity even in developed countries. Therefore there is an urgent need to reduce the reliance on fresh water and to find alternate sources of water to be used for irrigation. Thus treated wastewater and saline water are considered to be the most important alternate sources of water and are successfully used to irrigate the crops all over the world. Whereas in some parts of the world untreated wastewater is also used for irrigation. Untreated wastewater can reduce the reliance on fresh water but it can increases the chance of accumulation of some toxic trace elements in soil or crops thus increases the health risk among animals and mankind (Li et al., 2013). However there are contradictory evidences in the previous literature on trace elements accumulation to crops once irrigated with untreated wastewater (Rehman et al., 2013). Some authors reported that accumulation of trace elements in edible parts of the crops was not obvious over a short period of time whereas others reported that trace elements accumulation was obvious immediately (Denis et al., 2015). This difference in the trace elements accumulation to crops because of untreated wastewater irrigation primarily depend on the source period of exposure and secondarily on the nature of the soil. However long term effect of trace elements accumulation in crops is obvious over half a century (Rattan et al., 2005; Ebrahim et al., 2016). Nonetheless, trace elements concentration in wastewater varies, industrial wastewater usually contains greater concentration of trace elements whereas domestic wastewater had very low content of trace elements. Some trace elements (Cu, Mo, Ni and Zn) are considered to be toxic to living organisms when present at elevated levels in wastewater whereas others such as Mn, Fe, Al, Cr, Pb have no or negligible effect even present at toxic threshold levels in wastewater (Page et al., 1981).

However, trace elements accumulation in surface soil irrigated with wastewater is very low, more likely because a considerable portion of such elements may accumulate in the non-edible and edible parts of plants grown over wastewater irrigated soils (McGrath and Smith, 1990; Jones, 1991; Kabata-Pendias, 1992). Increased availability of these elements to plants increases their accumulation in plant tissues may result in some plants as stunted growth and chlorosis in young leaves whereas in others no toxicity symptoms appeared (Lund et al., 1981). Such crops when used may cause adverse health effect in animals and humans (Muchuweti et al., 2006; Sherameti and Varma, 2010; Yadev et al., 2010). Health risk to human and animals because of eating trace elements contaminated crops irrigated with wastewater remained a growing concern all over the world. Copper toxicity when present at concentration less than 16 µg ml-1 is enough to cause stunted growth, reduced leaf area, reduced dry matter production and reduced total chlorophyll content in tropical leafy vegetables (Huang and Gobran, 2005). Mohammad (1999) found that when Cu concentration exceeds the toxic threshold (< 100 µg per g) results in inhibition of root elongation in sugarcane irrigated with wastewater. As a consequence of this low yield of sugarcane is observed. Soils are likely to exceed their toxic threshold when the concentration of Cd, Cr, Co, Cu, Ni and Zn is more than 0.01, 0.05, 0.2, and 2 mg L-1 in the untreated wastewater used for irrigation (Andresen and Küpper, 2013). Apart from trace elements toxicity in soils irrigated with untreated wastewater over the long period of time wastewater can reduce the soil pH 2 to 3 and under such conditions many elements become mobile and available to plants (Kabata et al., 1989).

Like Cu, Zn when present at concentrations greater than 100 µg per g of soil cause inhibition of root growth and reduced surface area of leaves followed by stunted growth and chlorosis appeared in crops (Alloway, 1995). Kibria et al. (2012) reported that Zn accumulation in the root of aurum and radish ranged from 66.50 to 448.25 and 16.49 to 74.38 mg per kg when irrigated with wastewater and was enough to cause toxicity in such vegetables. Rizwan et al. (2013) found accumulation of Zn (223 mg per kg) in the root of spinach irrigated with wastewater. This was enough to cause health risks in livestocks and humans (Davis, 1990; Jones, 1991). Chromium is considered to be toxic when present as low as 10 mg L-1 in wastewater can cause adverse health effect on humans, whereas, 1-5 mg kg-1 of Cr is enough to cause phytotoxicity (Brar et al., 2010). Srivastava and Radha (2011) studied stunted growth of sugarcane grown in soil with 80 mg kg-1 of Cr. Apart from trace elements accumulation in edible and non-edible parts of crops when grown over soils become contaminated with untreated waste water, adverse health effect on livestock and human cannot be ignored (Saranga et al., 2016).

Peshawar-Charsadda boarder is a sugarcane growing area near Peshawar-Pakistan. Over the last several decades wastewater is used for irrigation. The fate of wastewater irrigation to leafy vegetables had been reported in several previous studies (Noor-ul-Amin et al., 2013). Nonetheless very limited information is available in the previous literature on trace elements accumulation in sugarcane plants and health risk to human. There is an urgent need to develop a monitoring policy to evaluate the risk to the environment through continuous applying wastewater to the soils. The objectives of this study were (a) to determine the trace elements concentrations in uncontaminated and wastewater (b) to evaluate the long term accumulation of some trace elements (Cd, Co, Cr, Cu, and Zn) in soil and sugarcane root, shoot and leaf irrigated with wastewater. Furthermore the total concentrations of Cd, Co, Cr, Cu, and Zn in soil and sugarcane root, leaves and shoots was compared with the WHO recommended value of such elements.

2. Methods and materials

2.1. Study site

The site selected for this study is

geographically located at 34.0167° N, 71.5833° E in Peshawar. The sugarcane is the main cash crop of the area and wastewater is used to irrigate the crop over the last several decades. Uncontaminated and untreated wastewater are used to irrigate the crops. Nearly 6 sugarcane growing fields namely Kankola, Khazana, Hussainabad, Manzoori, Dodakhana, Ahmadabad and Wahid Ghari were selected (Fig. 1). geographically located at 34.0167° N, 71.5833° E in Peshawar. The sugarcane is the main cash crop of the area and wastewater is used to irrigate the crop over the last several decades. Uncontaminated and untreated wastewater are used to irrigate the crops. Nearly 6 sugarcane growing fields namely Kankola, Khazana, Hussainabad, Manzoori, Dodakhana, Ahmadabad and Wahid Ghari were selected (Fig. 1).

Uncontaminated water sample was collected from irrigation channel. Whereas wastewater samples were collected from 1 main and 4 sub-main irrigation channels spread all over the sampling sites. Soil samples were collected from six sugarcane growing fields irrigated with uncontaminated and untreated wastewater. Nearly five soil samples were collected randomly at a depth of 0-15 cm from each sugarcane growing fields and were mixed thoroughly by hand in the field to represent a composite sample from each field. Around triplicate subsamples of 1 kg were collected from each field and were placed in plastic bags and were brought to the laboratory for further analysis.

Moist soil was separated into two parts: rhizosphere soil and bulk soils by sieving method as described by McGrath et al. (1997). However, rhizosphere and bulk soils were collected by the method of shaking and washing of root system as described by Berge et al. (2006).

The soil samples were analyzed for organic matter content, texture, pH and EC. Total soil organic matter was determined by wet digestion method as described by Parkinson and Allen (1975). Soil texture was determined by pipette method as described by Avery and Bascomb (1974). Soil pH and EC was estimated in all soils as explained by McLean (1982).

Soil samples were extracted for total content of Cd, Co, Cr, Cu and Zn following the aqua regia procedure of Buckley and Cranston (1971). Total trace elements such as Cd, Co, Cr, Cu and Zn was determined by the HF-per chloric acid digestion extractable method as described by Soltanpour (1985).

Sugarcane root, stem and leaves were washed with double deionized water and were oven dried at $120^{o}C$ for over-night. Sugarcane with roots were brought to the laboratory. The root and leave samples were dried and then were grind as described by Berge et al. (2006). Thereafter trace elements in root and leave samples was determined by dry ashing method as described by Campbell and Plank (1998).

Triplicate water samples were collected from one main and four sub main irrigation channels all over 20 sugarcane growing fields. Samples were collected from the middle of each water channels and were rinsed twice in the same water before water sample was collected. Tube well water was collected from the pipe used to irrigate the sugarcane field. All water samples were analyzed immediately for pH and EC once brought to the laboratory. Around 200 mL of water were placed in 250 mL plastic bottles and was acidified with 1 mL of HCO_3 (5%) and was incubated in the laboratory for further analysis. The pH, EC, TDS, major cations and anions such as Ca, Mg, K, Fe, Na, HCO_3-, in water samples was determined by the method as described by American Public Health Association (Clesceri et al., 1998). Bicarbonates was estimated by titrating an aliquot of effluent samples with H_2SO_4. Trace elements in water were determined by the method as described by Buckley and Cranston (1971).

Transfer of trace elements from soil to plants was determined by Bioconcentration or plant concentration factor (BCF) as described by Liu et al. (2005). The BCF is the ratio of trace elements in plant to soil.

BCF= heavy metals in plants/heavy metals in soil

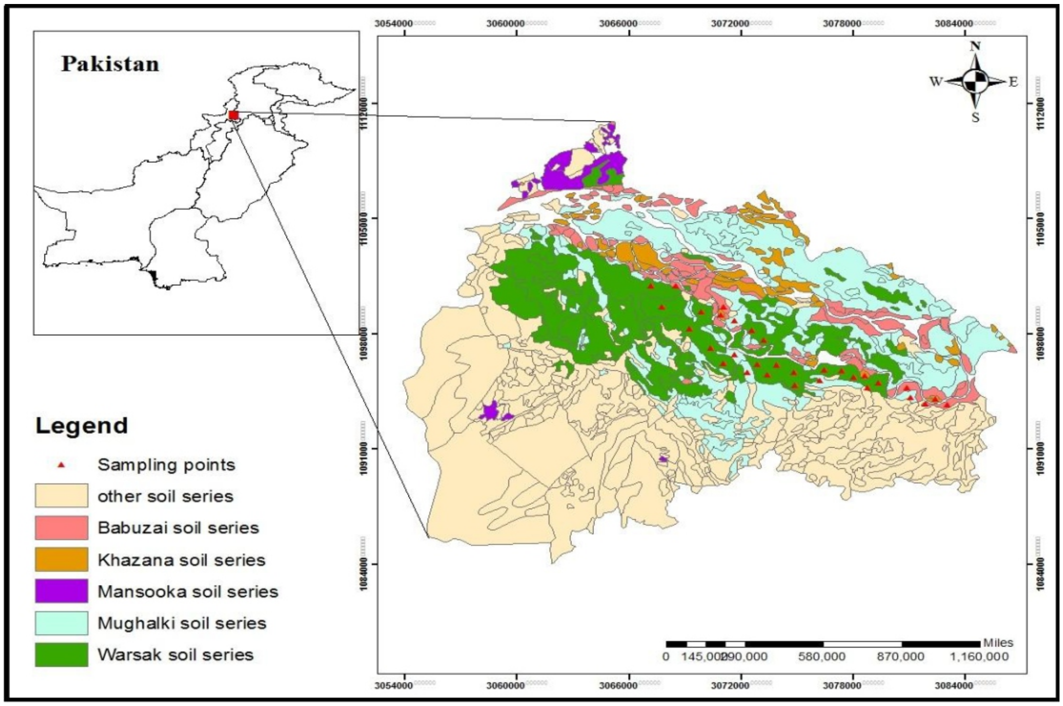

Fig. 1. The soil and water sampling sites in Charsadda-Peshawar (adapted from Soil Survey of Pakistan, 1998).

2.2. Data analysis

For contamination level of heavy metals, mean, median, minimum, maximum, standard deviation of wastewater, soil and sugarcane samples was performed by using Microsoft Excel (Version 2009).

3. Results

3.1. Heavy metals concentrations in wastewater

Difference in anions, major and trace elements concentrations (mg L^{-1}) between river and wastewater is presented in Table 1. The pH of uncontaminated water was 7.7 whereas in main untreated wastewater channel was 6.9 and sub channels were 7.0 to 7.3. The tolerance limit of pH for irrigation water ranged from 6.0 to 9.0. Thus, pH of all the effluent samples is within the permissible limit. Electrical conductivity (EC) and total dissolved solids (TDS) of uncontaminated water was 490 µS/cm and 245ppm and wastewater channels was ranged from 790-3550µS/cm and 396-1775ppm. The electrical conductivity of wastewater was more than 1000µS/cm or 1 dS/m this is suggested by the observation that wastewater was saline in nature (Al Omron et al., 2008). The salinity of wastewater ranged from 0.2 to 0.8 (Table 1).

Bicarbonate (HNO_3-) in uncontaminated water was 275 mg L^{-1} and in main wastewater channel was 1454 mg L^{-1} whereas in sub channels ranged from 132 to 325 mg L^{-1}.

Total Ca, K and Mg were ranged from 51, 22, 102 mg per kg in uncontaminated water whereas in main wastewater channel was 678, 880, 122 mg per kg and sub-wastewater channels were 38-115, 9-760 and 6-68ppm. Arsenic, Cd and Co were found at negligible value in all water samples. Nonetheless Cr, Cu and Zn in uncontaminated water was 1.07, 0.19 and 0.121 mg L^{-1} whereas in main and sub wastewater channels ranged from 3.2 to 4.62, 0.21 to 10 and 0.078 to 0.197 mg L^{-1} .

According to Pescod (1992), threshold values of heavy metals in irrigation water leading to crop damage are 2000 mg L-1 for Zn, 200 mg L^{-1} for Cu, 5000 mg L^{-1} for Fe, 200 mg L^{-1} for Mn, 200 mg L-1 for Ni, 5000 mg L^{-1} for Pb and 10 mg L^{-1} for Cd. Although sewage effluents had elevated concentrations of some of the metals compared to groundwater, the concentrations of these metals in these two sources of irrigation water were within the permissible limits for their use as irrigation water.

Table 1. Differences in chemical and anions, major and trace elements concentrations (mg L-1) between uncontaminated and wastewater.

Chemical characteristics	**Uncontaminated water (Site A)**	**Sugar mill effluent (Site B)**	**Main effluent channel (Site C)**	**Sub effluent channel 1 (Site D)**	**Sub effluent channel 2 (Site E)**	**Sub effluent channel 3 (Site F)**	**Max permissible limits for industrial wastewater for land irrigation (mg per L) (NEQs 2005)**
pH	8.2 ± 0.5*	8.1± 0.4	8.02± 0.5	8.03± 0.5	8.2± 0.5	8.2± 0.5	6-10
EC (µS m^{-1})	490± 10	3550±5	3200±2	2800±5	2520± 6	790±54	
TDS	260±23	1775±175	1600±125	1400±136	1260±128	396±12	3500
Salinity	0	0.8	0.2	0.2	0.2	0.2	
Anions (mg L^{-1})							
Cl^{-1}	14±1.2	500±125	55±18	20±5	25±3	23±2	1000
HCO_3^{-1}	275±23	1454±125	325±25	195±15	310±22	132±32	
SO_4^{--}	8± 0.5	1250±98	36±2.2	33±3	34±2	35±6	600
Elements (mg L^{-1})							
Major							
Ca	51± 5	678± 125	115± 12	102± 12	101± 13	38± 5	
K	22± 2	880± 55	760± 25	109± 15	9± 1.5	48± 6	
Mg	102± 10	122± 15	58± 9	6± 0.5	68± 16	37± 5	
Trace							
As	BDL	BDL	BDL	BDL	BDL	BDL	
Cd	0.001	0.005	0.011	0.01	0.01	BDL	0.1
Co	BDL	0.008	0.004	0.005	0.006	0.004	
Cr	1.07±15	4.62± 25	3.2± 23	3.26± 39	3.62± 32	3.20± 36	1
Cu	0.19±0.05	10± 0.5	2.4± 0.0025	2.2±0.001	0.23±0.001	0.21±0.001	1
Zn	0.121	0.197	0.142	0.1	0.087	0.078	5

Table 2. Differences in the physicochemical characteristics of soils A, B, C, D, E and F used for growing sugarcane (Saccharumofficinarum) irrigated with and without wastewater.

Physicochemical characteristics	**Soil A**	**Soil B**	**Soil C**	**Soil D**	**Soil E**	**Soil F**
pH	7.473	7.85	7.46	7.64	7.48	7.47
EC (µS m^{-1})	1.1	3.06	1.27	1.31	1.30	1.30
O.M(%)	0.5	1.1	0.5	0.4	0.45	0.35
Texture	Silty loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam

3.2.Trace elements concentrations in soils

The physicochemical characteristics of trace elements in soils is presented in Table 2. The soils were found to be deficient in organic matter, silty loam to sandy loam and alkaline in nature.

The total concentrations of trace elements in soils irrigated with uncontaminated and wastewater is presented in Table 3. The mean concentration of cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu) and zinc (Zn) was 0.675, 23, 32.55, 6 and 23.95 mg per kg of dry soil A irrigated with uncontaminated water. The concentrations of all trace elements except Cu in soil A remained within the background value of such elements in soil (Siddiqui and Khattak, 2010). Furthermore Cu content was 6 mg per kg in the study soil and was less than the background value of 20 mg per kg in soil.

The mean concentrations were 0.25, 14.25, 140, 99.7 and 76.65mg per kg in soil B irrigated with wastewater. Similarly the mean concentration of Cd was 0.06 to 0.23 mg per kg, Co was 7.6 to 14.85 mg per kg, Cr was 25 to 132 mg per kg, Cu was 90.30 to 93.05 mg per kg of soil and Zn was from 53.23 to 71.55 mg per kg of soil C, D, E and F irrigated with wastewater. None of the soils B to F irrigated with wastewater was found to be high in studied heavy metals and remained within the permissible limit for such metals in soil as reported by Awashthi (2000) for Cd, Cu and Zn was 3-6, 135-270 and 300-600 mg per kg of oven dry soil.

3.3. Heavy metals concentrations in sugarcane root, shoot and leaves

Very little concentration of Cr, Cu and Zn was observed in shoot and leaves (data not presented). Table 4 shows the accumulation of cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu) and zinc (Zn) (mg kg^{-1}) in sugarcane root once irrigated with untreated wastewater. The concentrations of Cd, Co, Cr, Cu, and Zn in soil irrigated with clean water remained within the Pescod (1992) permissible limit for vegetables grown over soils irrigated with wastewater. Nonetheless accumulation of Cd, Cu and Zn was observed in the sugarcane root when irrigated with wastewater. The concentrations of Cd, Cu and Zn in soil B were within the recommended value of 0.2, 20 and 50 mg per kg (Pescod, 1992; Rattan et al., 2005). The greater amount of all elements were found in the sugarcane root followed by shoot and then leaves. However, no accumulation of any of the studied heavy metals was observed in sugarcane root at sites E and F.

Bio-concentration factor (BCF) or plant concentration factor (PCF) for Cd, Cr, Cu and Zn remained less than 1 (Table 5). Virtually same BCF was observed for Co, in all samples except for soil A and B. This suggests that application of wastewater to irrigate soil causes no transfer of any of the studied trace elements to sugarcane root.

Table 3. Heavy metals concentrations (mg/kg) in soil irrigated with clean and wastewater collected from various sites (A, B, C, D, E, and F) of sugarcane growing agricultural land in Peshawar-Charsadda.

Sites	Cd		Co		Cr		Cu		Zn	
	Total	Labile	Total	labile	Total	Labile	Total	labile	Total	labile
Uncontaminated water irrigate soil A	0.675	0.01	23	0.45	32.55	0.5	6	0.02	14.85	1.25
Wastewater irrigate soil B	1.1	0.025	44.1	3.075	140.72	1.57	65.95	26.75	208.35	19.95
Wastewater irrigate soil C	0.47	0.6	41.275	3.075	125.25	0.35	59.40	11.15	142.25	18.47
Wastewater irrigate soil D	1.3	0.3	48.32	3.052	142.62	0.45	65.72	9.73	151.55	8.47
Wastewater irrigate soil E	0.275	ND	6.15	0.35	14.05	0.46	37.47	8.73	54.85	4.35
Wastewater irrigate soil F	0.15	ND	39.45	0.45	104.95	0.45	48.5	6.75	122.5	4.10
Safe limits (Awashthi, 2000)	3-6	----	---	----	-----	------	135-270		300-600	

Table 4. Trace elements (mg/kg) accumulation in the sugarcane root, shoot and leaves once irrigated with untreated wastewater.

Trace elements (mg kg^{-1})	**clean water (Site A)**			**Main effluent channel (Site B)**			**Sub-effluent channel 1(Site C)**			**Sub effluent channel 2 (Site D)**			**Sub effluent channel 3 (Site E)**			**Sub effluent channel 4 (Site F)**		
	Root	shoot	Leave	Root	Shoot	Leave	Root	shoot	Leave	Root	shoot	Leave	Root	shoot	Leave	Root	shoot	Leave
Cd	0.01	0.005	ND	1.2	1.2	ND	0.01	0	ND	ND	ND	ND	ND	ND	BDL	ND	ND	BDL
Co	0.25	0.15	ND	1.35	0.85	0.1	1.2	0.65	ND	0.4	0.1	ND	0.2	0.1	ND	0.25	0.15	ND
Cr	0.40	0.20	ND	170.0	23	2.0	16	6	2.0	8	4	2.0	0.20	0.1	0.10	0.20	0.2	0.12
Cu	1.6	1.2	1.2	382	24	2.0	10	5	2.2	6	3	1.5	0.05	0.05	nil	0.045	0.045	nil
Zn	1.0	0.8	0.1	75	50	1.0	16.5	7	1.0	15.5	6	0.5	0.5	0.3	ND	0.4	0.3	ND

Table 5. Enrichment and transfer factor of trace elements in soil or plants with wastewater and clean water.

Soil	Enrichment factor (EF)					Transfer Factor (TF)				
	Cd	Co	Cr	Cu	Zn	Cd	Co	Cr	Cu	Zn
B	1.925	1.912	4.9	12.05	14.03	0.4	1.45	19	16	19.5
C	0.185	1.47	4.36	10.45	0.942	1	4.8	45	4.35	15.90
D	0.148	1.086	3.08	9.45	9.56	nd	1.6	25	2.6	14.5
E	0.148	0.608	1.13	1.5	0.335	nd	0.8	0.75	0.017	0.45
F	0.148	0.434	1.075	1.0	0.269	nd	1	0.8	0.016	0.36

4. Discussion

Over the last several decades, untreated wastewater is used as an alternate source of irrigation. Untreated wastewater contain some phytotoxic trace elements such as Cr, Cu and Zn. Such elements when present at threshold level may cause toxicity in plants and injurious to animal and human health. Presence of such trace elements at elevated levels in leafy vegetables once grown over soil irrigated with wastewater is a major concern (Liu et al., 2005; Rehman and Haq, 2006; Arora et al., 2008; Leal et al., 2009; Anjula and Sangeeta, 2011, Khan et al., 2013; Rahman et al., 2014). Nonetheless information about the trace elements accumulation in sugarcane root grown over untreated wastewater is in scarcity. The present study shows that trace elements such as Zn was present within the safe limit of such element in untreated wastewater as reported by Awashthi (2000) and WHO (2007). However Cr and Cu was slightly greater than the safe limit for such elements in untreated wastewater. Four to sixteen fold increase in Cr and Cu concentration was observed in soil irrigated with untreated wastewater than uncontaminated water. This increase in Cr and Cu was more likely because of application of untreated wastewater. However greater content of Cr and Cu in untreated wastewater over which sugarcane was grown unlikely to appear any toxic symptom. This revealed the contention that Cr and Cu content was not at threshold level can cause phytotoxicity in sugarcane as reported by Pescod, (1992). Thus untreated wastewater is safe to irrigate the soil over which sugarcane was grown. The results of this study is in agreement with the findings of Kisku et al. (2000) and Segura-Muñoz et al. (2006) reported accumulation of Cd, Cr, Cu, Pb and Zn in the sugarcane root and shoot irrigated with wastewater. Gupta et al. (2008) reported that cadmium, chromium, copper, nickel, lead and zinc accumulation was more than 5 folds than their recommended value in spinach and radish once irrigated with wastewater.

Pescod (1992) reported that when irrigation water is composed of mean content of Cd, Cu, Fe, Mn, Ni, Pb and Zn at 10, 200, 5000, 200, 200, 5000 and 2000 mg per L considered to be unsuitable for irrigation.

Thus it is concluded that no accumulation of trace elements in sugarcane was observed in this study but continuous application of wastewater to irrigate the crops over a long period of time may cause server health risk to livestock and humans because it enters in their ecosystem through food chain. Therefore it is necessary to regularly monitor the status of heavy metals in soils and crops irrigated with wastewater and risk associated to animals and humans. This is recommended that untreated wastewater must be treated before used to irrigate the agriculture soils.

Bioconcentration factor or plant concentration factor is calculated by using the formula as described by Liu et al. (2005). Heavy metal concentration in plant/heavy metal concentration in soil.

Bioconcentration or plant concentration factor is presented in Table 5. According to the BCF or PCF of the study Co (3.85 and 1.7) in soils A and B whereas all other values remained less than 1. The high content of Co in such soils is not in agreement with the findings of (Gupta et al., 2008). This suggests that soil B was enriched with Co and the availability of these elements was more in soil B irrigated with wastewater. This agrees with the findings of Galal and Shehata, (2013) and Shukla et al. (2011). They found that plant concentration factor of Fe, Mn, Cd and Zn in *Triticum aestivum* and Cr and Zn for *Brassica campestries* was more than 1 suggested by the observation that availability of such elements were greater in the plants studied. Whereas soils C and D indicates greater accumulation of all elements except Cd. This suggests that Cd was present at low concentration to begin with therefore their accumulation was not observed in the sugarcane root. Similar result was reported by Kushwaha (2015) in which they found that accumulation of trace elements decreases when soil was irrigated with wastewater away from the source of contamination. Bose and Bhattacharyya (2008) also reported that transfer of Cd, Cu and Zn from soil to root suggests that these elements were enriched in the soil.

5. Conclusion

The content of Cr and Cu was high in untreated wastewater than the permissible limits. Nonetheless no accumulation of Cr and Cu was observed in soils over which sugarcane was grown when irrigated with untreated wastewater with high concentration of Cr and Cu. This is suggested by the observation that application of wastewater to irrigate the soil over a long period of time can cause accumulation of trace elements in sugarcane Thus there is a need to monitor the soil and plant samples regularly in future to evaluate the level of trace elements to avoid health risk to animals and mankind.

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Author's contribution

Samina Siddiqui performed sample collection, analysis and writing. Kamran Somroo did manuscript writing. Sumbal Bahar Saba did GIS Map development. Seema Anjum Khattak performed data presentation in the form of tables/data analysis and calculation.

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