Human Health Risk From Toxic Chemicals Via Consumption Of Food Crops In The Vicinity Of Selected Industrial Areas, Pakistan

QUAID-I-AZAM UNIVERSITY

BY

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APPROVAL CERTIFICATE

This is to certify that the dissertation entitled **"Human Health risk from toxic chemicals via consumption of food crops in the vicinity of selected industrial areas, Pakistan.''** submitted by **Muhammad Usman Khan** is accepted in its present form by the Department of Plant Sciences, Quaid-i-Azam University Islamabad, Pakistan, as satisfying the dissertation requirement for the degree of M. Phil in **Environmental Biology**.

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Dedicated

To my

Beloved parents

For their endless support and

Encouragement

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All prayers for Almighty Allah, the most merciful and beneficent, without whose consent and consecration nothing would ever be imaginable. I am absolutely beholden by my Lord's generosity in this effort. Praises be to Holy Prophet for He is a beacon as I pace on in my life and work.

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Muhammad Usman Khan

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LIST OF ABBREVIATIONS

°C	Centigrade
Ca	Calcium
Cd	Cadmium
CF	Conversion factor
Co	Cobalt
CPC	Cleaner production centre
Cr	Chromium
Cu	Copper
DIM	Daily intake of metals
EU	European Union
FAO	Food and Agricultural organization
Fe	Iron
GPS	Global Positioning System
HCl	Hydrochloric acid
$HCLO_4$	Perchloric acid
HNO_3	Nitric acid
HRI	Health risk index
hrs	Hours
IRIS	Integrated risk information system
K	Potassium
Kg	Kilogram
Km	Kilometer
m	Meter
M	Mean
S.D	Standard deviation
Zn	Zinc
M^3	Cubic meter
Mg	Magnesium

min	Minute
ml	milli liter
Mn	Manganese
Na	Sodium
Ni	Nickel
Pb	Lead
PCF	Plant concentration factor
RfD	Reference oral dose
TW	Tube well
US	Unknown source
WHO	World health organization
WW	Wastewater
WWF	World wide fund for nature
μg	Microgram
μl	Micro liter

Abstract

The current study was designed to evaluate heavy metals (Ni, Cr, Fe, Cu, Co, Mn, Pb, Zn, Cd) contamination in water, soil, and food crops (edible parts) with different irrigation sources from Sialkot and Wazirabad cities known for industrial activities for possible potential human health risk. Surface soil and 12 food crops irrigated with waste, tube well water and unknown sources were analyzed through atomic absorption spectrophotometer for selected heavy metals analyses. All the metals except Cd in the soil and Cd, Pb, Cu, Cr in the irrigation water and Cd, Pb, Cr in the food crops samples were within permissible limits. Mean concentrations of Cd (0.27-0.64 and 0.14-0.44 mg/l) and Cr (1.8-18.2 and 0.27-1.67 mg/l) in both waste and tube well water and Cu (0.18-0.66 mg/l) and Pb (3.08-7.32 mg/l) in the wastewater exceeded the permissible limits set by FAO 1985. Cd concentration in both waste (7.13-11.13 mg/kg) and tube well water (1.28-4.28 mg/kg) irrigated soils were above the European Union standard, 2002. All the food crops irrigated with waste, tube well and unknown sources accumulated high levels of Pb (22.4-40.85, 15.28-26.79, 18-32.26 mg/kg) and Cd (1.18-3.81, 0.41-1.20, 0.97-2.82 mg/kg) that can pose human health risk, while, Cr concentrations in wastewater and unknown irrigated food crops were above the permissible WHO/FAO, 2007 limits.

Plant concentration factor (PCF) was >1 for Mn and Pb in different food crops in particular to leafy vegetables. The Pb showed higher HRI>1 in all the food crops irrigated with three irrigation sources, Cd for all the vegetables irrigated with waste and unknown practices posing deleterious human health risk, while Health risk index was <1 for Mn in unknown and tube well irrigated food crops except *Spinacia oleracea* irrigated with wastewater. The study insights that wastewater irrigated samples revealed higher health risk as compared to unknown and tube well water irrigated samples. Prior treatment of waste water and its routine monitoring is suggested to avoid possible contamination of food chain.

Introduction

Enhancement of perilous impacts on ecosystem due to toxic metals contamination has become problem at local, regional and global level (Malik and Zeb, 2009; Malik et al., 2011). The current growing global problems in regard to environment are the toxic metals that have enhanced hazardous impacts on organisms (Zheng et al., 2007). Heavy metals pollution is well known for their toxic, ubiquitous, non degradable and accumulative nature (Dong et al., 2010). Heavy metals are non biodegradable due to their long half lives, have the potential to accumulate in different body parts to produce dangerous side effects. Heavy metals are suspected to enter into the environment as a result of natural and anthropogenic activities like mining, parent rock material, agricultural practices, waste disposal, smelting, sewage sludge and wastewater irrigation practices (Jarup, 2003; Sathawara et al., 2004; Cui et al., 2004a, 2005b). Worldwide rapid urbanization and industrialization in 20^{th} century, has dramatically increased the discharge wastewater (effluents and municipal wastes) accompanied with variety of toxic pollutants (including toxic metals) (Singh and Agrawal, 2009; Ping et al., 2011). All such kinds of pollutant accompanied with heavy metals made their way to water channels that further used for irrigation purposes of vegetables, cereals crops etc.

1.1 Wastewater irrigation practices

Wastewater is extensively used in different parts of world including developing and developed countries from Asia, Europe, South America and United States of America for the purpose of crops irrigation. The lands with 1.33 × 106 ha, 70,000 ha of China and Mexico are irrigated with processed wastewater. The central valley and coastal areas of California are in claim to irrigate their land with total of 78% of wastewater, while in India 2600 Mm^3 of wastewater is in favor for their crops irrigation. Wastewater is also used in 13 problematic region of Greece for vegetables production (Van der Hoek, 2004; Kalavrouziotis et al., 2008).

Total of 20 million ha of land are irrigated with wastewater throughout the world and the food crops contaminated with these wastewater are consumed by the world 10% population (Hamilton et al., 2007; WHO, 2006).

The water available for irrigation purpose in Pakistan is about 172 billion m^3 that is not the abundant quantity of water to fulfil crops prerequisite (Abbas et al., 2007). Pakistan produced total of 26% of vegetables with these waste water (AATSE, 2004; Ensink et al., 2004). According to 1998 population census report the total sewage discharge capacity in 14 problematic cities of Pakistan was $1.83 \times 107\ m^3\ h^{-1}$ (FAO, 2002). Wastewater irrigation for food crops is the most familiar practices in the urban, suburban and agricultural areas of Pakistan. Waste water refers to the marginal-quality water that originates from urban and suburban regions and nowadays got their values in water scanty areas for their irrigation. Marginal water comprised of domestic and industrial effluents posing risk to food crops and human health, if used without prior treatment (Srinivasan and Reddy, 2009). Wastewater is not only famous for organic matter and nutrients deposition but also act as an elevated source of different kind of heavy metals. However long term usage of wastewater for food crops productivity would leave deleterious effects on plants due to their increasing concentrations of heavy metals (Sarfaraz et al., 2007).

1.2 Impacts of wastewater on Soil

Soil as a sink, translocate toxic metals to other environmental compartments Viz: water, air, plants etc., resulted in food chain contamination and finally to humans. Soil allows depositing notable concentrations of heavy metals due to waste water irrigation. Soil fertility or alkalinity may be effected due to irrigation practices of industrial effluents with passage of time in the agricultural land (Kumar and Chandra, 2004; Rattan et al., 2005). The ability of soil to retain heavy metals decreases due to long term waste water irrigation, because in such cases the soil will prefer to leach down or release trace metals for absorption to plant into water or soil solution and this wastewater irrigation practices of food crops act as important route for metal translocation (Rai and Tripathi, 2008).

Metals for their persistence nature in soil become available for plant root and easily translocate to the leaves and edible part of plants (Singh et al., 2004; Barman et al., 2000). However the low horizon of soil is considered to be the least metals accumulator than the uppermost layer of soil because of their low mobility (Salmasi and Tavassoli, 2006; Lamy et al., 2006; Murtaza et al., 2008; Hussain et al., 2010). The overcrowding of heavy metals in soil potentially degrades health of the soil and also to contaminate food chain mainly due to the food crops grown on such soil (Rattan et al., 2002). Heavy metals accumulate in higher ratio in food crops irrigated on contaminated soil to non contaminated soil (Marshall et al., 2007; Sharma et al., 2006a, 2007b). Soil and vegetables are contaminated strongly with Cd and Pb of Copsa mica and Baia mare, Romania, and have decreased the chances of human life in the residency area to reduced average age at death by 9-10 years (Lacatusu et al., 1996). In agricultural soil China, heavy metals and metalloid is of great concern in regard of food safety and health risk issues with their deleterious impact on soil ecosystems (Hu et al., 2004; Sun et al., 2005; Zhang, 2005; Zhu et al., 2005; Li et al., 2006). Heavy metals experiences an adverse effect on human health due to soil contamination when come in contact or due to transfer (De Miguel et al., 1998; Mielke et al., 1999; Madrid et al., 2002; Cui et al., 2004).

1.3 Impacts of wastewater on Plants

Plant acts to exchange elements between living and nonliving environment in the natural ecosystem (Chojnacka et al., 2005). Heavy metals settled at high concentration in the root region as compare to shoot, while the lowest concentration was observed among edible parts (Kalavrouziotis et al., 2008). Food crops are considered as composite of carbohydrates, minerals, proteins, vitamins and essentials metals (Macro and Micro nutrients), having important part of our diet and also with some toxic elements (Thompson and killey, 1990; Khan et al., 2008).

Plants are also renowned for their absorbance capacity of heavy metals from the polluted soil and their deposition as dust particles on the surface of plants (Khairiah et al., 2004; Chojnacha et al., 2005). Different species of food crops show different accumulation rates to heavy metals due to their absorption capacity and tolerance limits at varying levels of sewage sludge amendments (Bhogal et al., 2003; Garrido et al., 2005; Lavado, 2006; Singh and Agrawal, 2008). Properties of soil and types of food crops are the main factors that influence heavy metals. Heavy metals intensively bioaccumulate in leafy vegetables in high proportion as compare to other food crops (Adriano, 2000) because of their broadened leaves or due to higher transpiration and translocation rates (Itanna, 2002).

The metabolic pathways in plants are also destabilized by the presence of heavy metals in the soil, which in turn reduce yield of vegetables (Al-Qurainy and megeed, 2009). Heavy metals like Cadmium and Lead have a negative role to inhibit photosynthesis activity, process of transpiration, metabolism of carbohydrates and various kinds of activities concerned to metabolism in plants (Chandra et al., 2009). The food crops cultivated on such polluted soil become an exposing way to organisms with heavy metals via food chain.

1.4 Effect on Human health via food crops consumption

Contaminated food crops consumption with heavy metals can also deplete the essential nutrient of body that are responsible further for various disorders (Lyengar and Nair, 2000; Turkdogan et al., 2002). Food safety is a major problem worldwide but growing demand for food and its safety have broaden the researchers attention toward the risks associated with the consumption of contaminated food stuffs i.e. heavy metals in the vegetables (Mello, 2003; Gholizadeh et al., 2009). Food consumption is a major contributor pathway (more than 90%) to human exposure than other pathways (Loutfy et al., 2006). Heavy metals intake via food chain by human population throughout the world is broadly recorded (Muchuweti et al., 2006).

The possible Human health related and environmental problems are produced due to excessive concentration in human tissues and their biomagnifications via food chain (Krogmann et al., 1999). Heavy metals accumulate in living organism's body or tissue through the main route of food chain exposing greater health risk to animals and humans as long with passage of time (Sarfaraz et al., 2007). Heavy metals accumulation (Cd, Pb, Cr) can led to severe health problems in the human body (Oliver, 1997), while Pb and Cd are also renowned for their mutagenesis, teratogenesis and carcinogenesis behaviour (Radwan and Salama, 2006). Cardiovascular, kidney and bone diseases (Jarup, 2003). This elevated level of heavy metals concentrations is causative for several lethal diseases among which kidney, autoimmunity are of great concern, depending on their exposure frequency and duration (Kerkvilet, 1995). Trace metals are also responsible for other problems in human like to stimulate genomic instability (Coen et al., 2001), endocrine disruption (Dyer, 2007), Neurotoxic (Myer et al., 1997), and damage blood neutrophils (Mushtakova et al., 2005). Contaminated food with these metals can experiences major problems in case of their health perspective such as decreased immunological defenses, intrauterine growth retardation and impaired psycho-social behavior disabilities associated with starvation and a high occurrence of upper gastrointestinal cancer (Scott et al., 1996; Arora et al., 2008). High intensity of Cd exposure may observe pulmonary and renal effects (European Union, 2002; Young, 2005). Other heavy metals problems recorded were diarrhoea, stomatitis, tremor, hemoglobinuria causing a rust-red Color to stool, ataxia, paralysis, vomiting and convulsion, depression and pneumonia (McCluggage, 1991). Zn and Cu considered being essential metals but their excessive accumulation in food crops led to toxicity in humans and animals (Kabata-Pendias and Mukherjee, 2007). Türkdoğan et al. (2002) stated that in Van Turkey cancer rates of upper gastrointestinal increases due to the heavy metals in soil and vegetables. Heavy metals are considered to be highly toxic due to their low solubility in water and in the body. They are hardly removed from the body of human and animals even at their low concentration (Arora et al., 2008).

Most of the industries in Pakistan discharge their huge quantities of wastes along with toxic chemicals i.e. heavy metals that vary from the type of industry in Pakistan. In Faisalabad, Pakistan, Qadir et al. (2000) have reported several fold higher concentration of Cd in wastewater than permissible level. Several other studies have noticed that industry wastewater of the major cities of Pakistan had higher Cd, Pb, Cr concentrations (Hussain et al., 2006; Khan et al., 2007; Murtaza et al., 2008). while Tariq et al. (2006) observed high level of Cr and Pb in wastewater drains of Peshawar city than the safe limits. Two rice varieties along the bank of Nullah Dek in Sheikhupura, Pakistan irrigated with this water with heavy metals were also investigated (Sarfaraz et al., 2007).

Nullah Aik and Nullah Palkhu are the most polluted streams passing through the industrial city of Sialkot and Wazirabad, receiving most of the industrials effluents, urban and domestic sewage and municipal wastes of the above cities. The farmers irrigated their food crops in the vicinity of both the Nullahs by the wastewater. This wastewater will subsequently builds up toxic chemicals, especially heavy metals in the soil and vegetables (Kumar and Chandra, 2004; Rattan et al., 2005; Singh et al., 2004; Sharma et al., 2007; Marshall et al., 2007).

The existence of heavy metal in environmental samples (soil, sediment, water and biota) can cause a potential risk to human health. It is necessary to monitor human exposure to toxic and trace metals (Arain et al., 2009). Thus information about heavy metals accumulation in food crops and their dietary intake is necessary for assessing their risk to human health. No previous data and scientific work is available on the assessment of heavy metals in food crops and potential human health risk via consumption of these food crops from different irrigation sources. This was the first study to evaluate human health risk via food consumption in the study area. But in future more study is needed on Human health risk assessments because human consumed not only that particular food crops but also other food crops and dietary food stuffs not mentioned in the current study were also consumed, which gains significance for future studies. Research in developing countries with increasing demand of quality food production and risk associated with contamination of heavy metals is scanty; hence such kind of research will be more useful for future perspective. However research work with regard of metals uptake, bioaccumulation and health risk in term of wastewater irrigation is still desirable.

1.5 Aims and Objective

Following main objectives have been focused:

- To quantify the concentration of heavy metals in the water, soil and commonly grown food crops irrigated with different sources.
- To evaluate Plant concentration factor (PCF) of the toxic chemicals from different irrigation practices.
- To calculate daily intake of metals (DIM) due to consumption of particular food crops by the local human population.
- To investigate potential Human health risks associated with consumption of food crops contaminated with toxic chemicals (heavy metals).

Materials and Methods

2.1 Study Area

A twelve sites comprising of four waste water (two each) along the banks of Nullah Aik and Palkhu, four tube well water (two each) in the same area were selected in Punjab province of Sialkot and Wazirabad for the collection of water, soil and food crops samples, while four market sites of the above mentioned areas were selected for the collection of unknown irrigation sources of food crops.

Sialkot which is an industrial city situated in the east of Pakistan between 32 24' N–32° 37'N Latitude and 73° 59'E and 75° 20'E longitude, having population of 903 per km^2 (Qadir et al., 2008). The maximum average rainfall in that area is 1000 mm and the climatic conditions characterized with hot summer with maximum temperature of 45 °C and cold winter season.

Wazirabad is also an industrial city positioned in the district of Gujranwala, Punjab at 32° 27' 0"N and 74° 7' 0" E on the bank of river Chenab, where Nullah Palkhu link. It is separated 45km away from Sialkot and 30 km from district Gujranwala.

Sialkot is the aggregate of total 3229 functional industrial unit major of which are tanneries (264), factories of surgical instruments (220), leather garment producing units (244), leather sport product units (900), rice husking mills (57) and flour mills (14) (Qadir et al., 2008).

There are about 300 industrial units in Wazirabad of which 50% were registered with authorized manufacturers association. The city is renowned for variety of their cutlery products like hunting, pocket, laguiole, table and military knives also in combination with production of different kind of swords and axes. Besides of cutlery product production it also strengthen country economy with leather goods, surgical items, beauty and sports products (http://www.phsadc.org/index.php).

The Cleaner production centre (CPC) reported that the leather industry in Sialkot city generates 297 tons/day of leather which accounts for total 9388 m^3 of tanneries effluents. Each Tannery industry in Sialkot city generates 547-814 m^3 day (ETPI, 1998) of effluents with total effluents production of 11000 m^3 (Dawn daily, 2006). There is no municipal sewage treatment plant for organic, inorganic and other kind of wastes, so therefore total of 19 million m^3 per annum of wastewater directly or indirectly discharged by the Sialkot city into Nullah Aik and Palkhu (WWF, 2007). The waste water production capacity of Sialkot city is estimated to be 1503 gallons per day (Randhawa, 2002).

Most of the effluents of the cutlery and other localized small or large scale industries, domestic and urban sewage and agricultural runoff of Wazirabad may be directly or indirectly find their way to Nullah Aik and Palkhu along with aggregates of high toxic chemicals (Heavy metals).

Nullah Aik (32°63'N- 74°99'E and 32°45'N- 74°69'E) and Nullah Palkhu (32°69'N- 74°99'E and 32°37'N- 74°02'E) with their altitudes of 530 m and 290 m comes from Himalayas of Jammu and Kashmir respectively to meet the River Chenab after passing through Sialkot and Wazirabad city. Nullah Aik and Palkhu flows in the east to west direction with total annual discharge of 315 and 288 Cs per second respectively and total of 2.5 million peoples are living in the vicinity of both the Nullahs. Domestic and urban sewage, municipal wastes, industrial effluents, solid wastes, fertilizers and pesticides runoff from agricultural lands are directly or indirectly dump into Nullah Aik and Palkhu that will deteriorate the water quality of both the streams and changes gradually into industrial and municipal drains.

Two kinds of irrigation practices are common in the agricultural area of Sialkot and Wazirabad i.e. waste water and tube well water irrigation. The agricultural lands are situated around the bank of Nullah Aik and Nullah Palkhu with varieties of cereal crops, pulses and vegetables which was grown for local population consumption. These food crops were irrigated with polluted waste water that is pumped through hundred of machines which is located along the banks of the Nullahs. The food crops were also irrigated in the same area with tube well water having no access to waste water. Such kind of waste water irrigation practices would significantly builds up heavy metals in soil and food crops. Consumption of such contaminated food crops with heavy metals is a major route in food chain and important pathway for human exposure and will experience hazardous health risk to human beings. The industrial effluents and all kinds of domestic, urban and municipal wastes require proper treatment prior of their disposal into the Nullah Aik and Nullah Palkhu.

Further details of the study sites are given below.

2.2 Sites Descriptions

The Geographical data of each site was taken with the help of GPS (Global Positioning System, Garmin). The description of each site is mentioned below.

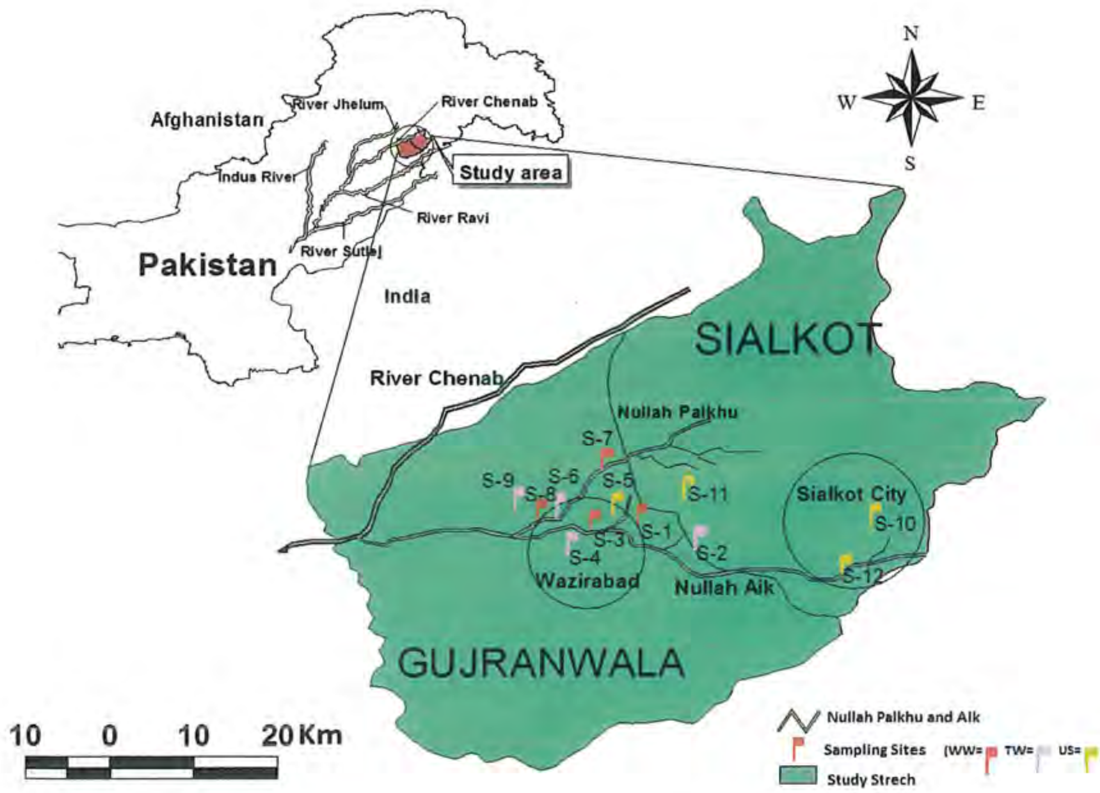

Fig. 3.1 Map of the study area showing twelve sampling sites irrigated with waste, tube well and unknown irrigation sources

Site 1 (32°26'20.0"N, 74°25'39.9"E) was located on Nullah Aik at Daska with altitude of 237 m. The waste water of these Nullahs was pumped through electric motor machine for irrigation activity of food crops. The water of this Nullah was polluted by various kind of industrial effluents, domestic sewage etc.

Site 2 (32°26'29.6"N, 74°25'18.4"E) was situated at 240 m altitude at the agricultural site of Daska irrigated with tube well or clean water. Fertilizers use and pesticides sprays were the common practices of the area.

Site 3 (32°25' 44.2"N, 74 °17'16.9"E) has altitude of 228 m located at Nullah Aik from where most of the lands along the bank of Nullah were irrigated with this polluted waste water. All the eminent anthropogenic activities of Sialkot district like industrial effluent, domestic sewage, municipal waste and surface runoff of fertilizer and pesticides from agricultural lands were linked to water pollution of that Nullah.

Site 4 (32°25' 24.0"N, 74°18' 22.3"E) was tube well water site having elevation of 231 m. Farmers used pesticides and fertilizers for their crops in that area.

Site 5 (32°28'91.7"N, 74°21'36.4"E) was the unknown or market source of sambrial where most of food crops were sold for consumption of local population. The vegetables were brought to the market from different sources of unknown origin.

Site 6 (32° 31' 7.10"N, 74°33'26.08"E) food crops were bought from bazaar of Sialkot, where the irrigated source of food crops were unknown.

Site 7 (32°28'31.9"N, 74°11'07.5"E) was located on Nullah Palkhu at Bailey having altitude of 227 m. Most of the food crops along their bank were watered with the polluted waste water with motor pump. This site was highly polluted with domestic sewage of sodhra town. The Palkhu Nullah was also potentially affected by industrial effluents, domestic sewage and urban runoff of Sialkot and Wazirabad which directly or indirectly discharged into that Nullah.

Site 8 (32°28'43.6"N, 74°11'30.4"E) was the site where food crops were irrigated with clean or tube well water. This site was situated at Bailey, Wazirabad at 225 m. Fertilizer and pesticides were the most prominent activities of the agricultural land.

Site 9 (32°27' 25.6"N,74°08'49.7"E) having elevation of 223 m was located along the bank of Nullah Palkhu where the waste water of the stream was sucked through pumps for the purpose of irrigation of lands by the farmer. At this point waste water was further polluted by the municipal and industrial wastes of Wazirabad.

Site 10 (32°27' 10.8"N, 74° 09' 1.5"E) was situated at 225 m elevation. The food crops were irrigated with tube well water. Agriculture practices were the major potential polluting activity in that area.

Site 11 (32°26'41.02"N, 74°6'56.87"E) was located at the main bazaar of Wazirabad where food crops were sold here, grown on unknown sources of irrigation.

Site 12 (32° 27'5.38"N, 74° 9' 25.30"E) was located at Chak satia from where food crops were bought.

2.3 Sampling Strategy

The research study for various samples collection was planned at the end of April 2011 in the industrial region of Sialkot and Wazirabad. All the samples of the desired purpose were collected in the early morning till before night.

In the study area of Sialkot and Wazirabad, Pakistan, two wastewater irrigation sites each along the Nullah Aik and Palkhu and two tube well water irrigation sites in the same areas were selected for samples collection of water, soils and food crops, while for unknown source, food crops were bought from both cities market (local market).

2.3.1 Soil Sampling

A total of twenty four soil samples measuring 1 kg were collected from 0-20 cm depth using prewashed steel auger in the vicinity of food crop species. Each sample comprised of 3-5 sub-samples combined to form composite which was kept in polythene bags, air dried at room temperature, crushed into powdered, sieved through 2 mm mesh and kept in prewashed metal free glass containers till further laboratory analysis.

2.3.2 Water Sampling

A twenty four samples comprised of both waste and tube well water were collected in triplicate from sites used for irrigation of food crops and preserved in a plastic bottles already pre-rinsed with 10% nitric acid solution followed by distilled water and stored at 4 °C prior to analysis.

2.3.3 Food crop sampling

Twelve food crops including vegetables (*Coriandrum sativum, Allium cepa, Abelmoschus esculentus, Allium sativum, Capsicum annuum, Daucus carota, Solanum melongena, Spinacia oleracea, Raphanus sativus, Lycopersicum esculentum*), and cereal crop (*Triticum aestivum*) grown on waste and tube well water were collected during April 2011. A total of twelve food crops from market or unknown source either for home consumption or sale were also collected during survey/sampling period. All food crops samples were kept in polythene bags and preserved at 4 °C in a freezer. Food crops of each species were collected as a composite or individually depend on the desired weight, required for the analysis. The plant samples were sectioned into edible and non edible parts and further washed with tape water and distilled water to remove all observable dust particles deposited and for the purpose of dryness it was further blotted with tissue paper and divided into small pieces for overnight dryness. The plant samples were further oven dried at temperature of 70-80 °C for 24 hours until all moisture are completely diminished. The dried samples were further pulverized into powdered by Micro hammer mill (Retsch, P-318, No. 611771), placed in small polythene zip-bags at ambient temperature. The fresh dried edible parts of all plant samples were weighed with digital balance (Sartorius, cp 622).

2.4 Digestion Procedures

2.4.1 Soil digestion

Powdered soil samples of 1g each were digested in 15 ml of aqua regia in 3:1 (HCL, HNO_3), left overnight and heated near about 150 °C until brown fumes turnoff and made addition of 5 ml $HClO_4$ (70-72 %) and heated it near to dryness. The remaining solution was filtered through Whatman filter paper No.42 and volume was raised up to the mark 50 ml with double distilled water (FAO/SIDA, 1983).

2.4.2 Water digestion

For dissolved metal analysis 250 ml of each water samples was filtered using Whatman filter paper No.45 (APHA, 1998) and pH was adjusted with addition of 1-2 ml of ultra pure HNO_3 kept at 4 °C till further analysis (De Carlo et al., 2004). For particulate metal analysis, filter papers cuttings were dried overnight and digested in the 10 ml acid mixture of HNO_3 and $HClO_4$ in 5:1 solution. The mixture was heated until transparent solution was obtained. Cool the solution for a while and then filter through Whatman filter paper no.45 to obtain a volume of 50 ml with distilled water and preserved them in plastic bottles already pre-rinsed with 10 % HNO_3 solution. All the digestion procedure was adopted by the method of USEPA (1990).

Total metals were calculated by combining dissolved metals and suspended particulate metals in water.

2.4.3 Plant Digestion

A total of 10 ml mixture of HNO_3 and $HCLO_4$ in 2:1 was added into 0.25g food crop sample which was left for overnight digestion. It was heated for a movement until brown fumes was changed into white fumes. The solution was filtered over filter paper no. 42 by raising the remaining volume with de-ionized distilled water up to the mark 50 ml and kept in plastic bottles at room temperature for heavy metals analysis.

2.5 Metals analyses

Total of nine heavy metals i.e. Co, Cr, Cu, Fe, Ni, Pb, Mn, Cd and Zn were analyzed in different samples of soil, water and food crops by Flame Atomic Absorption Spectrophotometer (Varian FAAS-240).

2.6 Data analyses

2.6.1 Transfer factor

Heavy metals exchange occurred from soil to food crops, so it is the ratio of the heavy metal in plant to soil. Metal concentrations in the soil and food crops for the transfer factor were calculated on the basis of dry weight, accompanied with their formulation as follows.

$$PCF = \frac{Cplant}{Csoil} \text{ (Cui et al., 2005)}$$

Where C_{plant} and C_{soil} show metals concentration on dry weight basis in the extracts of plant and soil respectively.

2.6.2 Human Health Risk Assessment

Different questionnaires from 65 peoples between ages of 14-50 years for evaluation of health risk were asked from the local population of the Sialkot and

Wazirabad. The information recorded from the local population in the questionnaires were their age, body weight, disease and daily consumption of each food crops.

2.6.2.1 Daily intake of metals (DIM)

Prior to calculate Health Risk Index (HRI), first of all daily intake of metals (DIM) were calculated.

$$DIM = \frac{C_{metal} \times C_{factor} \times D_{food\ intake}}{B_{average\ weight}}$$

Where C_{metal}, C_{factor}, $D_{food\ intake}$ and $B_{average\ weight}$ represent the heavy metals concentrations in plants, conversion factor, daily intake of food crops and average body weight respectively. The conversion factor (CF) of 0.085 was used for the conversion of fresh vegetables weight to dry weight (Rattan et al., 2005).

The average daily consumption of food crops and their average body weight for adult's population were 0.527 kg/person/day and 55.5 kg respectively.

2.6.2.2 Health Risk Index

HRI refers to the ratio of the daily intake of metals (DIM) in the food crops to the Reference oral dose (RfD) given by the formula.

$$HRI = \frac{DIM}{RfD} \text{ (US-EPA, 2002)}$$

The population will experience risk if the value of HRI is equal or exceeded than 1.The HRI<1 will limits the safe mode for local population through consumption of food crops and vice versa.

2.7 Statistical analysis

All the data are statistically represented in the form of means. Range and standard deviation. T-test were used for significance of difference at $P<0.05$ in response to different irrigation sources. Analysis of variance at $P<0.05$ were tested among waste, tube well and unknown irrigated food crops for significance of differences. All these statistical analyses were performed using Statistical package SPSS (version 13) and Statistica (version 7).

Results

3.1 Heavy metals in irrigation water

Range and mean concentrations of heavy metals are listed in Table 2. The mean concentrations of heavy metals in wastewater were in the order of Fe>Pb>Cr>Mn>Cd>Ni>Zn>Cu>Co, while in tube well water Fe concentrations were highest followed by Pb, Cr, Mn, Cd, Co, Ni, Zn and Cu. Fe Showed maximum concentrations between range of 2.19-26.39 and 1.23-9.78 mg/kg, while least concentrations was recorded for Co (0.19-0.41 mg/kg) and Cu (0.008-0.17 mg/kg) in waste and tube well water respectively. All the mean heavy metals concentrations except Fe were significantly higher in waste as compared to tube well water ($P<0.05$).

3.2 Heavy metals in soil

In the waste water irrigated soil heavy metals mean concentrations were significantly higher ($P<0.001$, $P<0.05$) compared with tube well water irrigated soil. Heavy metals in wastewater irrigated soil were found in the order of Fe>Zn>Cr>Ni>Pb>Mn>Cu>Cd>Co, while the trends revealed by heavy metals in tube well water irrigated soil were in order of Fe>Zn>Ni>Cr>Mn>Pb>Cu>Co>Cd as listed in Table 2. The maximum mean concentrations of heavy metals in waste and tube well water irrigated soil were 1473.52-1645.98 and 443.82-1559.48 mg/kg for Fe respectively while the minimum concentrations was observed in Co (5.55-10.05 mg/kg) and Cd (1.28- 4.28 mg/kg) in waste and tube well water irrigated soil respectively.

3.3 Heavy metals in Edible parts of Food crops

Heavy metals concentrations in the edible part of food crops irrigated with waste, tube well and unknown source of water are listed in Table 4, Table 5 and Table 6 respectively. In all food crops higher concentrations of Fe was recorded as listed in the Table 3 and ranged from 42.91-283.85, 24.04-135.71 and 14.37-150.33 mg/kg in waste, tube well and unknown sources respectively. The minimum mean concentrations for Cd (0.4-1.2 mg/kg) and Cu (0.69-4.72 mg/kg), (0.05-3.06 mg/kg) were observed in tube well, wastewater and unknown irrigated food crops respectively. Concentrations of studied metals recorded in wastewater irrigated food crops were relatively higher as compared to unknown source food crops and food crops irrigated with tube well water.

The distribution of all the heavy metals vary widely among different food crop species and also among sites irrigated with different sources. It can experienced that heavy metals mean concentrations in edible part of food crop irrigated with wastewater are higher than edible food part of tube well water and also higher heavy metals concentrations was observed in unknown source as compared to tube well water irrigated food crops.

The mean heavy metals concentrations in all the food crops samples grown on wastewater followed the order of: *Spinacia oleracea>Coriandrum sativum>Daucus carota>Mentha spicata>Raphanus sativus>Abelmoschus esculentus>Allium cepa>Triticum aestivum>Capsicum annum>Lycopersicum esculentum>Allium sativum>Solanum melongena* and for tube well irrigated food crops the trends followed were; *Mentha spicata>Spinacia oleracea>Coriandrum sativum>Abelmoschus esculentus>Raphanus sativus>Triticum aestivum>Daucus carota>Allium cepa>Solanum melongena>Lycopersicum esculentum>Allium sativum>Capsicum annum. The* unknown irrigation source obeys the following heavy metals concentrations trends in all the food crops shown as: *Spinacia oleracea>Mentha spicata>Daucus carrota>Coriandrum sativum>Lycopersicum esculentum> Triticum aestivum>Raphanus sativus>Abelmoschus esculentus>Capsicum annum> Solanum melongena>Allium cepa>Allium sativum.* It was observed that highest heavy metals concentrations were revealed by leafy vegetables irrigated with different irrigation practices as compared to all other food crops as shown in Table 3.

Among all the heavy metals Fe was recorded as maximum in all of the food crops except *Triticum aestivum* irrigated with waste and unknown sources, whereas observed highest value of Mn, While the minimum concentrations for Cu was observed in *Allium sativum, Capsicum annum, Daucus carota, Raphanus sativus, Spinacia oleracea, Lycopersicum esculentum* irrigated with waste, tube well and unknown irrigation practices and also in *Coriandrum sativum*, *Allium cepa*, *Mentha spicata* grown on waste and unknown sources, while the lowest values in *Solanum melongena* of waste and tube well irrigation sources. The minimum concentrations for Cd was revealed in *Abelmoschus esculentus*, *Triticum aestivum*, *Coriandrum sativum* (tube well), *Solanum melongena* (unknown source), *Mentha spicata* (tube well) irrigated with waste, tube well and unknown source of water, while only the lowest concentrations of Cr was detected in Allium cepa grown on tube well water.

Among heavy metals the maximum mean concentrations of Cr were 6.08, 5.47 and 2.08 mg/kg in *Spinacia oleracea* and *Mentha spicata* while the minimum concentrations were in *Lycopersicum esculentus* (1.46 mg/kg), *Triticum aestivum* (1.82 mg/kg) and *Allium cepa* (0.48mg/kg) irrigated with waste, unknown source and tube well sources of irrigation respectively as listed in Fig. 3.2. The highest value for Ni were recorded as in *Solanum melongena* (6.40 mg/kg) and *Mentha spicata* (5.15,2.72 mg/kg), while it highlights (3.36,2.64 and 1.34 mg/kg) concentrations for *Triticum aestivum* and *Spinacia oleracea* irrigated with waste, unknown and tube well water respectively (Fig. 3.2). The maximum and minimum concentrations of Fe was revealed in *Coriandrum sativum* (283.85 mg/kg), *Mentha spicata* (135.71 mg/kg) *Daucus carota* (150.33 mg/kg) and *Triticum aestivum* (42.91 mg/kg), *Allium sativum* (24.04 mg/kg) and *Allium cepa* (30.66 mg/kg) irrigated with waste, tube well and unknown irrigation practices respectively as shown in Fig. 3.3. When food crops were irrigated with waste and tube well water maximum concentration of Cu was observed in *Abelmoschus esculentus* (4.72, 1.66 mg/kg) and minimum in *Daucus carota* (0.70, 0.17 mg/kg) respectively, while for *Trititicum aestivum* (3.06 mg/kg) maximum and for *Allium cepa* (0.79 mg/kg) minimum concentrations were observed. when the treatment was unknown as enlisted in Fig. 3.4. *Mentha spicata* revealed highest Co concentrations of 11.36, 7.91, 8.17 mg/kg and lowest of 3.28, 0.71 mg/kg in *Lycopersicum esculentum* and 2.03 mg/kg in *Solanum melongena*. when the source of irrigation was waste, tube well and unknown respectively as shown in Fig. 3.5. Waste, tube well and unknown irrigation practices build up high concentrations of Mn in *Spinacia oleracea* (201.26 mg/kg), *Mentha spicata* (52.58 mg/kg) *Triticum aestivum* (52.15 mg/kg) with minimum values shown in *Solanum melongena* (14.89, 8.49, 7.56

mg/kg) respectively (Fig. 3.6). Highest values for Pb were detected in food crops of *Allium cepa* (40.85 mg/kg), Mentha spicata (26.79 mg/kg) and *Lycopersicum esculentum* (32.26 mg/kg) and were 22.41 mg/kg for Spinacia oleracea and 15.28.18 mg/kg for *capsicum annum* revealing the least concentrations when grown on the above three irrigation practices (Fig. 3.7). Lycopersicum esculentum (20.32 mg/kg) and *Abelmoschus esculentus* (14.46, 18.63 mg/kg) showing maximum concentrations for Zn when the treatment of irrigation were waste ,tube well and unknown sources, while the least concentrations were exhibited by *Allium sativum* (8.94,10.32 mg/kg) and *Solanum melongena* (4.36 mg/kg) for waste ,unknown and tube well water respectively (Fig. 3.8). The food crops including *Mentha spicata* (3.81 mg/kg), *Allium cepa* and *Spinacia oleracea* showing highest concentrations for Cd with the least concentrations followed by *Triticum aestivum* (1.18,0.41,0.97 mg/kg) irrigated with waste, tube well and unknown source respectively as shown in Fig. 3.9.

Analysis of variance (one way ANOVA) of all the studied heavy metals for waste, tube well and unknown irrigation sources were significantly higher at $P<0.000$. Tamhane's T2 test for conservative pair wise comparisons for heavy metals i.e. Cr, Ni, Fe, Cu, Co, Mn, Zn, Pb, and Cd were significantly different at $P<0.0001$ and $P<0.001$ among wastewater vs tube well water sites. Wastewater vs unknown source were significant higher for Ni, Fe, Co, Mn, Pb, Cd ($P<0.000$ and $P<0.05$). The Tube well vs unknown sites were significant different at $P<0.0001$, $P<0.00$ and $P<0.05$ for Cr, Ni, Fe, Cu, Pb, Zn, and Cd respectively.

3.4 Transfer factor in edible part of Food crops

The transfer factor for the food crops irrigated with waste and tube well water were >1 for Mn and Pb as shown in Table 7 and 8. The highest PCF were exhibited in wastewater between range of 4.94-6.07 and 0.91-1.43 for Mn, Pb in food crops of *Spinacia oleracea* and *Allium cepa* respectively, while in tube well water irrigated food crops it were maximum in *Mentha spicata* for Pb (2.66-3.96) and Mn (2.20-3.43).

The wastewater irrigated food crops show the following trends of heavy metals of PCF in order of; Mn>Pb>Zn>Cd>Cu>Ni>Cr, while the trends in tube well water irrigated food crops were; Pb> Mn>Zn>Cd>Cu>Ni>Cr for heavy metals.

The PCF in wastewater irrigated food crops for Cr, Ni, Cu, Mn, Pb, Zn, and Cd ranged between (0.03-0.14), (0.08-0.15), (0.05-0.34), (0.41-5.52), (0.61-1.11), (0.20-0.45), (0.13-0.42) respectively and in tube well irrigated food crops it were between (0.02-0.08), (0.04-0.09), (0.03-0.34), (0.43-2.94), (1.20-3.29), (0.14-0.47), (0.14-0.41) for Cr, Ni, Cu, Mn, Pb, Zn, and Cd respectively.

3.5 Daily intake of metals (DIM) and Human Health risk Assessment

DIM for heavy metals were evaluated for different food crops presented in Table 9, Table 10 and Table 11 irrigated with tube well, wastewater and unknown sources respectively. The mean concentrations of all the heavy metals result high DIM values in waste water irrigated food crops followed by unknown and tube well water irrigated food crops.

Different food crops species of *Spinacia oleracea*, *Solanum melongena*, *Coriandrum sativum*, *Abelmoschus esculentus*, *Allium cepa*, *Lycopersicum esculentum*, and *Mentha spicata* proved elevated DIM values for Cr, Mn and Ni, Fe, Cu, Pb, Zn, Co and Cd when treated with wastewater irrigation practices, while in tube well irrigated food crops the highest DIM value for Cr, Ni and Cu, Zn and Mn, Pb and Cd were observed in different food crops of *Mentha spicata*, *Abelmoschus esculentus*, *Coriandrum sativum*, *Allium cepa* respectively, while the maximum DIM values revealed by heavy metals were in *Spinacia oleracea* (Cr, Cd), *Mentha spicata* (Ni), *Abelmoschus esculentus* (Pb, Zn) and *Triticum aestivum* (Cu, Mn) respectively, when treated with unknown source of irrigation.

HRI for tube well, waste and unknown irrigated food crops were listed in Table 12, Table 13 and Table 14 respectively.HRI was more than 1 for Cd, Pb and Mn. HRI was observed greater than 1 for Cd in all food crops except *Triticum aestivum* in waste and unknown irrigated food crops, whereas for tube well irrigated food crops HRI were < 1. Maximum HRI of 3.0731 and 2.272 in waste and unknown sources were Shown in *Mentha spicata* and *Spinacia oleracea* respectively. The Mn

HRI value were <1 in all the three irrigated food crops types, except in *Spinacia oleracea* irrigated with wastewater, whereas observed HRI of 1.1603. Pb showed elevated health risk (HRI>1) in all the three irrigated food crops as compared to Mn and Cd. The maximum health risk for Pb were exhibited in *Allium cepa* (9.4208), *Lycopersicum esculentum* (7.4399) and *Coriandrum sativum* (6.2309) grown in waste, unknown and tube well irrigated practices.

Table 3.1 Food crops species collected from different sites

SPECIES	English name	Families	Edible part of food crops
***Coriandrum sativum* L.**	Coriander	Apiaceae	Leaves
***Allium cepa* L.**	Onion	Liliaceae	Bulb
***Abelmoschus esculentus* L.**	Lady s finger	Malvaceae	Fruit
***Allium sativum* L.**	Garlic	Liliaceae	Bulb
***Capsicum annum* L.**	Capsicum	Solanaceae	Fruit
***Daucus carota* L.**	Carrot	Apiaceae	Root
***Spinacia oleracea* L.**	Spinach	Chenopodiaceae	Leaves
***Raphanus sativus* L.**	Radish	Brassicaceae	Root
***Mentha spicata* L.**	Mint	Lamiaceae	Leaves
***Solanum melongena* L.**	Brinjal	Solanaceae	Fruit
***Lycopersicum esculentum* L.**	Tomato	Solanaceae	Fruit
***Triticum aestivum* L.**	Wheat	Poaceae	Grain

Table 3.2 Heavy metals concentrations in waste (n=12) and tube well water (n=12) (mg/L) and soil (mg/kg) irrigated with waste (n=12) and tube well water (n=12)

Heavy metals	Wastewater irrigated soil		Tube well irrigated soil		P Values	Wastewater		Tube well water		P Value
	Mean ±S.D.	Range	Mean ±S.D	Range		Mean ±S.D	Range	Mean ±S.D	Range	
Cr	43.03 ±11.095	31.65-61.65	*24.87±6.0088*	*14.2-37.7*	0.0001	4.74±4.43	1.8-18.2	0.85±0.55	0.27-1.67	0.0063
Ni	42.09 ±11.73	30.05-64.3	*30.71±6.15*	*22.8-43.6*	0.0070	0.46±0.29	0.21-1.29	0.12±0.04	0.05-0.2	0.0006
Fe	1551.08 ±59.38	1473.52-1645.98	*1280.17±387.47*	*443.82-1559.48*	0.026	9.46±7.83	2.19-26.39	4.73±3.76	1.23-9.78	0.073
Cu	13.704 ±5.5735	5.33-22.03	*5.823±3.61*	*0.13-11.13*	0.0005	0.35±0.126	0.18-0.66	0.07±0.05	0.008-0.17	0.0000
Co	8.34 ±1.29	5.55-10.05	*5.23±1.76*	*1.85-7.7*	0.0001	0.33±0.06	0.19-0.41	0.15±0.059	0.05-0.27	0.0000
Mn	36.47±15.59	18.33-66.78	*19.84±5.5*	*12.72-28.03*	0.0021	1.99±1.23	0.64-4.88	0.35±0.16	0.12-0.72	0.0001
Pb	36.91 ±29.37	11.5-90	*12.75±9.44*	*0.00-29.5*	0.013	5.03±1.59	3.08-7.32	2.47±0.74	1.32-4.12	0.0000
Zn	45.19 ±13.22	22.39-60.71	*30.71±11.7*	*11.14-45.47*	0.0095	0.45±0.1	0.19-0.6	0.07±0.058	0.03-0.24	0.0000
Cd	9.15 ±1.33	7.13-11.13	*2.89±1.004*	*1.28-4.28*	0.0000	0.55±0.09	0.27-0.64	0.27±0.08	0.14-0.44	0.000

Table 3.3 Heavy metals concentrations in Total Edible Food crops irrigated with Tube well water, Wastewater and unknown source

Heavy metals	T.W		W.W		U.S	
	Mean±S.D	Range	Mean±S.D	Range	Mean±S.D	Range
Cr	1.27±0.46	0.48-2.08	3.21±1.17	1.46-6.08	2.69±1.21	0.91-5.47
Ni	1.99±0.48	1.34-2.72	4.61±0.79	3.36-6.39	3.61±0.86	2.33-5.15
Fe	57.4±37.33	24.04-135.71	117.66±88.19	42.91-283.85	72.15±46.03	14.37-150.33
Cu	0.91±0.55	0.17-1.99	1.84±1.21	0.69-4.72	1.35±0.77	0.05-3.06
Co	3.44±1.81	0.71-7.91	7.24±2.54	3.28-11.36	4.07±2.17	1.54-8.17
Mn	19.7±14.65	8.48-58.39	55.02±49.43	14.89-201.26	22.55±13.89	6.91-52.15
Pb	21.56±7.13	15.28-42	32.22±4.89	22.41-40.85	23.67±6.08	11.46-32.26
Zn	9.69±3.27	4.36-14.46	15.85±3.44	8.94-20.32	14.15±2.86	8.91-18.63
Cd	0.82±0.25	0.4-1.2	2.64±0.91	1.18-3.81	1.84±0.61	0.94-2.82

WW=wastewater, TW=tube well water, US=unknown source

Table 3.4 Heavy metals concentrations (mg/kg) in Food crops (n=4) (edible part) irrigated with waste water

Species	Value	Cr	Ni	Fe	Cu	Co	Mn	Pb	Zn	Cd
Coriandrum sativum	M±S.D	4.25 ± 3.67	4.43 ± 1.12	283.85 ± 183.27	3.03 ± 2.37	7.93 ± 3.40	76.38 ± 49.94	34.46 ± 13.45	15.58 ± 2.63	3.75 ± 0.45
	Range	1.10 - 9.55	3.14 - 5.75	120.45 - 484.60	0.15 - 5.95	3.40 - 11.40	16.50 - 127.90	21.00 - 53.00	12.95 - 19.23	3.37 - 4.35
Allium cepa	M±S.D	3.05 ± 2.49	4.99 ± 1.54	50.20 ± 3.35	1.45 ± 0.33	10.76 ± 1.13	44.69 ± 20.67	40.85 ± 8.85	15.09 ± 5.02	3.79 ± 0.20
	Range	0.45 - 5.60	3.70 - 7.10	46.85 - 54.85	1.05 - 1.85	9.20 - 11.65	24.10 - 70.20	33.50 - 52.91	8.58 - 20.15	3.50 - 3.95
Abelmoschus esculentus	M±S.D	4.03 ± 2.00	4.01 ± 1.83	57.11 ± 1.65	4.72 ± 3.17	8.35 ± 3.77	50.33 ± 30.47	35.29 ± 9.62	19.48 ± 5.18	2.07 ± 0.27
	Range	1.10 - 5.50	2.37 - 5.86	54.71 - 58.48	0.90 - 8.17	3.20 - 12.25	11.95 - 86.50	24.00 - 47.50	14.35 - 25.31	1.77 - 2.35
Allium sativum	M±S.D	2.57 ± 0.39	5.22 ± 1.46	61.93 ± 22.25	1.21 ± 0.68	8.18 ± 4.15	24.44 ± 11.01	31.00 ± 5.80	8.94 ± 2.11	3.07 ± 0.53
	Range	2.20 - 3.11	3.33 - 6.70	44.05 - 94.45	0.30 - 1.95	2.20 - 11.40	8.55 - 33.60	24.50 - 38.50	7.10 - 11.47	2.30 - 3.50
Capsicum annum	M±S.D	2.60 ± 2.15	4.58 ± 0.76	55.82 ± 13.86	1.80 ± 1.26	9.06 ± 5.60	38.95 ± 17.99	28.00 ± 7.27	14.58 ± 4.09	1.85 ± 0.61
	Range	0.35 - 5.30	3.65 - 5.45	40.20 - 73.75	0.25 - 2.90	1.55 - 14.80	12.85 - 53.80	21.00 - 35.00	9.54 - 18.76	1.12 - 2.47
Daucus carota	M±S.D	3.45 ± 2.46	4.30 ± 1.64	224.87 ± 88.53	0.70 ± 0.56	5.75 ± 4.66	51.75 ± 40.81	26.85 ± 3.08	12.42 ± 2.40	2.61 ± 0.24
	Range	0.85 - 5.60	2.90 - 6.35	149.37-352.20	0.15 - 1.40	1.54 - 11.05	15.34 - 96.05	24.00 - 31.00	10.78 - 15.89	2.30 - 2.80
Spinacia oleracea	M±S.D	6.08 ± 1.83	4.16 ± 0.55	229.24 ± 33.67	2.09 ± 0.46	7.22 ± 1.18	201.26 ± 20.05	22.41 ± 2.42	17.47 ± 1.01	3.26 ±1.18
	Range	4.20 - 7.90	3.63 - 4.93	198.29 - 262.90	1.64 - 2.50	6.11 - 8.35	180.21 - 221.35	19.33 - 25.00	16.39 - 18.35	1.84 -4.50
Raphanus sativus	M±S.D	2.75 ± 1.24	5.31 ± 2.05	101.46 ± 62.97	0.77 ± 0.26	5.20 ± 3.66	21.88 ± 17.98	34.07 ± 3.80	12.58 ± 7.76	2.60 ±0.30
	Range	0.88 - 3.40	2.85 - 7.00	39.32 - 155.70	0.55 - 1.05	2.75 - 10.50	5.92 - 47.70	28.50 - 36.50	7.07 -23.53	2.45 - 3.05
Mentha spicata	M±S.D	3.21 ± 1.64	3.89 ± 0.69	191.50 ± 19.85	1.69 ± 0.15	11.36 ± 1.25	54.95 ± 8.67	37.30 ± 19.20	18.63 ± 2.14	3.81 ± 0.51
	Range	1.70 - 4.97	3.25 - 4.75	171.31 - 214.20	1.46 - 1.80	10.11 - 12.83	43.76 - 64.74	20.39 - 55.23	16.43 - 21.51	3.12 - 4.35
Solanum melongena	M±S.D	2.74 ± 0.49	6.40 ± 1.59	50.26 ± 4.89	0.94 ± 0.34	3.74 ± 0.77	14.89 ± 1.08	31.85 ± 2.20	15.57 ± 1.62	1.40 ± 0.28
	Range	2.25 - 3.22	4.88 -8.15	43.64 - 55.38	0.58 - 1.32	2.80 - 4.52	13.94 - 16.25	29.78 - 34.00	14.23 - 17.90	1.11 - 1.76
Lycopersicum esculentum	M±S.D	1.46 ± 0.70	4.74 ± 1.53	62.79 ± 5.36	0.79 ± 0.56	3.28 ± 0.70	23.61 ± 2.11	32.41 ± 2.04	20.32 ± 2.39	2.35 ± 0.41
	Range	0.80 - 2.13	3.28 - 6.21	56.65 - 68.86	0.20 - 1.35	2.46 - 3.96	21.05 - 25.89	30.00 - 34.32	17.37 - 22.83	1.84 - 2.75
Triticum aestivum	M±S.D	2.39 ±0.89	3.36±0.34	42.91 ± 3.23	2.93 ± 1.32	6.06 ± 0.94	57.15 ± 1.76	32.13 ± 7.11	19.58 ± 0.73	1.18 ± 0.20
	Range	1.74 - 3.70	3.05 - 3.65	38.35 - 45.20	2.20 - 4.90	5.50 - 7.45	54.80 - 58.50	22.50 - 37.50	18.93 - 20.22	0.97 - 1.45

Table 3.5 Heavy metals concentrations (mg/kg) in Food crops (n=4) (edible part) irrigated with Tube well water

Species	Values	Cr	Ni	Fe	Cu	Co	Mn	Pb	Zn	Cd
Coriandrum sativum	M±S.D	1.61 ± 1.46	1.71 ± 0.25	83.47 ± 33.75	1.33 ± 1.25	4.37 ± 3.28	28.27 ± 31.16	27.02 ± 1.39	11.90 ± 3.87	0.99 ± 0.41
	Range	0.20 - 3.61	1.50 - 2.00	51.66 - 127.00	0.02 - 2.43	0.75 - 8.35	3.85 - 73.55	25.50 - 28.87	9.76 - 17.70	0.45 - 1.32
Allium cepa	M±S.D	0.48 ± 0.33	2.40 ± 0.81	31.23 ± 9.11	0.75 ± 0.61	3.35 ± 3.22	14.72 ± 9.69	23.05 ± 9.59	8.25 ± 1.78	1.20 ± 0.42
	Range	0.05 - 0.85	1.56 - 3.40	23.05 - 44.20	0.02 - 1.50	1.35 - 8.15	4.95 - 28.11	16.50 - 37.00	6.15 - 10.50	0.60 - 1.55
Abelmoschus esculentus	M±S.D	1.41 ± 0.59	2.70 ± 1.16	46.47 ± 2.91	1.66 ± 1.21	2.85 ± 1.82	22.27 ± 14.55	19.94 ± 1.72	14.46 ± 6.28	0.67 ± 0.26
	Range	0.69 - 1.93	1.93 - 4.40	42.63 - 49.60	0.24 - 4.55	1.35 - 5.45	7.82 - 39.30	17.82 - 21.52	10.97 - 23.88	0.33 - 0.95
Allium sativum	M±S.D	1.32 ± 1.12	2.24 ± 0.96	24.04 ± 9.21	0.65 ± 0.58	4.02 ± 2.79	9.54 ± 3.18	19.06 ± 3.34	6.75 ± 0.88	1.16 ± 0.52
	Range	0.35 - 2.55	1.05 - 3.21	12.05 - 32.55	0.11 - 1.35	0.77 - 7.26	6.37 - 13.70	15.50 - 23.53	5.66 - 7.70	0.55 - 1.80
Capsicum annum	M±S.D	0.98 ± 0.67	2.42 ± 0.57	26.25 ± 6.34	0.89 ± 0.65	2.95 ± 2.51	12.00 ± 3.88	15.28 ± 7.65	6.67 ± 1.59	1.07 ± 0.66
	Range	0.12 - 1.72	1.65 - 2.91	19.64 - 33.72	0.07 - 2.30	0.87 - 6.60	7.45 - 16.93	9.39 - 26.43	4.41 - 8.07	0.34 - 1.94
Daucus carota	M±S.D	1.44 ± 0.98	1.94 ± 0.63	43.61 ± 9.13	0.17 ± 0.1	3.31 ± 2.68	11.21 ± 7.75	16.92 ± 1.39	7.02 ± 1.22	0.64 ± 0.39
	Range	0.53 - 2.65	1.12 - 2.63	33.45 - 55.57	0.02 - 0.55	0.86 - 5.86	5.10 - 22.56	15.10 - 18.44	5.43 - 8.04	0.11 - 0.97
Spinacia oleracea	M±S.D	0.52 ± 0.22	1.34 ± 0.22	114.43±3.65	0.56 ± 0.21	2.64 ± 0.88	27.85 ± 3.09	17.66 ± 4.94	8.90 ± 1.29	0.66 ± 0.16
	Range	0.30 - 0.80	1.14 - 1.65	110.54-119.32	0.33 - 0.79	1.95 - 3.90	24.38 – 31.34	11.57 - 23.00	7.49 - 10.48	0.48 - 0.84
Raphanus sativus	M±S.D	1.52 ± 0.88	1.52 ± 0.98	47.36 ± 18.57	0.50 ± 0.26	3.37 ± 2.38	11.52 ± 9.74	21.68 ± 3.77	10.29 ± 5.89	0.85 ± 0.26
	Range	0.50 - 2.60	0.15 - 2.44	28.10 - 66.72	0.23 - 0.80	1.37 - 6.50	3.90 - 25.80	18.50 -27.00	5.34 - 18.83	0.55 - 1.15
Mentha spicata	M±S.D	2.08 ± 1.85	2.72 ± 0.64	135.71 ± 21.34	1.24 ± 0.5	7.91 ± 3.14	52.58 ± 9.38	26.79 ±2.5	13.44 ± 2.82	0.81 ± 0.46
	Range	0.55 - 4.60	1.77 - 3.11	115.84 - 161.15	0.88 - 1.86	3.83 -11.25	43.73 - 61.25	24.54 – 30.12	10.34 - 16.56	0.35 - 1.44
Solanum melongena	M±S.D	1.41 ± 0.13	1.81 ± 0.09	44.67 ± 3.72	0.55 ± 0.18	1.27 ± 0.47	8.49 ± 1.67	19.33 ± 3.05	4.36 ± 0.57	0.56 ± 0.21
	Range	1.28 - 1.58	1.69 - 1.90	39.74 - 48.78	0.31 - 0.75	0.71 - 1.83	6.33 - 10.29	15.72 - 22.97	3.82 - 4.96	0.25 - 0.74
Lycopersicum esculentum	M±S.D	0.97 ± 0.57	1.57 ± 0.47	34.24 ± 3.20	0.53 ± 0.32	0.71 ± 0.27	12.52 ± 1.06	18.03 ± 2.42	10.13 ± 2.21	0.82 ± 0.14
	Range	0.13 - 1.38	0.95 - 1.99	29.59 - 36.77	0.07 - 0.82	0.47 - 0.98	11.45 - 13.87	14.94 - 20.43	7.67 - 12.98	0.65 - 0.99
Triticum aestivum	M±S.D	1.52 ± 0.88	1.63 ± 0.81	31.13 ± 4.26	1.39 ± 1.24	4.58 ± 2.13	23.39 ± 23.05	18.82 ± 5.30	14.07 ± 2.57	0.41 ± 0.22
	Range	0.85 - 2.75	0.45 - 2.20	25.85 - 35.50	0.25 - 2.80	1.63 - 6.70	3.50 - 50.95	14.41 - 26.35	11.49 - 16.33	0.17 - 0.70

Table 3.6 Heavy metals concentrations (mg/kg) in Food crops (n=4) (edible part) irrigated with unknown source

Species	Value	Cr	Ni	Fe	Cu	Co	Mn	Pb	Zn	Cd
Coriandrum sativum	M±S.D	4.13 ± 2.09	3.58 ± 1.13	109.03 ± 9.53	1.62 ± 0.61	6.84 ± 3.90	30.50 ± 14.73	22.18 ± 16.94	17.38 ± 3.15	2.67 ± 1.38
	Range	2.30 - 7.12	2.86 - 5.25	96.77 - 119.05	0.88 - 2.34	3.25 - 11.89	16.40 - 51.15	5.00 - 38.78	15.11 - 21.83	1.35 -4.54
Allium cepa	M±S.D	2.06 ± 0.28	3.39 ± 1.08	30.66 ± 8.45	0.79 ± 0.36	5.88 ± 4.57	13.75 ± 1.73	20.91 ± 5.09	12.13 ± 2.19	1.46 ± 0.81
	Range	1.80 - 2.41	2.11 - 4.60	23.45 - 40.55	0.30 - 1.15	1.21 - 11.67	11.65 - 15.87	14.50 - 26.50	9.99 -14.81	0.96 - 2.66
Abelmoschus esculentus	M±S.D	2.14 ± 1.13	3.37 ± 0.54	49.47 ± 14.99	2.09 ± 0.65	3.62 ± 1.22	8.37 ± 3.81	31.56 ± 8.35	18.63 ± 2.74	1.81 ± 0.41
	Range	1.13 - 3.35	2.93 - 4.15	31.40 - 67.25	1.33 - 2.90	2.50 - 5.33	4.75 - 12.54	21.50 - 41.42	15.16 - 21.33	1.30 - 2.31
Allium sativum	M±S.D	2.28±0.86	3.63±0.81	45.85±19.79	1.11±0.66	4.33±1.75	10.01±1.95	21.49±6.3	10.32±0.88	1.88±0.58
	Range	1.45-3.2	2.85-4.77	29.4-73.66	0.3-1.77	2.85-6.64	7.95-12.55	13.5-27.44	9.22-11.15	1.2-2.63
Capsicum annum	M±S.D	1.84 ± 0.75	3.52 ± 0.30	43.32 ± 15.40	1.33 ± 0.97	2.42 ± 1.06	25.18 ± 5.17	18.00 ± 6.74	14.21 ± 2.98	2.03 ± 0.88
	Range	1.00 - 2.50	3.20 - 3.85	29.65 - 62.22	0.32 - 2.65	1.05 - 3.54	19.45 - 31.95	11.00 - 26.45	10.42 -17.47	1.10 - 2.98
Daucus carota	M±S.D	2.73 ± 1.80	3.57 ± 1.48	150.33 ± 20.46	0.80 ± 0.41	4.67 ± 2.70	23.17 ± 9.68	19.32 ± 7.04	12.01 ± 2.48	1.67 ± 0.35
	Range	0.75 - 4.67	1.50 - 4.87	128.75 - 177.33	0.25 - 1.23	1.25 - 7.76	11.85 - 34.22	10.00 - 26.87	8.86 - 14.76	1.25 - 2.10
Solanum melongena	M±S.D	2.23 ± 0.54	4.65 ± 0.82	36.47 ± 5.42	1.79 ± 0.19	2.03 ± 0.38	7.56 ± 2.05	26.42 ± 3.30	12.98 ± 1.32	1.57 ± 0.36
	Range	1.75 - 2.96	3.85 - 5.63	31.40 - 42.73	1.65 - 2.05	1.55 - 2.35	4.80 - 9.35	23.00 - 29.50	11.51 - 14.66	1.05 - 1.85
Spinacia oleracea	M±S.D	5.47 ± 1.40	2.68 ± 0.98	140.89 ± 20.77	1.67 ± 0.19	2.38 ± 0.77	34.15 ± 10.04	23.30 ± 2.73	15.81 ± 2.05	2.82 ± 1.05
	Range	3.40 - 6.50	1.54 - 3.70	123.70 - 168.44	1.40 - 1.83	1.50 - 3.20	21.95 - 45.74	19.87 - 25.50	13.55 - 18.22	1.40 - 3.84
Lycopersicum esculentum	M±S.D	2.46 ± 1.07	3.82 ± 1.08	76.02 ± 53.77	0.99 ± 0.63	2.38 ± 0.50	20.53 ± 13.77	32.26 ± 12.20	14.95 ± 3.52	2.00 ± 0.49
	Range	1.40 -3.60	2.85 - 4.80	15.95 - 123.34	0.05 - 1.38	1.80 - 2.83	6.75 - 33.47	20.50 - 43.22	10.16 - 18.45	1.34 - 2.50
Mentha spicata	M±S.D	3.25 ± 0.74	5.15 ± 1.30	118.56 ± 24.38	1.04 ± 0.84	8.17 ± 4.42	36.14 ± 5.19	29.07 ± 2.29	14.83 ± 1.86	2.59 ± 1.12
	Range	2.34 -3.95	4.18 - 7.05	86.15 -144.59	0.30 - 1.95	3.05 - 12.34	31.70 - 42.43	27.45 - 32.34	12.77 - 16.93	1.10 - 3.77
Raphanus sativus	M±S.D	3.31 ± 0.96	4.64 ± 0.93	56.45 ± 27.88	0.98 ± 0.66	3.00 ± 1.57	12.22 ± 5.62	21.44 ± 6.83	11.01 ± 3.56	1.61 ± 0.61
	Range	2.48 - 4.30	3.80 - 5.78	30.45 - 87.11	0.15 - 1.75	1.25 - 4.82	5.70 - 17.75	13.00 - 28.87	7.40 - 14.89	0.75 - 2.20
Triticum aestivum	M±S.D	1.82 ± 0.58	2.64 ± 0.73	40.26 ± 4.11	3.06 ± 1.48	5.93 ± 2.35	52.15 ± 5.22	28.07 ± 8.45	17.02 ± 5.57	0.97 ± 0.75
	Range	1.05 - 2.47	1.93 - 3.65	35.29 - 45.19	1.28 - 4.90	3.33 - 8.95	48.27 - 59.78	19.48 - 39.23	11.13 - 23.86	0.11 - 1.89

Table 3.7 Plant concentration factor (PCF) (on dry weight basis) for food crops (n=4) grown in wastewater

Species	Value	Cr	Ni	Cu	Mn	Pb	Zn	Cd
Coriandrum sativum	M±S.D	0.10 ± 0.09	0.11 ± 0.03	0.22 ± 0.17	2.09 ± 1.37	0.93 ± 0.36	0.34 ± 0.06	0.41 ± 0.05
	Range	0.03 - 0.22	0.07 - 0.14	0.01 - 0.43	0.45 - 3.51	0.57 - 1.44	0.29 - 0.43	0.37 - 0.48
Allium cepa	M±S.D	0.07 ± 0.06	0.12 ± 0.04	0.11 ± 0.02	1.23 ± 0.57	1.11 ± 0.24	0.33 ± 0.11	0.41 ± 0.02
	Range	0.01 - 0.13	0.09 - 0.17	0.08 - 0.13	0.66 - 1.93	0.91 - 1.43	0.19 - 0.45	0.38 - 0.43
Abelmoschus esculentus	M±S.D	0.09 ± 0.05	0.10 ± 0.04	0.34 ± 0.23	1.38 ± 0.84	0.96 ± 0.26	0.43 ± 0.11	0.23 ± 0.03
	Range	0.03 - 0.13	0.06 - 0.14	0.07 - 0.60	0.33 - 2.37	0.65 - 1.29	0.32 - 0.56	0.19 - 0.26
Allium sativum	M±S.D	0.06 ± 0.01	0.12 ± 0.03	0.09 ± 0.05	0.67 ± 0.30	0.84 ± 0.16	0.20 ± 0.05	0.34 ± 0.06
	Range	0.05 - 0.07	0.08 - 0.16	0.02 - 0.14	0.23 - 0.92	0.66 - 1.04	0.16 - 0.25	0.25 - 0.38
Capsicum annum	M±S.D	0.06 ± 0.05	0.11 ± 0.02	0.13 ± 0.09	1.07 ± 0.49	0.76 ± 0.20	0.32 ± 0.09	0.20 ± 0.07
	Range	0.01 - 0.12	0.09 - 0.13	0.02 - 0.21	0.35 - 1.48	0.57 - 0.95	0.21 - 0.42	0.12 - 0.27
Daucus carota	M±S.D	0.08 ± 0.06	0.10 ± 0.04	0.05 ± 0.04	1.42 ± 1.12	0.73 ± 0.08	0.27 ± 0.05	0.29 ± 0.03
	Range	0.02 - 0.13	0.07 - 0.15	0.01 - 0.10	0.42 - 2.63	0.65 - 0.84	0.24 - 0.35	0.25 - 0.31
Spinacia oleracea	M±S.D	0.14 ± 0.04	0.10 ± 0.01	0.15 ± 0.03	5.52 ± 0.55	0.61 ± 0.07	0.39 ± 0.02	0.36 ± 0.13
	Range	0.10 - 0.18	0.09 - 0.12	0.12 - 0.18	4.94 - 6.07	0.52 - 0.68	0.36 - 0.41	0.20 - 0.49
Raphanus sativus	M±S.D	0.06 ± 0.03	0.13 ± 0.05	0.06 ± 0.02	0.60 ± 0.49	0.92 ± 0.10	0.28 ± 0.17	0.28 ± 0.03
	Range	0.02 - 0.08	0.07 - 0.17	0.04 - 0.08	0.16 - 1.31	0.77 - 0.99	0.16 - 0.52	0.27 - 0.33
Mentha spicata	M±S.D	0.07 ± 0.04	0.09 ± 0.02	0.12 ± 0.01	1.51 ± 0.24	1.01 ± 0.52	0.41 ± 0.05	0.42 ± 0.06
	Range	0.04 - 0.12	0.08 - 0.11	0.11 - 0.13	1.20 - 1.78	0.55 - 1.50	0.36 - 0.48	0.34 - 0.48
Solanum melongena	M±S.D	0.06 ± 0.01	0.15 ± 0.04	0.07 ± 0.02	0.41 ± 0.03	0.86 ± 0.06	0.34 ± 0.04	0.15 ± 0.03
	Range	0.05 - 0.07	0.12 - 0.19	0.04 - 0.10	0.38 - 0.45	0.81 - 0.92	0.31 - 0.40	0.12 - 0.19
Lycopersicum esculentum	M±S.D	0.03 ± 0.02	0.11 ± 0.04	0.06 ± 0.04	0.65 ± 0.06	0.88 ± 0.06	0.45 ± 0.05	0.26 ± 0.04
	Range	0.02 - 0.05	0.08 - 0.15	0.01 - 0.10	0.58 - 0.71	0.81 - 0.93	0.38 - 0.51	0.20 - 0.30
Triticum aestivum	M±S.D	0.06 ± 0.02	0.08 ± 0.01	0.21 ± 0.12	1.57 ± 0.10	0.87 ± 0.17	0.43 ± 0.02	0.13 ± 0.03
	Range	0.04 - 0.09	0.05 - 0.09	0.07 - 0.36	1.50 - 1.73	0.61 - 1.02	0.39 - 0.45	0.11 - 0.18

Table 3.8 Plant concentration factor (PCF) (on dry weight basis) for food crops (n=4) grown on Tube well water

Species	Value	Cr	Ni	Cu	Mn	Pb	Zn	Cd
Coriandrum sativum	M±S.D	0.06 ± 0.06	0.06 ± 0.01	0.23 ± 0.21	1.43 ± 1.57	2.12 ± 0.11	0.39 ± 0.13	0.34 ± 0.14
	Range	0.01 - 0.15	0.05 - 0.07	0.00 - 0.42	0.19 - 3.71	2.00 - 2.26	0.32 - 0.58	0.16 - 0.46
Allium cepa	M±S.D	0.02 ± 0.01	0.08 ± 0.03	0.13 ± 0.10	0.74 ± 0.49	1.81 ± 0.75	0.27 ± 0.06	0.41 ± 0.14
	Range	0.00 - 0.03	0.05 - 0.11	0.00 - 0.26	0.25 - 1.42	1.29 - 2.90	0.20 - 0.34	0.21 - 0.53
Abelmoschus esculentus	M±S.D	0.06 ± 0.02	0.09 ± 0.04	0.28 ± 0.34	1.12 ± 0.73	1.56 ± 0.13	0.47 ± 0.20	0.23 ± 0.09
	Range	0.03 - 0.08	0.06 - 0.14	0.04 - 0.78	0.39 - 1.98	1.40 - 1.69	0.36 - 0.78	0.11 - 0.33
Allium sativum	M±S.D	0.05 ± 0.04	0.07 ± 0.03	0.11 ± 0.10	0.48 ± 0.16	1.49 ± 0.26	0.22 ± 0.03	0.40 ± 0.18
	Range	0.01 - 0.10	0.03 - 0.10	0.02 - 0.23	0.32 - 0.69	1.22 - 1.85	0.18 - 0.25	0.19 - 0.62
Capsicum annum	M±S.D	0.04 ± 0.03	0.08 ± 0.02	0.15 ± 0.17	0.60 ± 0.20	1.20 ± 0.60	0.22 ± 0.05	0.37 ± 0.23
	Range	0.00 - 0.07	0.05 - 0.09	0.01 - 0.39	0.38 - 0.85	0.74 - 2.07	0.14 - 0.26	0.12 - 0.67
Daucus carota	M±S.D	0.06 ± 0.04	0.06 ± 0.02	0.03 ± 0.04	0.57 ± 0.39	1.33 ± 0.11	0.23 ± 0.04	0.22 ± 0.13
	Range	0.02 - 0.11	0.04 - 0.09	0.00 - 0.09	0.26 - 1.14	1.18 - 1.45	0.18 - 0.26	0.04 - 0.33
Spinacia oleracea	M±S.D	0.02 ± 0.01	0.04 ± 0.01	0.10 ± 0.04	1.4± 0.15	1.38 ± 0.39	0.29 ± 0.04	0.23 ± 0.05
	Range	0.01 - 0.03	0.04 - 0.05	0.06 - 0.14	1.23 – 1.58	0.91 - 1.80	0.24 - 0.34	0.17 - 0.29
Raphanus sativus	M±S.D	0.06 ± 0.04	0.05 ± 0.03	0.08 ± 0.04	0.58 ± 0.49	1.70 ± 0.30	0.34 ± 0.19	0.29 ± 0.09
	Range	0.02 - 0.10	0.00 - 0.08	0.04 - 0.14	0.20 - 1.30	1.45 - 2.12	0.17 - 0.61	0.19 - 0.40
Mentha spicata	M±S.D	0.08 ± 0.07	0.09 ± 0.02	0.34 ± 0.27	2.94 ± 0.52	3.29 ± 0.63	0.44 ± 0.09	0.28 ± 0.16
	Range	0.02 - 0.18	0.06 - 0.10	0.15 - 0.73	2.20 - 3.43	2.66 - 3.96	0.34 - 0.54	0.12 - 0.50
Solanum melongena	M±S.D	0.06 ± 0.01	0.06 ± 0.00	0.09 ± 0.03	0.43 ± 0.08	1.52 ± 0.24	0.14 ± 0.02	0.19 ± 0.07
	Range	0.05 - 0.06	0.06 - 0.06	0.05 - 0.13	0.32 - 0.52	1.23 - 1.80	0.12 - 0.16	0.09 - 0.26
Lycopersicum esculentum	M±S.D	0.04 ± 0.02	0.05 ± 0.02	0.09 ± 0.06	0.63 ± 0.05	1.41 ± 0.19	0.33 ± 0.07	0.28 ± 0.05
	Range	0.01 - 0.06	0.03 - 0.06	0.01 - 0.14	0.58 - 0.70	1.17 - 1.60	0.25 - 0.42	0.22 - 0.34
Triticum aestivum	M±S.D	0.06 ± 0.04	0.05 ± 0.03	0.24 ± 0.21	1.18 ± 1.16	1.48 ± 0.42	0.46 ± 0.08	0.14 ± 0.08
	Range	0.03 - 0.11	0.01 - 0.07	0.04 - 0.48	0.18 - 2.57	1.13 - 2.07	0.37 - 0.53	0.06 - 0.24

Table 3.9 Daily intake of metals (mg) for individual heavy metal in food crops irrigated with tube well water

Metals	Cr	Ni	Cu	Mn	Pb	Zn	Cd
Coriandrum sativum	0.0013	0.0014	0.0011	0.0228	0.0218	0.0096	0.0008
Allium cepa	0.0004	0.0019	0.0006	0.0119	0.0186	0.0067	0.0010
Abelmoschus esculentus	0.0011	0.0022	0.0013	0.0180	0.0161	0.0117	0.0005
Allium sativum	0.0011	0.0018	0.0005	0.0077	0.0154	0.0054	0.0009
Capsicum annum	0.0008	0.0019	0.0007	0.0097	0.0123	0.0054	0.0009
Daucus carota	0.0012	0.0016	0.0001	0.0090	0.0137	0.0057	0.0005
Spinacia oleracea	0.0004	0.0011	0.0005	0.0225	0.0142	0.0072	0.0005
Raphanus sativus	0.0012	0.0012	0.0004	0.0093	0.0175	0.0083	0.0007
Mentha spicata	0.0017	0.0022	0.0010	0.0424	0.0216	0.0108	0.0006
Solanum melongena	0.0011	0.0015	0.0004	0.0069	0.0156	0.0035	0.0005
Lycopersicum esculentum	0.0008	0.0013	0.0004	0.0101	0.0146	0.0082	0.0007
Triticum aestivum	0.0012	0.0013	0.0011	0.0189	0.0152	0.0114	0.0003

Table 3.10 Daily intake of metals (mg) for individual heavy metal in food crops irrigated with wastewater

Metals	Cr	Ni	Cu	Mn	Pb	Zn	Cd
Coriandrum sativum	0.0034	0.0036	0.0024	0.0616	0.0278	0.0126	0.0030
Allium cepa	0.0025	0.0040	0.0012	0.0361	0.0330	0.0122	0.0031
Abelmoschus esculentus	0.0033	0.0032	0.0038	0.0406	0.0285	0.0157	0.0017
Allium sativum	0.0021	0.0042	0.0010	0.0197	0.0250	0.0072	0.0025
Capsicum annum	0.0021	0.0037	0.0015	0.0314	0.0226	0.0118	0.0015
Daucus carota	0.0028	0.0035	0.0006	0.0418	0.0217	0.0100	0.0021
Spinacia oleracea	0.0049	0.0034	0.0017	0.1624	0.0181	0.0141	0.0026
Raphanus sativus	0.0022	0.0043	0.0006	0.0177	0.0275	0.0102	0.0021
Mentha spicata	0.0026	0.0031	0.0014	0.0443	0.0301	0.0150	0.0031
Solanum melongena	0.0022	0.0052	0.0008	0.0120	0.0257	0.0126	0.0011
Lycopersicum esculentum	0.0012	0.0038	0.0006	0.0191	0.0262	0.0164	0.0019
Triticum aestivum	0.0019	0.0027	0.0024	0.0461	0.0259	0.0158	0.0010

Table 3.11 Daily intake of metals (mg) for individual heavy metal in food crops irrigated with Unknown source of irrigation

Metals	Cr	Ni	Cu	Mn	Pb	Zn	Cd
Coriandrum sativum	0.0033	0.0029	0.0013	0.0246	0.0179	0.0140	0.0022
Allium cepa	0.0017	0.0027	0.0006	0.0111	0.0169	0.0098	0.0012
Abelmoschus esculentus	0.0017	0.0027	0.0017	0.0068	0.0255	0.0150	0.0015
Allium sativum	0.0018	0.0029	0.0009	0.0081	0.0173	0.0083	0.0015
Capsicum annum	0.0015	0.0028	0.0011	0.0203	0.0145	0.0115	0.0016
Daucus carota	0.0022	0.0029	0.0006	0.0187	0.0156	0.0097	0.0013
Spinacia oleracea	0.0044	0.0022	0.0013	0.0276	0.0188	0.0128	0.0023
Raphanus sativus	0.0027	0.0037	0.0008	0.0099	0.0173	0.0089	0.0013
Mentha spicata	0.0026	0.0042	0.0008	0.0292	0.0235	0.0120	0.0021
Solanum melongena	0.0018	0.0038	0.0014	0.0061	0.0213	0.0105	0.0013
Lycopersicum esculentum	0.0020	0.0031	0.0008	0.0166	0.0260	0.0121	0.0016
Triticum aestivum	0.0015	0.0021	0.0025	0.0421	0.0227	0.0137	0.0008

Table 3.12 Health Risk index for individual heavy metal from different food crops irrigated with tube well water

Metals	Cr	Ni	Cu	Mn	Pb	Zn	Cd
Coriandrum sativum	0.0009	0.0689	0.0267	0.1630	6.2309	0.0320	0.8011
Allium cepa	0.0003	0.0968	0.0152	0.0848	5.3154	0.0222	0.9685
Abelmoschus esculentus	0.0008	0.1089	0.0335	0.1284	4.5983	0.0389	0.5428
Allium sativum	0.0007	0.0904	0.0131	0.0550	4.3948	0.0182	0.9322
Capsicum annum	0.0005	0.0975	0.0179	0.0692	3.5231	0.0180	0.8616
Daucus carota	0.0008	0.0783	0.0034	0.0646	3.9024	0.0189	0.5186
Spinacia oleracea	0.0003	0.0542	0.0113	0.1606	4.0713	0.0239	0.5347
Raphanus sativus	0.0008	0.0612	0.0100	0.0664	4.9984	0.0277	0.6840
Mentha spicata	0.0011	0.1098	0.0249	0.3031	6.1779	0.0362	0.6497
Solanum melongena	0.0008	0.0730	0.0110	0.0489	4.4564	0.0117	0.4528
Lycopersicum esculentum	0.0005	0.0633	0.0107	0.0722	4.1584	0.0272	0.6639
Triticum aestivum	0.0008	0.0656	0.0280	0.1348	4.3388	0.0378	0.3269

Table 3.13 Health Risk index for individual heavy metal from different food crops irrigated with wastewater

Metals	Cr	Ni	Cu	Mn	Pb	Zn	Cd
Coriandrum sativum	0.0023	0.1787	0.0612	0.4403	7.9455	0.0419	3.0227
Allium cepa	0.0016	0.2013	0.0293	0.2576	9.4208	0.0406	3.0610
Abelmoschus esculentus	0.0022	0.1617	0.0952	0.2902	8.1369	0.0524	1.6667
Allium sativum	0.0014	0.2106	0.0243	0.1409	7.1488	0.0240	2.4799
Capsicum annum	0.0014	0.1849	0.0363	0.2246	6.4569	0.0392	1.4932
Daucus carota	0.0019	0.1733	0.0140	0.2983	6.1923	0.0334	2.1066
Spinacia oleracea	0.0033	0.1680	0.0421	1.1603	5.1686	0.0470	2.6312
Raphanus sativus	0.0015	0.2144	0.0155	0.1261	7.8556	0.0338	2.1005
Mentha spicata	0.0017	0.1569	0.0341	0.3168	8.6004	0.0501	3.0731
Solanum melongena	0.0015	0.2582	0.0190	0.0858	7.3442	0.0419	1.1279
Lycopersicum esculentum	0.0008	0.1912	0.0159	0.1361	7.4739	0.0547	1.8947
Triticum aestivum	0.0013	0.1356	0.0590	0.3295	7.4082	0.0527	0.9524

Table 3.14 Health Risk index for individual heavy metal from different food crops irrigated with unknown source

Metals	Cr	Ni	Cu	Mn	Pb	Zn	Cd
Coriandrum sativum	0.0022	0.1443	0.0326	0.1758	5.1142	0.0468	2.1530
Allium cepa	0.0011	0.1367	0.0159	0.0793	4.8225	0.0326	1.1744
Abelmoschus esculentus	0.0012	0.1359	0.0421	0.0483	7.2785	0.0501	1.4568
Allium sativum	0.0012	0.1461	0.0224	0.0577	4.9557	0.0278	1.5174
Capsicum annum	0.0010	0.1419	0.0268	0.1451	4.1509	0.0382	1.6405
Daucus carota	0.0015	0.1441	0.0161	0.1336	4.4559	0.0323	1.3499
Spinacia oleracea	0.0029	0.1082	0.0337	0.1969	5.3719	0.0425	2.2720
Raphanus sativus	0.0018	0.1873	0.0198	0.0704	4.9430	0.0296	1.2954
Mentha spicata	0.0017	0.2078	0.0209	0.2083	6.7043	0.0399	2.0904
Solanum melongena	0.0012	0.1877	0.0361	0.0436	6.0932	0.0349	1.2672
Lycopersicum esculentum	0.0013	0.1543	0.0199	0.1184	7.4399	0.0402	1.6142
Triticum aestivum	0.0010	0.1067	0.0618	0.3007	6.4731	0.0458	0.7829

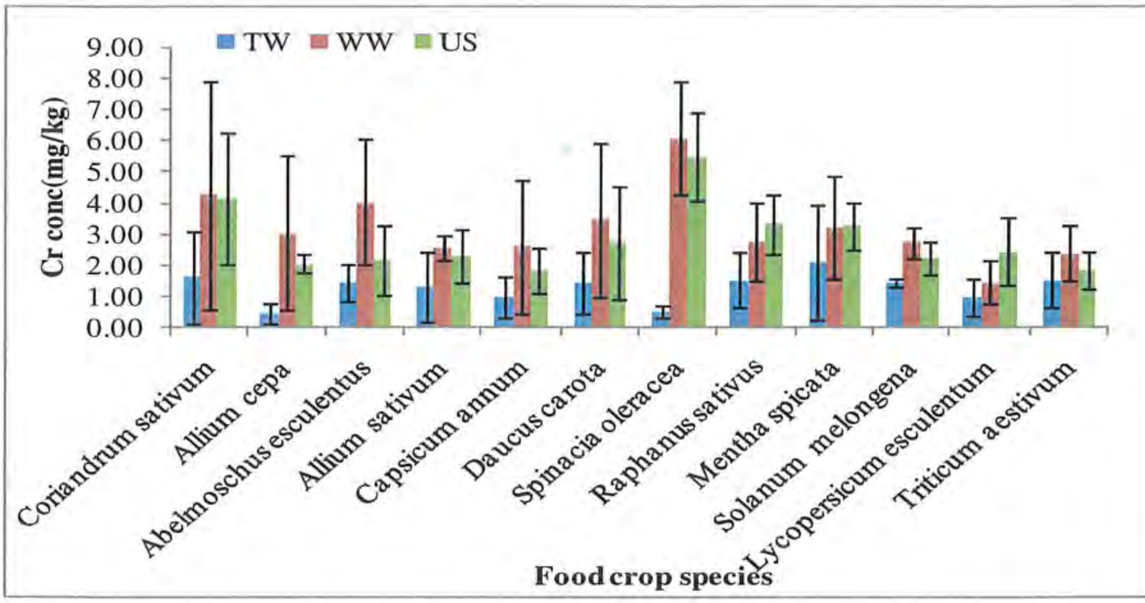

Fig. 3.2 Heavy metals concentrations in the Edible parts of Food crops grown with Tube well, Wastewater and Unknown source of irrigation for Cr. The bar indicates standard deviation of different Food crop species with their mean values.

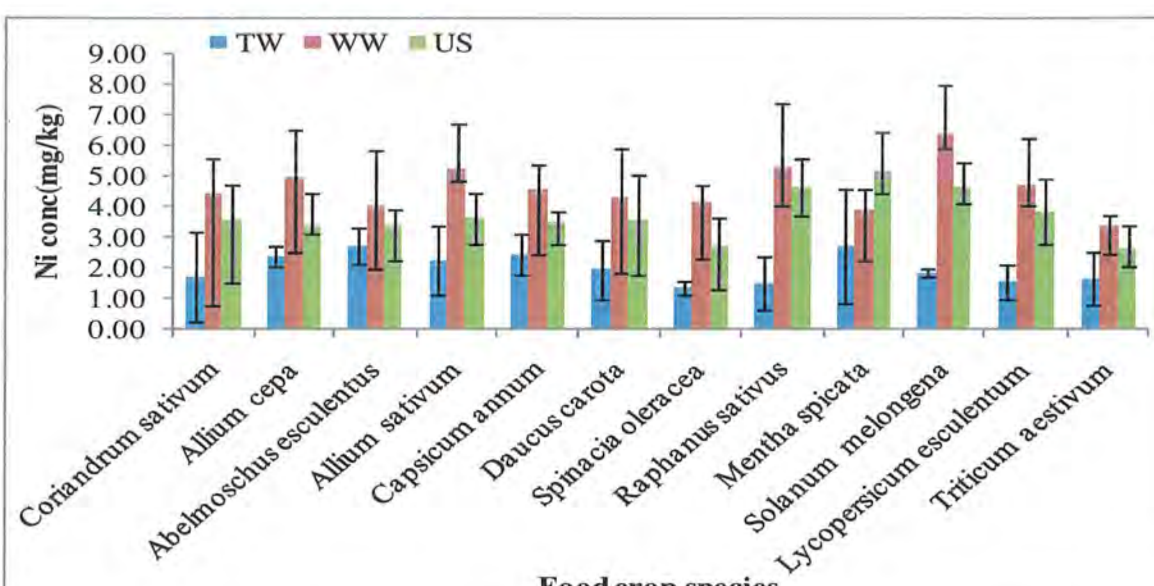

Fig. 3.3 Heavy metals concentrations in the Edible parts of Food crops grown with Tube well, Wastewater and Unknown source of irrigation for Ni. The bar indicates standard deviation of different Food crop species with their mean values.

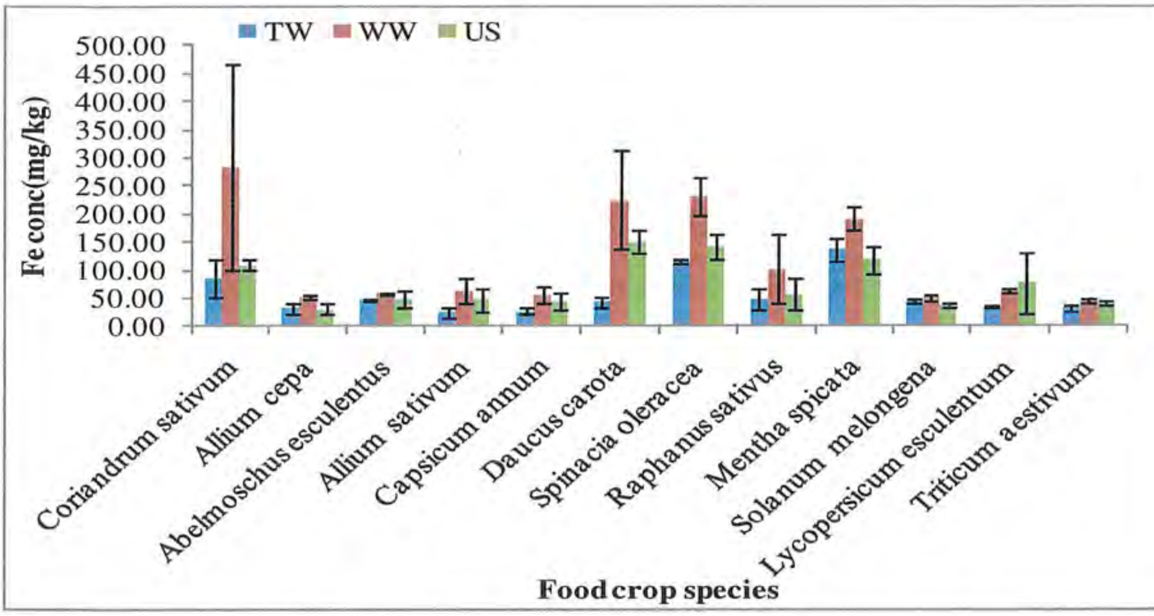

Fig. 3.4 Heavy metals concentrations in the Edible parts of Food crops grown with Tube well, Wastewater and Unknown source of irrigation for Fe. The bar indicates standard deviation of different Food crop species with their mean values.

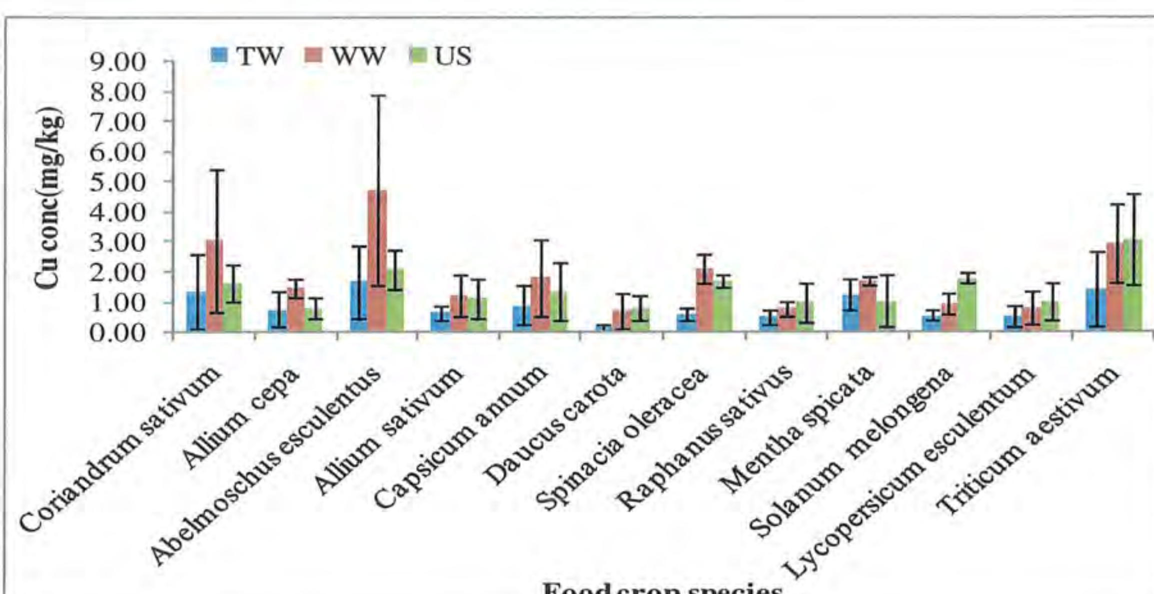

Fig. 3.5 Heavy metals concentrations in the Edible parts of Food crops grown with Tube well, Wastewater and Unknown source of irrigation for Cu. The bar indicates standard deviation of different Food crop species with their mean values.

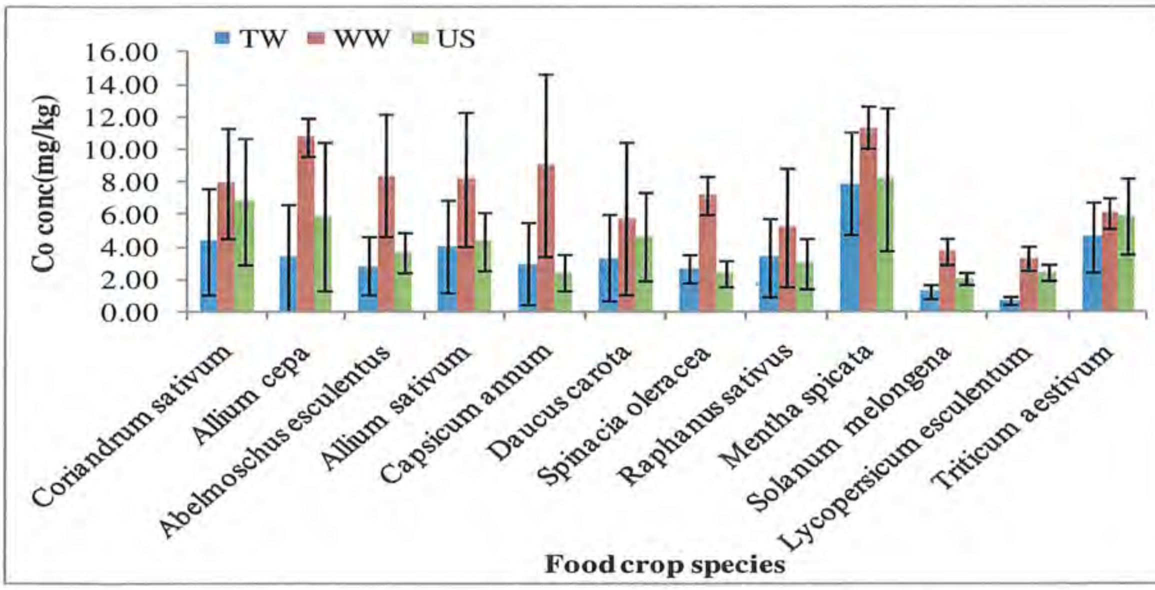

Fig. 3.6 Heavy metals concentrations in the Edible parts of Food crops grown with Tube well, Wastewater and Unknown source of irrigation for Co. The bar indicates standard deviation of different Food crop species with their mean values.

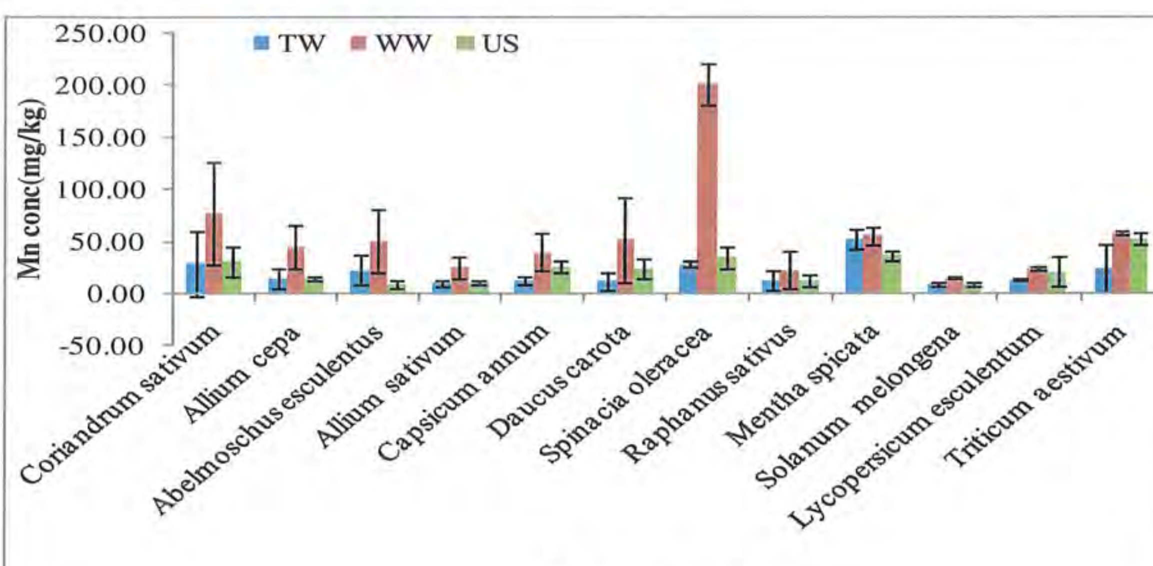

Fig. 3.7 Heavy metals concentrations in the Edible parts of Food crops grown with Tube well, Wastewater and Unknown source of irrigation for Mn. The bar indicates standard deviation of different Food crop species with their mean values.

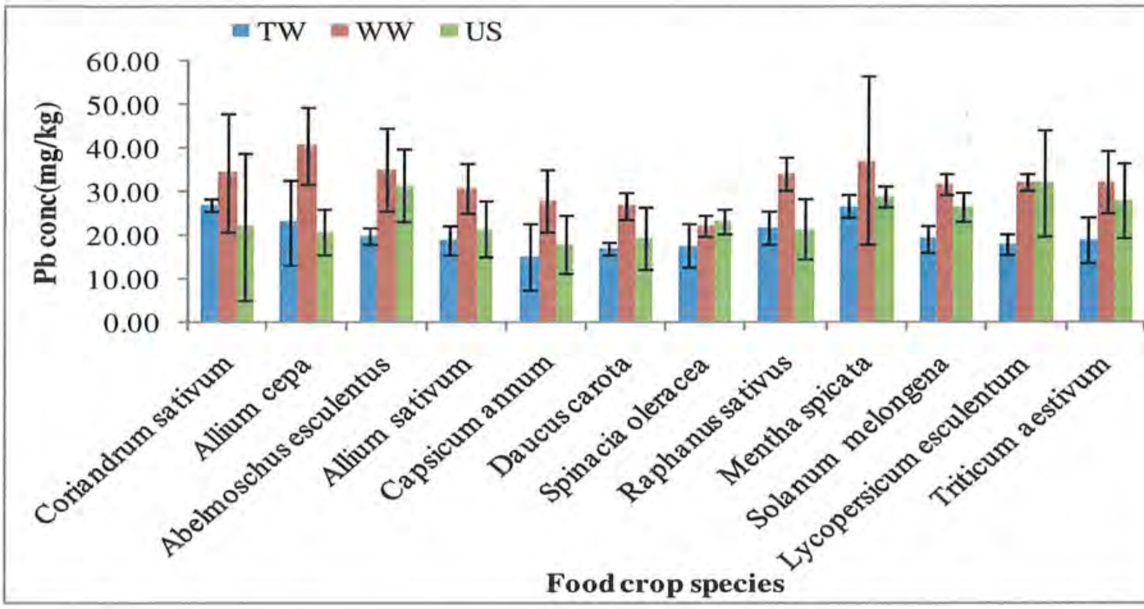

Fig. 3.8 Heavy metals concentrations in the Edible parts of Food crops grown with Tube well, Wastewater and Unknown source of irrigation for Pb. The bar indicates standard deviation of different Food crop species with their mean values.

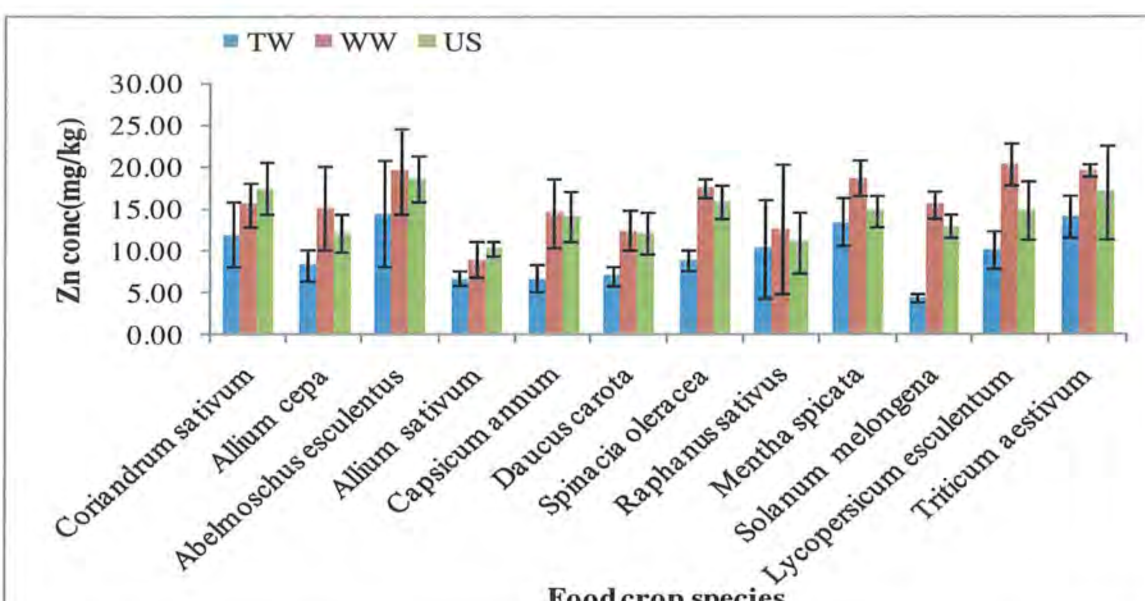

Fig. 3.9 Heavy metals concentrations in the Edible parts of Food crops grown with Tube well, Wastewater and Unknown source of irrigation for Zn. The bar indicates standard deviation of different Food crop species with their mean values.

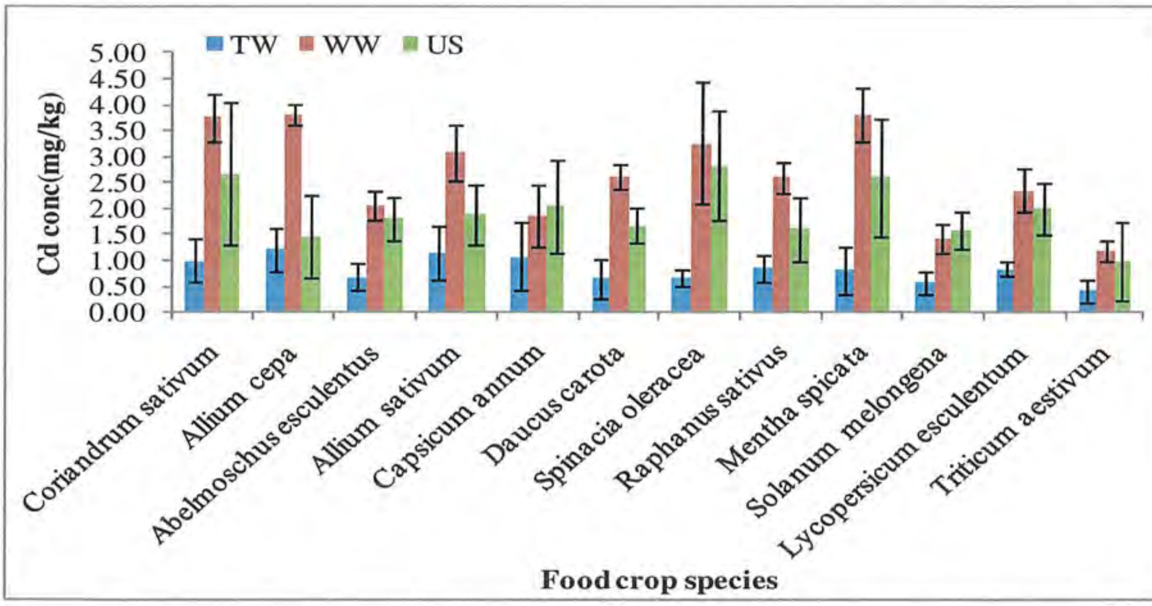

Fig. 3.10 Heavy metals concentrations in the Edible parts of Food crops grown with Tube well, Wastewater and Unknown source of irrigation for Cd. The bar indicates standard deviation of different Food crop species with their mean values.

Discussion

4.1 Heavy metals in irrigation water

Maximum permissible limits for heavy metals in water are Fe (500), Co (50) μg/ml (Koenig et al., 1990), Cd (0.01), Cu (0.20), Pb (5), Zn (2), Mn (2), Ni (2) and Cr (0.10) μg/ml (FAO, 1985). Heavy metals like Cd, Pb, Cu and Cr exceeded the permissible limit in the wastewater of Nullah Aik and Palkhu but Cd and Cr in tube well water also surpass the FAO 1985 limits. This may be due to possible leaching of these heavy metals from the soil into water table with excessive wastewater irrigation in the area. Industrial and urban wastewater is directly/in directly released into the surface water without prior treatment in the study area. Various activities electroplating, coloring, metal surface treatment, fabric printing, batteries, paints, Surgical instruments and Garages wastes disposed into the irrigation water, that further used for irrigation purposes. Beside that anthropogenic activities i.e., parental rocks materials degradation of Himalayas of Jammu and Kashmir and addition of wastes from many industries like Tanneries and cutlery industries, Domestic and municipal wastes, and different agricultural practices of Sialkot and Wazirabad contribute to pollute the water of the study area. This wastewater irrigation with passage of time enriched the agricultural soil with different toxic metals.

Higher concentrations of Cr in tube well water was due to the leathers and tanneries industry in the area. Ullah et al. (2009) also recorded such higher concentrations of Cr in the ground water of Sialkot, Gujrat and Lahore. The mean concentrations in the wastewater were 0.55 for Cd, 0.35 for Cu, 5.03 for Pb and 4.74 mg/kg for Cr, as recorded several fold higher concentrations in the present study.

In comparison to the present study, Singh et al. (2010) have reported lower values for Cd (0.02), Pb (0.09), Ni (0.06), Cu (0.056) and Cr (0.05) μg/ml in waste water of Varanasi, India, Similarly Sharma et al. (2006) also found lower concentration of Cd (0.03), Pb (0.26), Ni (0.070) and Cr (0.09) in the waste water collected from Dinapur, India. In contrast higher concentrations of Pb, Cu and Ni were recorded in treated and untreated wastewater samples from India (Gupta et al., 2007).

The present study highlights higher concentration of wastewater than tube well water. Similar results were also obtained in the study of Rattan et al. (2005); where except Fe, all trace metals showed significant values ($P< 0.05$) in wastewater than tube well water. Irrigation practices such as with wastewater may increase the concentrations of Mn, Zn, Pb, Cu, Cd and Fe in surface soils. These results are in agreement with other studies (Xiong et al., 2003; He et al., 2003a, 2004b; Zhang et al., 2005; Feng et al., 2005; yang, 2005).

4.2 Heavy metals in soil

The present study indicated that mean heavy metals concentrations were higher in soils irrigated with wastewater diverted from Aik and Palkhu streams as compared to soils irrigated with tube well water. Wastewater irrigation is a known practice in Pakistan and surface water from streams and rivers is diverted or pumped into nearby agricultural fields (Qadir et al., 2008). Surface water of Nullah Palkhu and Aik has been reported to irrigate food crops from last few decades. There is linear relationship of heavy metals accumulation in soil with irrigation time (Lucho-contantino et al., 2005). It is suspected that irrigation of agricultural soils with waste water for longer period may be one the factor responsible for contamination of heavy metals (Chary et al., 2008).

The permissible limits for metals in soil are Mn (2000), Fe (50000) and Co (50), Cd (3), Cu (140), Pb (300), Zn (300), Ni (75), Cr (150) µg/g as given by Pendias et al., 1992; Ewers, 1991; Ayers and Westcott, 1985; European Union Standards, 2002. Among all the metals, Cd concentration was calculated in the range from 7.13 to 11.13 mg/kg that exceeded than permissible limits set by European Union Standards (2002), while other metals were within safe limits. All the heavy metals except Cd were within safe range in soil irrigated with waste and tube well water and that was due to regular elimination of heavy metals by food crops and leaching activity of heavy metals into deeper zone of soil in the area (Singh et al., 2010). Easy availability, readily solubility and high exchangeable capacity of Cd in soil are the factors that favors Cd uptake into the edible parts by the plant (Luo et al., 2011). As compared to the current study, higher level of Cd (22.2-51 mg/kg) were found in wastewater irrigated soil samples collected from Titagarh, India, while lower concentrations (0.41-1.71 mg/kg) in the wastewater irrigated soils from Beijing, China (Gupta et al., 2007; Khan et al., 2008). Mapanda et al. (2005) studied lower values for Cd (3.4 µg/gm) in the wastewater irrigated soil of Harare, Zimbabwe.

Hooda et al. (1997) and Yu et al. (2006) have studied increased metals concentrations in soil. Our results were also in accordance with Singh et al. (2010) and Sharma et al. (2004) that high Cd, Pb, Zn, Ni and Cr were accumulated in the wastewater irrigated soil as compare to Clean water irrigated soil due to regular sewage irrigation practices. Besides wastewater irrigation practices, Agrochemicals and possible atmospheric deposition are also responsible for soil contamination in agricultural lands.

4.3 Heavy metals in Edible part of food crops

Soil contamination with wastewater led to an elevated level of heavy metals in the edible parts of vegetables (Khan et al., 2008 and Mapanda et al., 2007). Wastewater irrigation has the potential to characterize some physico chemical changes in the soil and also uptake of metals in food crops especially by vegetables (Khan et al., 2008).

Permissible limits for food crops are 500, 425, 67, 50 mg/kg set by FAO-WHO, 1985 for Mn, Fe, Ni and Co respectively, while for Cd (0.2), Cu (40), Pb (5), Cr (2.3) and Zn (60) mg/kg WHO/FAO 2007. All the heavy metals except Cd, Pb and Cr are within permissible limits. Heavy metals like Cd and Pb exceeded the permissible limits in all the food crops irrigated with waste, tube well and collected unknown sources. Cr also surpasses the permissible limits in most of the food crops irrigated with wastewater food crops except *Lycopersicum esculentum*. Similarly, Cr concentration was also above permissible limit in leafy vegetables (*Coriandrum sativum, Mentha spicata, Spinacia oleracea*), Root vegetables (*Daucus carota, Raphanus sativus*) and *Lycopersicum esculentum* from unknown source.

The toxic accumulation of heavy metals (Cd, Pb, Cr) in the food crops may be due to wastewater irrigation practices and possible atmospheric pollution (industrial, heavy traffic and Kiln emissions etc) and leaching of heavy metals into water table which contaminate the underground water. Other activities in current study area were agricultural practices, Animals dung's and human excreta are the possible sources of contamination in the food crops. Phosphate fertilizers are also recorded as possible heavy metals source of pollution in agricultural land due to massive application because Cd is present as impurity in phosphate rocks (Zhou et al., 1994). Most of the heavy metals are the part of the earth crust as a natural constituent. The concentration of Cd, Pb and Cr in vegetables field reached at phytotoxic level irrigated with wastewater (Hussain, 2000; Qadir et al., 2000). The food crops grown on the wastewater irrigated soil become enriched with heavy metals, posing deleterious effect to population and our study are in concurrent with previous studies findings (Liu et al., 2005; Cui et al., 2005; Bi et al., 2006; Muchuweti et al., 2006; Sharma et al., 2007; Khan et al., 2008).

Khan et al. (2008) indicated accumulation of these metals in various food crops. Gupta et al. (2007) and Singh et al. (2010) also reported greater level of Pb, Cd, Cr, Zn, Ni which exceeded permissible limits in the vegetables samples collected from Titagarh and Varanasi, India respectively. Vegetables collected from different sites of Shaoguan city, China have found also higher concentrations of Cd and Pb than the permissible limits (Zhuang et al., 2009). Our results also show similarities with other studies on behalf of their increased heavy metals in the edible parts of food crops due to long-term wastewater irrigation (Khan et al., 2007; Arora et al., 2008; Liu et al., 2005). The present study clearly indicated that all the heavy metals concentrations in the wastewater irrigated food crops were higher than tube well water irrigated food crops that brought manifold increment in different food crops which were in agreements with Arora et al. (2008) and Singh et al. (2010). Food crops grown on wastewater irrigated soil also deposited higher metals concentrations than the food crops grown on reference and control soil (Jan et al., 2010).

Majority of the food crops bought from unknown source or market in the present study revealed metals concentrations closer to the wastewater irrigated food crops as compared to those which are irrigated with tube well water. It can suspected that market food crop might have some sources of contamination either grown in contaminated soils or irrigated water. Food crops of study area are practiced with wastewater of Nullah Aik and Palkhu for recent few decades that contaminated the food chain with toxic heavy metals of the study area with their deleterious effects to population. These results are also in agreement with findings of Arora et al., 2008 for vegetables.

Leafy vegetables (*Spinacia oleracea, Mentha spicata, Coriandrum sativum*) exhibited maximum metal concentration among food crops studied. Relatively high transpiration rate, fast growth rate and large broadened area of leaf may enhanced the metals translocation in leafy vegetables (Itanna, 2002; Muchuweti et al., 2006) and these factors make them sensitive as a recipient to atmospheric pollution, dust from soil and splashing of rainwater (Luo et al., 2011; Zhuang et al., 2009).

Low concentrations in species such as *Triticum aestivum, Allium sativum, Solanum melongena and Allium cepa* were observed which may be due to the regular elimination of heavy metals by food crops or leaching of the heavy metals into deeper zone of soil (Singh et al., 2010). Morphological and physiological changes play a vital role in metals translocation, elimination, and accumulation that may be due to the variation of food crops grown on different sites (Carlton-smith and Davis, 1983; Kumar et al., 2009). Our result also in concurrent with that of Kawatra and Bakhetia (2008) that reported high heavy metals concentrations in vegetables irrigated with sewage irrigated areas as in comparison with tube well irrigated of Ludhiana city of Punjab, India. These non essential heavy metals become toxic via consumption of food crops. As the consumption rates increases, their deleterious effects may also become increases for human and the study suggesting to avoid those food crops that posing greater health risk.

4.4 Transfer factor in edible parts of Food crops

The plant concentration factor (PCF) play key role in transferring heavy metals from soil to plant for human exposure via food chain. PCF changes widely for plant species of the proposed metals (Alloway and Jackson, 1991; Cui et al., 2004). In the present study PCF for Mn, Pb were >1 in most of food crops irrigated with waste and tube well water. However, high transfer values showed greater accumulation of individual heavy metals in the food crops, especially in leafy vegetables than other metals. The high Pb concentration above permissible limits in tube well water irrigated food crops is due to the higher PCF values than Wastewater irrigated food crops. Those metals that have high transfer factor make their way to edible part easier than that of low transfer factor (Luo et al., 2011). PCF changes widely for food crops species and also with irrigation sites. In the present study decreased values of PCF in food crops were observed as the metals concentrations in soil increased, showing an inverse association among transfer factor and total metals concentrations. Such inverse relationships are correlated with findings of Wang et al. (2006) and Khan et al. (2008) for vegetables. PCF were lower for wastewater irrigated food crops as compared to tube well water irrigated food crops (in case of Pb and Cu except *Daucus* *carota* and *Spinacia oleracea*) and also in Cd, Zn, Cr for some food crops species, while for other metals and food crops not so and is indication of food crops not to increase linearly with their elevated concentrations in metals and also in agreement with Hooda et al. (1997), where they recorded low transfer factor in case of Zn and Fe for wastewater irrigated food crops than tube well water irrigated food crops. Singh et al. (2010) reported high PCF for all metals except Cu in wastewater irrigated site as compared to control site and our study also show such trends for PCF for some metals and food crops mentioned above.

4.5 Daily intake of metals and Human health risk assessment

It is of prime importance to locate the exposure pathways of any pollutant to the organism for the quantification of their health risk. In spite of other routes, food chain is one of the key pathways to human exposure. Several exposure pathways for individual metals are responsible due to their contaminated sources of air, water, soil, food and the consuming population (Caussy et al., 2003). Food is the key pathway for several metals to the population consuming local food crops grown on wastewater and contaminated soil.

Food crops produced in the present study may consume directly by the local inhabitants or sold to the market for dispersed population consumption. Some of the leafy vegetables (*Spinacia oleracea, Coriandrum sativum, Mentha spicata*) and *Capsicum annum*, *Lycopersicum esculentum*, *Daucus carota*, *Raphanus sativus*, *Allium cepa* are used as salad and pose greater health risk as compared to vegetables cooked. Studied food crops are consumed daily in their meals by the local population as a Salad and/or as in cooked form. Among the studied food crops, *Triticum aestivum* is used as cereal crop consumed in higher proportion as compared to other vegetables.

Reference oral dose (RfD) is the daily exposure of any toxic or pollutant to the population that pose no appreciable risk of hazardous effect in their lifetime (US-EPA, IRIS). Oral reference doses (RfD) estimation for different deleterious metals Cd, Cr, Cu, Ni, Pb, Zn and Mn are $1E^{-03}$, $1.5E^{-0}$, $4E^{-2}$, $2E^{-2,}$ $3.5E^{-3}$, $0.3E^{-0}$, $1.4E^{-1}$ mg/kg/day respectively (US-EPA, IRIS). Studied heavy metals except Cd, Pb and Mn have HR<1 showing that these metals are health risk causative in different food crops. Cd showing HRI>1 in all the wastewater and unknown irrigated food crops except *Triticum aestivum*, while tube well water irrigated food crops were free of risk

(HRI<1). The highest HRI values >1 was exhibited by Pb in all the food crops irrigated with waste, tube well and unknown sources, while Mn revealed HRI>1 only in *Spinacia oleracea* when irrigated with wastewater and the others waste, tube well and unknown water irrigated food crops were free of risk posing no health risk to the population. However Cd and Pb in view of as the non essential metal contributing their hazardous health effect at extreme low concentrations (Ikeda et al., 2000).

In comparison to the current study Zhuang et al. (2009) and Singh et al. (2010) also reported HRI for Cd and Pb above the permissible limits in vegetables and cereals. Our study revealed HRI>1 for Mn that was observed only in *Spinacia oleracea*. Jan et al. (2010) also reported HRI>1 for Mn in *Spinacia oleracea* and other vegetables grown on wastewater irrigated soil. Khan et al. (2010) recoded HRI>1 for Pb in all the selected vegetables of gilgit, Pakistan, while Cd, Cu, Ni and Zn showed HRI<1 experiences no health risk to the consuming population except Cd.

The present study gains significance in-term of health perspective posing risk to the human population from the toxic metals like Pb, Cd and Mn via studied food crops consumption.

Conclusion

Wastewater irrigation practices significantly builds-up heavy metals accumulation in all the samples of soils and food crops as compared to the tube well water irrigated soil and food crops but besides wastewater irrigation practices atmospheric pollution for metals in food crops also problematic for human population. Consumption of these food crops contaminated with heavy metals is a major route via food chain and important pathway for human exposure. The mean concentrations of Cd in waste and tube well water irrigated soil and for Cd and Cr in both waste and tube well water and for Pb and Cu in wastewater and also in edible parts of food crops for Pb, Cd and Cr crossed the permissible limits. High HRI>1 for all the food crops were recorded for Pb in waste, tube well and unknown irrigation practices and for Cd in all the vegetables samples of waste and unknown irrigation sources, while HRI>1 for Mn in Spinacia oleracea irrigated with wastewater. The PCF values >1 for Mn, Pb were found in the order of Mn>Pb>Cd. This study will strengthen our awareness about those species which accumulate high toxic chemicals or metals and also about management plan strategies for abatement of future heavy metals pollution in food crops that led to chronically health risk to the exposing population.

References

Al-Qurainy, F., and Abdel-Megeed, A., 2009. Phytoremediation and Detoxification of Two Organophosphorous Pesticides Residues in Riyadh Area. World App. Sci. J. 6(7): 987-998.

Abbas, S. T., Sarfaraz, M., Mehdi, S. M., Hassan, G., and Rehman, O. U., 2007. Trace elements accumulation in soil and rice plants irrigated with the contaminated water. Soil Tillage Res. 94: 503–509.

Abdollatif, G. A., Ardalan, M., Mohammadi, M. T., Hosseini, H. M., and Karimian, N., 2009. Solubility Test in Some Phosphate Rocks and their Potential for Direct Application in Soil. World App. Sci. J. 6(2): 182-190.

Adriano, D. C., 2000. Trace Elements in Terrestrial Environments: Biogeochemistry, Bioavailability and Risks of Metals, 2nd ed., Springer Verilog.

Alloway, B. J., and Jackson, A. P., 1991. The behaviour of heavy metals in sewage sludge-amended soils. Sci Total Environ. 100: 151–76.

APHA., 1998. Standard methods for the examination of water and waste water, 20th ed., American Public Health Association, Washington DC, USA.

Arain, M. B., Kazi, T. G., Baig, J. A., Jamali, M. K., Afridi, H. I., Shah, A. Q., Jalbani, N., and Sarfraz, R. A., 2009. Determination of arsenic levels in lake water, sediment, and foodstuff from selected area of Sindh, Pakistan: Estimation of daily dietary intake. Food Chem Toxicol. 47: 242–248.

Arora, M., Kiran, B., Rani, S., Rani, A., Barinder, K., and Neeraj, M., 2008. Heavy metal accumulation in vegetables irrigated with water from different sources. Food Chem. 111: 811–815.

Ayers, R.S., and Westcott, D.W., 1985. Water Quality of Agriculture. FAO Irrigation and Drainage Paper. 29, Rome, 174.

AATSE (Australian Academy of Technological Sciences and Engineering)., 2004. Water Recycling in Australia. AATSE, Victoria, Australia.

Barman, S. C., Sahu, R. K., Bhargava, S. K., and Chatterjee, C., 2000. Distribution of heavy metals in wheat, mustard, and weed grown in fields irrigated with industrial effluents. Bull Environ. Contam. Toxicol. 64: 489–496.

Bhogal, A., Nicholson, F. A., and Chambers, B. J., 2003. Effects of past sewage sludge additions on heavy metal availability in light textured soils: implications for crop yields and metal uptake. Environ. Pollut. 121: 413–423.

Bi, X., Feng, X., Yang, Y., Qiu, G., Li, G., Li, F., Liu, T., Fu, Z., and Jin, Z., 2006. Environmental contamination of heavy metals from zinc smelting areas in Hezhang County, western Guizhou, China. Environ. Int. 32: 883-890.

Carlton-Smith, C. H., and Davis, R. D., 1983. Comparative uptake of heavy metals by forage crops grown on sludge-treated soils. In: Proceeding of International Conference on Heavy metals in the Environment. CEP Consultants Ltd., Edinburg, UK. 3933–3940.

Caussy, D., Gochfeld, M., and Gurzan, E., 2003. Lessons from case studies of metals investigating exposure, bioavailability and risk. Ecotoxicol. Environ. Saf. 56: 45–51.

Chandra, R., Bharagava, R. N., Yadav, S., and Mohan, D., 2009. Accumulation and distribution of toxic metals in wheat (Triticum aestivum L.) and Indian mustard (Brassica campestris L.) irrigated with distillery and tannery effluents. J. Hazard. Mater. 162 : 1514–1521.

Chary, N. S., Kamala, C. T., and Raj, D. S. S., 2008. Assessing risk of heavy metals from consuming food grown on sewage irrigated soils and food chain transfer. Ecotoxicol. Environ. Saf. 69: 513–524.

Chojnacka, K., Chojnacki, A., Go' recka, H., and Go' recki, H., 2005. Bioavailability of heavy metals from polluted soils to plants. Sci. Total Environ. 337: 175– 182.

Coen, N., Mothersill, C., and Kadhim, M., 2001. Heavy metals of relevance to human health induce genomic instability. J Pathol. 195(3): 293–9.

Cui, Y. J., Zhu, Y. G., Zhai, R. H., Chen, D. Y., Huang, Y. Z., and Qui, Y., 2004a. Transfer of metals from soil to vegetables in an area near a smelter in Nanning, China. Environ Int. 30(6): 785– 91.

Cui, Y. J., Zhu, Y. G., Zhai, R., Huang, Y., Qiu, Y., and Liang, J., 2005b. Exposure to metal mixtures and human health impacts in a contaminated area in Nanning, China. Environ. Int. 31: 784-790.

Date, 4-10-211: http:// www . phsadc. Org / index. p

Dawn Daily., 2006. No step taken to check tanneries pollution (p. 12). March 26. Published from Karachi, Pakistan.

De Carlo, E. H., Beltran, V. L., and Tomlinson, M. S., 2004. Composition of water and suspended sediment in streams of urbanized subtropical watersheds in Hawaii. Appl Geochem. 19: 1011 - 1037.

De Miguel, E., Jimenez de, G. M., Liamas, J. F., and Martı'n-Dorado, A., 1998. The overlooked contribution of compost application to the trace element. load in the urban soil of Madrid (Spain). Sci. Total Environ. 215: 113–22.

Dong, X., Li, C., Ji, L., Jiaxin, W., Liu, S., and Ye, B., 2010. A novel approach for soil contamination assessment from heavy metal pollution: A linkage between discharge and adsorption. J. Hazard. Mater. 175: 1022–1030.

Dyer, C. A., 2007. Heavy metals as endocrine disrupting chemicals. In: Gore AC, editor. Endocrine-Disrupting Chemicals: From Basic Research to Clinical Practice. Totowa, Humana Press. 111–33.

Ensink, H. H., Mehmood, T., Vand der Hoeck, W., Raschid-Sally, L., and Amerasinghe, F. P., 2004. A nation-wide assessment of wastewater use in Pakistan: an obscure activity or a vitally important one? Water Policy 6: 197–206.

ETPI., 1998. The leather sector: Environmental report, Environmental Technology Programme for Industry (ETPI), Federation of Pakistan Chamber of Pakistan. Available on http://www. cpp. org. pk/ etpirpt/ LeatherSectorReport. Pdf

European Union., 2002. Heavy Metals in Wastes, European Commission on Environment [http: //ec. e uropa. eu/environment/waste/studies/pdf/heavy metals report. pdf.

Ewers, U., 1991. Standards, guidelines and legislative regulations concerning metals and their compounds. In: Merian E, ed. Metals and Their Compounds in the Environment: Occurrence, Analysis and Biological Relevance. Weinheim: VCH. 458-468.

FAO., 1985. Water Quality for Agriculture. Paper No. 29 (Rev. 1) UNESCO, Publication, Rome. Ge, K. Y. 1992. The Status of Nutrient and Meal of Chinese in the 1990s. Beijing People's Hygiene Press.

FAO/SIDA., 1983. Manual of methods in aquatic environment research. Part 9. Analysis of metals and organochlorine in fish. FAO Fish Technical Paper 212. (FAO, Rome) Section 2. 30–61.

Feng, W. H., and Miao, C. F., 2005. The research of web pages information extraction based on Web. J Luoyang Tech College. 15(3): 16-18.

Food and Agriculture Organization of the United Nations (FAO)., 2002. Investment in Land and Water. In Proceedings of the regional consultation Bangkok, Thailand 3-5

October, 2001. Publication 2002/09. FAO Regional Office for Asia and the Pacific, Bangkok.

Garrido, S., Delcampo, G. M., Esteller, M. V., Vaca, R., and Lugo, J., 2005. Heavy metals in soil treated with sewage sludge composting, their effect on yield and uptake of broad bean seeds (Vicia faba L.). Water Air Soil Pollut. 166: 303–319.

Glover-Kerkvilet., 1995. J. Environmental assault on immunity. Environ. Health Perspect. 103: 236–237.

Gholizadeh, A., Ardalan, A. M., Mohammadi, M.T., Hosseini, H.M., and Karimian, N., 2009. Solubility Test in Some Phosphate Rocks and their Potential for Direct Application in Soil. World App. Sci. J. 6(2): 182-190.

Gupta, N., Khan, D. K., and Sandra, S. C., 2007. An Assessment of Heavy Metal Contamination in Vegetables Grown in Wastewater-Irrigated Areas of Titagarh, West Bengal, India. Bulletin of Environ. Cont. Toxicol.

Hamilton, A. J., Stagnitti, F., Xiong, X., Kreidil, S. L., Benke, K. K., and Maher, P., 2007. Wastewater irrigation: the state of play. VZJ. 6: 823–840.

Glover-Kerkvliet, j., 1995. Environmental Assault on Immunity, *Environmental Health Perspectives*. 103: 236 –237.

He, J., Li, C. S., and Wang, J. W., 2003a. An experimental study of adsorption and transportations on CdB of the Yellow River sediment. J Agri- Environment Sci. 22 (2): 134-137.

He, J., Mi, N., Kuang, Y. C., 2004b. Study on the adsorption characteristics of REE on the Yellow River sediment. Acta Sci. Circumst. 24(4): 607-672.

Hooda, P. S., McNulty, D., and Alloway, B. J., 1997. Plant availability of heavy metals in soils previously amended with heavy applications of sewage sludge. J Sci Food Agric. 73: 446-454.

Hu, K. L., Zhang, F. R., and Yizhong, L. B., 2004. Spatial distribution of concentrations of soil heavy metals in Daxing County, Beijing. Acta Sci. Circumst. 24(3): 464-469.

Hussain, A., Murtaza, G., Ghafoor, A., Basra, S. M. A., Qadir, M., and Sabir, M., 2010. Cadmium Contamination of Soils and Crops by Long Term Use of Raw Effluent, Ground and Canal Waters in Agricultural Lands. Int. J. Agric. Biol. 12(6): 851–856.

Hussain, S. I., 2000. Irrigation of crops with sewage effluent: Implications and movement of lead and chromium as affected by soil texture, lime gypsum and organic matter. Ph. D. Thesis, Dept. Soil Sci., Univ. Agri., Faisalabad, Pakistan.

Hussain, S. I., Ghafoor, A., Ahmad, S., Murtaza, G. and Sabir, M. 2006. Irrigation of crops with raw sewage: hazard and assessment in effluent, soil and vegetables. Pak. J. Agric. Sci. 43(3–4): 97–101.

Itanna, F., 2002. Metals in leafy vegetables grown in Addis Ababa and toxicological implications. Ethiopian. J. Health Dev. 6: 295-302.

Ikeda, M., Zhang, Z. W., Shimbo, S., Watanabe, T., Nakatsuka, H., Moon, C. S., Matsuda-nInoguchi, N., and Higashikawa, K., 2000. Urban population exposure to lead and cadmium in east and south-east Asia. Sci. Total Environ. 249: 373–384.

Jan, F. A., Ishaq, M., Khan, S., Ihsanullah, I., Ahmad, I., and Shakirullah, M., 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.

Jarup, L., 2003. Hazards of heavy metal contamination. Br. Med. Bull. 68: 167–182.

Kabata-Pendias, A., Mukherjee, A. B., 2007. Trace elements from soil to human. NewYork: Springer-Verlag.

Kalavrouziotis, I. K., Robolas, P., Koukoulakis, P. H., and Papadopoulos, A. H., 2008. Effects of municipal reclaimed wastewater on the macro- and micro-elements status of soil and of Brassica oleracea var. Italica, and B. oleracea var. Gemmifera. Agric. Water Manage. 95: 419-426.

Kawatra, B. L., and Bakhetia, P., 2008. Consumption of heavy metal and minerals by adult women through food in sewage and tube well irrigated area around Ludhiana city (Punjab, India). J. Human Ecol. 23(4): 351–354.

Khairiah, T., Zalifah, M. K., Yin, Y. H., and Aminah, A., 2004. The uptake of heavy metals by fruit type vegetables grown in selected agricultural areas. Pak. J. Biol. Sci. 7(8): 1438–1442.

Khan, M. J., Bhatti, A. U., Hussain, S., and Wasiullah., 2007. Heavy metal contamination of soil and vegetables with industrial effluents from sugar mills and tanneries. Soil Environ. 26(2): 139–145.

Khan, S., Cao Q., Zheng Y. M., Huang Y. Z., and Zhu Y. G., 2008. Health risks of heavy metals in contaminated soils and food crops irrigated with wastewater in Beijing, China. Environ. Int. 152: 686-692.

Khan, S., Cao, Q., Zheng, Y. M., Huang, Y. Z., and Zhu, Y. G., 2007. Health risks of heavy metals in contaminated soils and food crops irrigated with wastewater in Beijing, China. Environ. Int. 1–7.

Krogmann, U., Boyles, L. S., Bamka, W. J., Chaiprapat, S., and Martel, C. J., 1999. Biosolids and sludge management. Water Environ. Res. 71: 692–714.

Kumar, A., Sharma, I. K., Sharma, A., Varshney, S., and Verma, P. S., 2009. Heavy metals contamination of vegetable foodstuffs in Jaipur (India). Electron. J. Environ. Agri. Food Chem. 8(2): 96–101.

Kumar, P., and Chandra, R., 2004. Detoxification of distillery effluent through Bacillus thuringiensis (MTCC 4714) enhanced phytoremediation potential of Spirodela polyrrhiza L. Schliden. Bull. Environ. Contam. Toxicol. 73: 903–910.

Lacatusu, R., Rauta, C., and Carstea, S., 1996. Soil-plant-man relationships in heavy metal polluted areas in Romania. Appl Geochem. 11: 105-107.

Lamy, I., Van Oort F., Dere C., and Baize, D., 2006. Use of major and trace element correlations to assess metal migration in sandy luvisols irrigated with wastewater. European J. Soil Sci. 57: 731–740.

Lavado, R. S., 2006. Effects of sewage sludge application on soils and sunflower yield: quality and toxic element accumulation. J. Plant Nutr. 29: 975–984.

Li, Y., Gou, X., and Wang, G., 2006. Heavy metal concentrations and comlations in rain-fed fmn soils of Sifangwu village, central Gansu Province, China. Land Degrad Develop. 17: 1-12.

Loutfy, N., Fuerhacker, M., Tundo, P., Raccanelli, S., Dien, A. G., and Ahmed, M. T., 2006. Dietary intake of dioxins and dioxin-like PCBs, due to the consumption of dairy products, fish/seafood and meat from Ismailia city, Egypt. Sci Total Environ. 2006; 370:1–8.

Liu, W. H., Zhao, J. Z., Ouyang, Z. Y., Soderlund, L., and Liu, G. H., 2005. Impacts of sewage irrigation on heavy metals distribution and contamination in Beijing, China. Environ. Int. 31: 805-812.

Lucho-Contantino, C. A., Alvarez-Sua'rez, M., Beltra'n-Herna'dez, R. I., Prieto- Garcia, F., and Poggi-Varaldo, H. M., 2005. A multivariate analysis of the accumulation and fractionation of major and trace elements in agricultural soils in Hidalgo State, Mexico irrigated with wastewater. Environ. Int. 31: 313-323.

Luo, C., Liu, C., Wang, Y., Liu, X., Li, F., Gan Zhang, G., and Li, X., 2011. Heavy metal contamination in soils and vegetables near an e-waste processing site, south China. J. Hazard. Mater. 186: 481–490.

Madrid, L., Dı´az-Barrientos, E., and Madrid, F., 2002. Distribution of heavy metals contents of urban soils in parks of Seville. Chemosphere. 49: 1301– 8.

Malik, R. N., and Zeb, N., 2009. Assessment of environmental contamination using feathers of *Bubulcus ibis* L., as a biomonitor of heavy metal pollution, *Pakistan. Ecotoxicology. 18*: 522–536. doi: 10.1007/s10646-009-0310-9.

Malik, R. N., Sidra, R.A., M., Syed-Ali-Musstjab-Akber, S. E., and Karam, A., 2011. Organochlorine residual concentrations in cattle egret from the Punjab Province, Pakistan. Environ Monit Assess. 173: 325–341. Doi: 10.1007/s10661-010-1390-y

Mapanda, F., Mangwayana, E. N., Nyamangara, J., and Giller, K. E., 2007. Uptake of heavy metals by vegetables irrigated using wastewater and the subsequent risks in Harare, Zimbabwe. Phys. Chem. Earth. 32: 1399–1405.

Marshall, F. M., Holden, J., Ghose, C., Chisala, B., Kapungwe, E., Volk, J., Agrawal, M. R., Sharma, R. K., and Singh, R. P., 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. University of Sussex. www. Pollution and food.

McCluggage, D., 1991. Heavy Metal Poisoning, NCS Magazine. The Bird Hospital, CO, USA. [www. cockatiels. org/articles/Diseases/metals. html.

Mello, D. J. P. F., 2003. Food safety: Contaminants and Toxins. CABI Publishing, Wallingford, Oxon, UK, Cambridge, MA. 480.

Mielke, H. W., Gonzales, C. R., Smith, M. K., and Mielke, P. W., 1999. The urban environment and children health: soils as an integrator of lead, zinc and cadmium in New Orleans, Louisiana, USA. Environ Res. 81: 117–29.

Muchuweti, M., Birkett, J. W., Chinyanga, E., Zvauya, R., Scrimshaw, M. D., and Lester, J. N., 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.

Murtaza, G., Ghafoor, A., and Qadir, M. J., 2008. Accumulation and implications of cadmium, cobalt and manganese in soils and vegetables irrigated with city effluent. J. Sci. Food Agric. 88(1): 100–107.

Mushtakova, V. M., Fomina, V. A., and Rogovin, V. V., 2005. Toxic effect of heavy metals on human blood neutrophils. Biol Bull. 32(3): 276–8.

Myers, G. J., Davidson, P. W., Weitzman, M., 1997. Contribution of heavy metals to developmental disabilities in children. Ment Retard Dev Disabil Res Rev. 3(3): 239–45.

Oliver, M. A., 1997. Soil and human health: A review. Eur. J. Soil Sci. 48: 573–592.

Pendias, A. K., and Pendias, H., 1992. Elements of Group VIII. In: Trace Elements in Soils and Plants. Boca Raton: CRC Press. 271-276.

Ping, L., Hai-jun, Z., Li-li, W., Zhao-hui, L., Lin, J. W., Yan-qin, W., Li-hua, J., Liang, D., and Yu-feng, Z., 2011. Analysis of Heavy Metal Sources for Vegetable Soils from Shandong Province, China. Agricultural Sciences in China. 10(1): 109 119.

Qadir, A., Malik, R. N., and Husain, S. Z., 2008. Spatio-temporal variations in water quality of Nullah Aik-tributary of the river Chenab, Pakistan. Environ. Monit. Assess. 140: 43–59.

Qadir, M., Ghafoor, A., and Murtaza, G., 2000. Cadmium concentration in vegetables grown on urban soils irrigated with untreated municipal sewage. Environ. Dev. Sustain. 2(1): 11–19.

Radwan, M. A., Salama, A. K., 2006. Market basket survey for some heavy metals in Egyptian fruits and vegetables. Food Chem Toxicol. 44: 1273-1278.

Rai, P. K., and Tripathi, B. D., 2008. Heavy metals in industrial wastewater, soil and vegetables in Lohta village, India. Toxicol. Environ. Chem. 90(2): 247–257.

Randhawa, H. A., 2002. Water development for irrigated agriculture in Pakistan: past trends, returns and future requirements. Investment in Land and Water. Proceedings of the Regional Consultation, Bangkok, Thailand organized by Food and Agriculture Organization of the United Nations.

Rattan, R. K., Datta, S. P., Chhonkar, P. K., Suribabu, K., and Singh, A. K., 2005. Long-term impact of irrigation with sewage effluents on heavy metal content in soils, crops and groundwater—a case study. Agriculture, Ecosyst. Environ. 109: 310–322.

Rattan, R. K., Dutta, S. P., Chandra, S., and Saharaan N., 2002. Heavy metals in environments-Indian scenario. Fertil News. 47: 21–40.

Salmasi, R., and Tavassoli, A., 2006. Pollution of south of Tehran ground waters with heavy metals. Int. J. Environ. Sci. Technol. 3: 147–152.

Sarfaraz, M., Mehdi, S. M., Hassan, G., and Abbas, S. T., 2007. Metal Contamination in Nullah Dek Water and Accumulation in Rice. Pedosphere. 17(1): 130-136.

Sathawara, N. G., Parikh, D. J., and Agarwal, Y. K., 2004. Essential heavy metals in environmental samples from western India. Bull. Environ. Contam. Toxicol. 73: 756–761.

Scott, D., Keoghan, J. M., and Allen, B. E., 1996. Native and low input grasses a New Zealand high country perspective. N. Z. J. Agric. Res. 39: 499–512.

Sharma, R. K., Agrawal, M., and Marshall, F. M., 2006a. Heavy metals contamination in vegetables grown in waste water irrigated areas of Varanasi, India. Bulletin of Environ. Cont. Toxicol. 77: 311-318.

Sharma, R. K., Agrawal, M., and Marshall, F. M., 2007b. Heavy metals contamination of soil and vegetables in suburban areas of Varanasi, India. Ecotoxicol. Environ. Saf. 66: 258-266.

Sial, R. A., 2000. Effect of effluents from Hattar industrial area on soil and crop productivity. Ph. d. Thesis, Department of Biological Sci. Quid-e-Azam Univ. Islamabad.

Singh, A., Rajesh, K. S., Madhoolika, A., and Fiona, M. M., 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.

Singh, R. P., and Agrawal, M., 2008. Potential benefits and risks of land application of sewage sludge. Waste Manage. 28: 347–358.

Singh, R. P., and Agrawal, M., 2010. Variations in heavy metal accumulation, growth and yield of rice plants grown at different sewage sludge amendment rates. Ecotoxicol. Environ. Saf. 73: 632–641.

Singh, S., Sinha, S., Saxena, R., Pandey, K., and Bhatt, K., 2004. Translocation of metals and its effects in the tomato plants grown on various amendment of tannery waste: evidence for involvement of antioxidants. Chemosphere. 57: 91–99.

Srinivasan, J. T., and Reddy, V. R., 2009. Impact of irrigation water quality on human health: A case study in India. Ecolog. Econ. 68: 2800–2807.

Sun, Y. F., Xie, Z. M., and Li, J., 2005. Assessment of toxicity of heavy metal contaminated soils by toxicity characteristic leaching procedure. Environ Sci. 26(3): 152-156.

Tariq, M., Ali, M., and Shah, Z., 2006. Characteristic of industrial effluents and their possible impacts on quality of underground water. *Soil Environ.* 25(1): 64–69.

Thompson, H. C., Kelly, W. C., 1990. Vegetable Crops, 5th ed., McGraw Hill Publishing Company Ltd., New Delhi.

Türkdoğan, M. K., Kilicel, F., Kara, K., Tuncer, I., and Uygan, I., 2002. Heavy metals in soil, vegetables and fruits in the endemic upper gastrointestinal cancer region of Turkey. Environ Toxicol Pharmacol. 13: 175–9.

Ullah, R., Malik, R. N., and Qadir, A., 2009. Assessment of groundwater contamination in an industrial city, Sialkot, Pakistan. Afr J Environ Sci Technol. 3: 429–46.

US-EPA, IRIS., 2006. United States, Environmental Protection Agency, Integrated Risk Information System. http://www. epa. gov/iris/subst.

USEPA., 1990. Recommended protocols for measuring conventional water quality variables and metals in fresh water of the Puget Sound, 1200 6^{th} Avenue Seattle, WA 98101, retrieved from http//www. psat. a. gov/Publications/ protocols / protocol _ pdfs / freshwater. pdf.

Van der Hoek, W., 2004. A framework for a global assessment of the extent of wastewater irrigation: the need for a common wastewater typology. In: Scott, C. A., Farunqui, N. I., Raschid-Sally, L. (Eds.), Wastewater Use in Irrigated Agriculture, Confronting the Livelihood and Environmental Realities. CAB International, International Water Management Institute, International Development Research Centre, Trowbridge. 11–24.

Wang, G., Su, M. Y., Chen, Y. H., Lin, F. F., Luo, D., and Gao, S. F., 2006. Transfer characteristics of cadmium and lead from soil to the edible parts of six vegetable species in southeastern China. Environ. Int. 144: 127-135.

WHO., 2006a. Guidelines for the safe use of wastewater, excreta and greywater. Waste Water Use in Agriculture. (2) World Health Organization, Geneva.

WHO., 2006b. Guidelines for the Safe use of wastewater, excreta and greywater. Policy and regulatory aspects, (1) World Health Organization, Geneva.

WHO/FAO., 2007. Joint FAO/WHO Food Standard Programme Codex Alimentarius Commission 13th Session. Report of the Thirty Eight Session of the Codex Committee on Food Hygiene. Houston, United States of America, ALINORM 07/30/13.

WWF., 2007. Pakistan's water at risk: And health related issues in Pakistan and key recommendation (special report), Fresh water and toxic programme. WWF, Pakistan.

Xiong, Y. Q, Yang, Z. S., and Liu, Z. X., 2003. A review of source study of the changjiang and yellow river sediments. I. Advances in Marine Science. 21(3): 355-362.

Yang, J., 2005. Pollution risks of heavy metals in irrigated water on soils and crops [D. M. S. thesis. Agricultural University of Southwest. 7-79.

Young, R. A., 2005. Toxicity Profiles : Toxicity Summary for Cadmium, Risk Assessment Information System. University of Tennessee. [rais. ornl. Gov/tox/profiles/ cadmium. html.

Yu, L., Wang, Y. B., Gou, X., Su, Y. B., and Wang, G., 2006. Risk assessment of heavy metals in soils and vegetables around non-ferrous metals mining and smelting sites, Baiyin, China. Acta Sci. Circumst. 18(6): 1124-1134.

Zhang, M. K., 2005. Preferential transfer of the heavy metals in the polluted soils. Acta Scientiae Circumstantiae. 25(2): 192 - 197.

Zheng, N., Qichao, W., Xiuwu, Z., Dongmei, Z., Zhongsheng, Z., and Shaoqing, Z., 2007. Population health risk due to dietary intake of heavy metals in the industrial area of Huludao city, China. Sci. Total Environ. 387: 96–104.

Zheng, N., Wang, Q., and Zheng, D., 2007. Health risk of Hg, Pb, Cd, Zn and Cu to the inhabitants around Huludao Zinc plant in China via consumption of vegetables. Sci. Total Environ. 383: 81–89.

Zhou, Q., Wu, Y. and Xiong, X., 1994. Compound pollution of Cd and Zn and its ecological effect on rice plant. Chin. J. Appl. Ecol. 5: 428-441.

Zhu, J. B., Chen, F., Lu, L. D., 2005. Heavy metal geochemistry behavior during the oxidation of the Fankou Pb/Zn mine tailings in Guangdong province and the implications for environmental remediation of the mines. Acta Sci. Circumst. 25(3): 414-452.

Zhuang, P., Zou, B., Li, N. Y., and Li, Z. A., 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.

Appendix 1: Table showing Analysis of variance (ANOVA) among Heavy metals of waste, tube well and unknown source sites.

ANOVA				
Metals		df	F	Sig.
Cr	Between Groups	2	21.56629	<0.0001
Ni	Between Groups	2	61.89058	<0.0001
Fe	Between Groups	2	13.39818	<0.0001
Cu	Between Groups	2	8.028412	0.0004
Co	Between Groups	2	19.57189	<0.0001
Mn	Between Groups	2	18.29379	<0.0001
Pb	Between Groups	2	29.08858	<0.0001
Zn	Between Groups	2	27.71822	<0.0001
Cd	Between Groups	2	65.74761	<0.0001

Appendix 2: Tamhane's T2 test for conservative pair wise comparisons among sampling Sites

Heavy metals	Sources of sample		P-value	95% Confidence Interval	
				Lower	Bound
	Waste water	Tube well	<0.0001	1.161	2.73
Cr	Tube well	Unknown sources	<0.0001	-2.15	-0.93
	Waste water	Tube well	<0.0001	1.99	3.171
	Waste water	Unknown sources	0.004	0.229	1.519
Ni	Tube well	Unknown sources	<0.0001	-2.19	-1.231
	Waste water	Tube well	<0.0001	32.7	108.9
	Waste water	Unknown sources	0.03	3.15	82.22
Fe	Tube well	Unknown sources	0.003	-48.43	-7.89
	Waste water	Tube well	0.001	0.31	1.62
Cu	Tube well	Unknown sources	0.005	-1.031	-0.14
	Waste water	Tube well	<0.0001	2.139	5.23
Co	Waste water	Unknown sources	<0.0001	1.27	4.43
	Waste water	Tube well	<0.0001	17.9	56.9
Mn	Waste water	Unknown sources	0.0003	12.93	51.53
	Waste water	Tube well	<0.0001	8.25	15.56
	Waste water	Unknown sources	0.000101	3.41	12.04
Pb	Tube well	Unknown sources	0.01	-7.74	-0.61
	Waste water	Tube well	<0.0001	3.76	7.96
Zn	Tube well	Unknown sources	<0.0001	-6.21	-2.49
	Waste water	Tube well	0.0001	1.46	2.21
	Waste water	Unknown sources	0.0005	0.27	1.193
Cd	Tube well	Unknown sources	<0.0001	-1.45	-0.769

Appendix 3: Showing Daily consumption of each food crops per person per day (Kg) by the local population of Sialkot and Wazirabad and also their body weight, Age and diseases concerned

S.No	Name	Age	Weight (Kg)	Diseases	Coriandrum sativum	Allium cepa	Abelmoschus esculentus	Allium sativum	Capsicum annum	Daucus carota	Solanum melongena	Spinacia oleracea	Raphanus sativus	Mentha spicata	Lycopersicum esculentum	Triticum aestivum
1	Mubeen	25	55	spontylesis	0.0002	0.0014	0.03	0.002	0.00003	0.002	0.023	0.032	0.02	0.00002	0.02	0.21
2	Afsar	29	60	Rhinitis	0.0003	0.004	0.14	0.0003	0.0002	0.003	0.12	0.023	0.004	0.0003	0.03	0.2
3	Shehzad	20	50	Kidney problem and gastro intestinal infection	0.0021	0.005	0.1	0.00004	0.0002	0.002	0.02	0.02	0.02	0.0002	0.04	0.164
4	Arbaas	32		Nil	0.003	0.005	0.13	0.001	0.00005	0.003	0.17	0.03	0.004	0.0003	0.06	0.25
5	bilal	15	48	Debility	0.0012	0.003	0.14	0.0001	0.0003	0.004	0.13	0.17	0.033	0.00001	0.001	0.23
6	shamim	41	69	High Blood Pressure +weakness	0.0003	0.006	0.15	0.0005	0.0003	0.025	0.03	0.042	0.013	0.0003	0.04	0.31
7	Farzeen Jan	25	55	Nil	0.004	0.004		0.003	0.00004	0.02	0.04	0.13	0.01	0.0003	0.05	0.18
8	Akram Sheikh	39	73	High Blood Pressure and Diabetes	0.0005	0.0006	0.02	0.00001	0.00023	0.004	0.01	0.027	0.006	0.0001	0.001	0.33
9	Masooma bibi	36	65	Obesity + Weakness	0.002	0.004	0.1	0.0003	0.00003	0.0204	0.1	0.17	0.0006	0.00003	0.03	0.3
10	Afsana khan	43	81	High Blood Pressure +weakness	0.0002	0.004	0.1	0.0001	0.001	0.0027	0.03	0.13	0.003	0.0003	0.04	0.233
11	Jameel bloer	50	78	Diabetes +weakness	0.003	0.006	0.17	0.001	0.00003	0.0027	0.1	0.17	0.003	0.0003	0.01	0.166
12	Aamir nasif	15	40	Nil	0.003	0.0003	0.01	0.0004	0.0001	0.0033	0.023	0.13	0.01	0.00005	0.02	0.333
13	Aftaab alam	22	59	Nil	0.0004	0.005	0.17	0.003	0.0001	0.013	0.14	0.027	0.013	0.0001	0.03	0.2
14	Rashid	45	68	Diabetes	0.00001	0.0007	0.13	0.0027	0.0000008	0.003	0.1	0.023	0.01	0.00002	0.03	0.3
15	Umer	19	50	Nil	0.0023	0.003	0.027	0.001	0.00007	0.003	0.023	0.1	0.01	0.00023	0.01	0.167
16	Sohail	21	49	Under weight	0.002	0.006	0.13	0.002	0.00003	0.01	0.1	0.02	0.006	0.001	0.006	0.2
17	Nabeel	26	70	Nil	0.0003	0.007	0.13	0.0003	0.00001	0.002	0.1	0.13	0.0006	0.0003	0.001	0.3
18	Sehrish	19	52	Nil	0.001	0.006	0.1	0.0003	0.00003	0.003	0.02	0.033	0.02	0.0003	0.006	0.23
19	Badar raj	18	49	Nil	0.0002	0.003	0.1	0.001	0.000027	0.003	0.13	0.13	0.013	0.001	0.03	0.16

20	Munaffa	21	51	Diabetes type	0.0003	0.008	0.1	0.0005	0.000006	0.002	0.02	0.13	0.01	0.0002	0.003	0.18
21	Kamram	28	55	Nil	0.001	0.003	0.1	0.003	0.00003	0.003	0.11	0.026	0.013	0.0004	0.03	0.16
22	Barkat	35	69	Blood pressure	0.0001	0.0009	0.03	0.003	0.00004	0.013	0.1	0.13	0.01	0.0001	0.05	0.3
23	Jan bibi	39	78	Nil	0.0001	0.004	0.1	0.001	0.00004	0.007	0.13	0.027	0.016	0.00003	0.03	0.267
24	Bostaan khan	44	82	Obesty	0.0001	0.0012	0.01	0.003	0.00002	0.0023	0.13	0.02	0.01	0.0003	0.03	0.17
25	Shameem	31	58	Nil	0.001	0.001	0.1	0.001	0.0001	0.02	0.13	0.03	0.003	0.0003	0.03	0.2
26	Marjaan	20	56	Nil	0.001	0.0009	0.004	0.01	0.0001	0.002	0.1	0.16	0.01	0.0003	0.03	0.16
27	Jamshed Ali	23	58	Allergy	0.001	0.006	0.1	0.0003	0.00003	0.016	0.13	0.03	0.003	0.0003	0.03	0.264
28	Shahida	40	71	Weakness epilepsy since childhood	0.003	0.001	0.16	0.0003	0.000007	0.001	0.021	0.033	0.0006	0.001	0.05	0.27
29	Kaleem fakhir	30	56	Nil	0.0003	0.004	0.1	0.003	0.00003	0.002	0.16	0.033	0.0006	0.0003	0.03	0.167
30	Fakhir khan	28	60	Head ach occastional	0.001	0.006	0.1	0.0003	0.00002	0.02	0.023	0.02	0.002	0.0003	0.03	0.167
31	Ambreen	21	52	Nil	0.003	0.001	0.1	0.0003	0.000003	0.005	0.1	0.023	0.016	0.002	0.003	0.3
32	Waseem Changez	31	63	Head ach rare	0.0001	0.005	0.1	0.003	0.0003	0.006	0.01	0.03	0.0006	0.0003	0.03	0.234
33	Talha	18	48	Weakness	0.003	0.003	0.1	0.01	0.0001	0.01	0.03	0.02	0.006	0.0002	0.001	0.234
34	Rashid	33	68	Nil	0.003	0.002	0.13	0.0005	0.000007	0.003	0.1	0.03	0.003	0.0001	0.03	0.2
35	Baber Ali	15	50	Nil	0.003	0.003	0.1	0.003	0.00002	0.01	0.13	0.13	0.003	0.0003	0.003	0.13
36	Ehsan-ul-Haq	20	53	Nil	0.0002	0.006	0.02	0.001	0.001	0.003	0.1	0.13	0.012	0.001	0.05	0.13
37	Fazal	30	69	Nil	0.0003	0.008	0.16	0.0003	0.001	0.004	0.03	0.16	0.015	0.0003	0.06	0.233
38	Amjad	15	48	Nil	0.0004	0.006	0.16	0.001	0.0001	0.0033	0.02	0.3	0.013	0.002	0.03	0.257
39	Imran	35	76	Nil	0.03	0.006	0.1	0.0003	0.00003	0.003	0.13	0.3	0.0006	0.0003	0.06	0.267
40	Ali Qasim	14	45	Nil	0.001	0.003	0.16	0.0003	0.0001	0.001	0.13	0.1	0.0006	0.001	0.006	0.167
41	Fahad	16	56	Nil	0.001	0.003	0.13	0.0003	0.00003	0.003	0.1	0.3	0.013	0.002	0.001	0.167
42	Sara	15	47	Nil	0.001	0.001	0.13	0.0003	0.000024	0.017	0.023	0.2	0.016	0.003	0.03	0.2
43	Aftab	31	60	Nil	0.003	0.001	0.1	0.001	0.000006	0.003	0.4	0.13	0.0003	0.001	0.03	0.3
44	Kiran	16	39	Nil	0.0001	0.003	0.03	0.00003	0.00002	0.002	0.023	0.03	0.0006	0.00005	0.001	0.133

45	Shakeel	14	41	Nil	0.001	0.0027	0.1	0.001	0.0001	0.01	0.06	0.13	0.0005	0.00005	0.01	0.133
46	Afsar khan	21	50	Allergy	0.001	0.0033	0.023	0.001	0.0001	0.023	0.02	0.03	0.00083	0.0003	0.033	0.2
47	Abdul safer	22	48	Weakness	0.001	0.006	0.023	0.0003	0.00003	0.013	0.02	0.05	0.0006	0.001	0.03	0.167
48	Afsheen	15	42	Nil	0.0001	0.003	0.16	0.002	0.001	0.0033	0.13	0.23	0.0006	0.00005	0.006	0.133
49	Umair	17	48	Weak	0.00001	0.005	0.13	0.0003	0.00003	0.013	0.03	0.03	0.013	0.00006	0.03	0.1667
50	Waqar	20	48	Diabetes	0.001	0.006	0.06	0.0005	0.0003	0.023	0.16	0.2	0.013	0.001	0.03	0.2
51	Ambar	16	45	Weakness	0.0023	0.0063	0.1	0.016	0.00003	0.0023	0.13	0.04	0.006	0.000006	0.03	0.167
52	Sadaf jan	22	52	Weakness	0.001	0.003	0.01	0.0003	0.001	0.02	0.16	0.04	0.006	0.00003	0.03	0.133
53	Dawar	50	65	Blood pressure	0.001	0.001	0.14	0.001	0.0003	0.014	0.03	0.033	0.01	0.01	0.06	0.2
54	Akbari	19	49	Sleeplessness	0.001	0.003	0.013	0.002	0.00001	0.004	0.1	0.03	0.002	0.00006	0.003	0.167
55	Shahbaz khan	29	59	Nil	0.027	0.009	0.13	0.001	0.0001	0.004	0.1	0.03	0.01	0.00003	0.03	0.23
56	Basit	20	48	Diabetes	0.001	0.006	0.16	0.0016	0.00003	0.0004	0.03	0.13	0.013	0.0001	0.05	0.23
57	Shamim	15	45	Nil	0.0001	0.003	0.1	0.001	0.0001	0.002	0.01	0.04	0.01	0.00002	0.03	0.167
58	Saleem khan	27	50	Nil	0.001	0.006	0.023	0.0006	0.00003	0.013	0.1	0.23	0.013	0.0001	0.03	0.2
59	Idrees khan	25	56	Nil	0.0009	0.006	0.03	0.002	0.00003	0.0025	0.013	0.04	0.013	0.00003	0.03	0.23
60	Mobeen	30	50	Feeble	0.0001	0.0006	0.13	0.003	0.00003	0.004	0.031	0.03	0.0002	0.001	0.06	0.267
61	Rema noor	19	49	Luck of appetite	0.0001	0.006	0.06	0.0003	0.00003	0.027	0.1	0.23	0.01	0.00003	0.03	0.23
62	Barkat bibi	22	52	Colic pain bouts	0.0002	0.006	0.13	0.0003	0.00002	0.003	0.01	0.06	0.0003	0.001	0.03	0.23
63	Laiba jan	25	59	Nil	0.0027	0.003	0.1	0.003	0.0003	0.0023	0.006	0.14	0.01	0.00003	0.03	0.267
64	Sidra	14	35	Nil	0.003	0.001	0.014	0.001	0.00003	0.003	0.03	0.1	0.003	0.00005	0.001	0.13
65	Sohail	30	76	allergy	0.005	0.005	0.013	0.001	0.00003	0.00067	0.023	0.14	0.013	0.001	0.06	0.3
Total Consumption of Each Food Crop/Person/day					0.0021	0.003875	0.09297	0.0016151	0.00014724	0.0073565	0.078185	0.09295	0.008079	0.00058748	0.02732	0.21335

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