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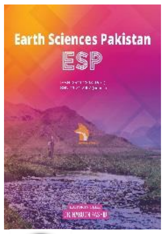

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RESEARCH ARTICLE

HEALTH RISK ASSESSMENT OF HEAVY METALS DUE TO UNTREATED WASTEWATER IRRIGATED VEGETABLES

Ayesha Nawaz[a], Sana Basheer[a*], Awais Masood Ahmed[b], Haroon Rashid[a], Abdul Nasir[a], Shamim Umer[c]

[a] Department of Structures and Environmental Engineering, University of Agriculture, Faisalabad, Pakistan
[b] Department of Civil Engineering, Khawaja Fareed University of Engineering and Technology, Rahim Yar Khan, Pakistan
[c] Department of Botany, University of Agriculture, Faisalabad, Pakistan
**Corresponding Author Email: sana_basheer96@yahoo.com*

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ABSTRACT

The present research study was conducted on Health risk assessment of heavy metals due to untreated wastewater irrigated vegetables in Faisalabad city. Samples of soil, groundwater, wastewater and vegetables were collected from different regions of the city where wastewater irrigation was in practice. The ground water and wastewater samples were analyzed for all the basic physical and chemical parameters and heavy metals like (Nickel, Lead, Cadmium, Zinc, Copper and Chromium). Most of the chemical parameters where in access to standard limits of USEPA. It was found that the majority the heavy metal concentrations in soil are deteriorated because of wastewater. Analysis of heavy metals in Vegetables that their concentrations in vegetables were in the order of Zn>Ni>Cr>Cu>Pb>Cd. The concentration of heavy metals like (Zn, Ni, Cr and Cu) in vegetables were above the safe limit. While TF was lower for all metals except Cd. HRI was maximum for Pb and Ni in all vegetables. HQ was maximum for Ni, Pb and Cd. The vegetables tested were not safe for human use, especially those directly consumed by human beings.

KEYWORDS

Health risk assessment, Wastewater characteristics, Vegetables, Heavy metals.

1. INTRODUCTION

The use of wastewater for irrigation give good crop yields, as it consists of lots of good organic and inorganic elements for growth and development of crops (Mitra and Gupta, 1999). Heavy Metals in different industrial waste are Cr, Cd, Cu, Pb, Ni, Zn, Co, Mg, Fe and As (Asaolu, 1995). Some of the heavy metals are beneficial for proper plant growth, but the others are not so good after the accumulation in soil that can transfer to the food chain and caused adverse effects (Ghafoor et al., 1995; Malla et al., 2007). Elements such as Fe, Mn, Co, Cu and Ni are essential and their permissible limits are very low but in wastewater are present in concentrations above permissible limits and show their toxic effects on the biological system. Heavy metals are dangerous due to their non-biodegradable nature, long biological half-lives and metal enzymes. Among the heavy metals, cadmium shows many effects on seedling length and dry weight (Raza et al., 2013), reduces the activity of photosystem causes structural change in chloroplasts and therefore reduces photosynthesis availability carbon dioxide, decreased stomatal conductance, reducing total lipids, glycolipids and neutral lipids interfere with the permeability of the membrane and reduces respiration in leaves (Agarwal, 2002).

With rapid development of industrialization and urbanization, the discharge amount of waste water, residue and gas containing heavy metals was greatly increased. Those heavy metals could deposit in soil and then accumulate in crops, which may possibly causes serious health problems. Thus, it is important to figure out heavy metal pollution situations in soil and crops. Soil contamination with metals is a primary route of toxic element exposure to humans. Poisonous metals can enter the human body through intake of contaminated food plants, water or inhalation of dust. The contamination of vegetables with heavy metals because of soil and atmospheric infection poses a risk to its great and safety. Food safety problems and capacity fitness risks make such unconventional wastewater as one of the most critical environmental concerns. Vegetables grown on contaminated land may accumulate toxic metals. Prolonged intake of contaminated meals stuff may additionally cause the unceasing accumulation of heavy metals in the liver and kidney of human's ensuing in the disturbance of biochemical processes, such as, liver, kidney, cardiovascular, nervous and bone problems. It has been estimated that greater than 70% of dietary intake of cadmium is contributed by food chain (Wagner, 1993).

Heavy metal is a term that is used extensively for a wide range of trace elements which are important both biologically and industrially with the atomic density greater than 6 mg/m^3 (Alloway, 1990). Owing to persistent nature of toxic metals, these are collected in specific organs of human body consisting of liver, bones and kidneys. They also cause various critical health problems and diseases (Duruibe et al., 2007). The nature of effects

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varies from metal to metal and depends on time of exposure and concentration. It can be carcinogenic, toxic (acute, chronic or sub-chronic), neurotoxic, teratogen or mutagenic (European Union, 2002).

Heavy metals are notably toxic, due to their cumulative nature inside the different frame organs leading to unfavorable consequences (Jarup, 2003; Sathawara et al., 2004). Metals generally tend to bio accumulate within the surroundings and bio magnify in meal chains (Caggiano et al., 2004), their ranges may additionally reach toxic limits even supposing discovered in low concentrations in environmental samples. In view that this ought to be restricted to an unavoidable minimal, a good deal attention is paid to the incidence of those factors in food (Milicevic et al., 2009). Intervention of heavy metals in plants mainly through the roots from the soil and travel on the food chain length. Once entered in the bodies of living organisms, can be heavy metals pose serious threats due to the nature of non-biodegradable, half-lives biological long and because of their ability to collect in numerous elements of the body, for example, adipose tissue (Shahid et al., 2015a). Furthermore, most of the heavy metals is extremely toxic as it dissolves in water.

Daily uptake of metals through crops irrigated with contaminated wastewater is an important route of exposure for metals (Sharma et al., 2008). Even low concentrations of heavy metals have adverse results on people and animals by causing the heart, blood vessels, kidneys and nervous system, mental impairment, bone diseases (UZU et al., 2011a; UZU et al., 2011b; Yargholi et al., 2008). It has been reported that the consumption of a long period of heavy metal contaminated food can impair the liver, kidneys, heart and blood vessels, nervous system and / or can CERs (Jarup, 2003). For example, acute and chronic exposure can cause skin, respiratory, cardiovascular and digestive system, diseases of the blood, liver, kidneys, nervous system, growth, and reproductive health, immune, and the impact of toxic, mutagenic and carcinogenic, such as liver cancer (Lin et al., 2013).

Health risk evaluation of heavy metals in contaminated greens is being carried out in advanced international locations; however, little is explored in developing countries. In Pakistan, very few published data on heavy metal contamination in vegetables is available. Environmental abetment practice is almost missing due to the lack of environmental management and un-operational environmental pollution laws. Wastewater irrigation to increase the yield of food crops (vegetables) is the principal source of contamination in urban agricultural lands. These effluents are rich in toxic metals and are a chief contributor to metals loading in waste irrigated and amended soils. Health risk assessment method depend on hazard quotient and do not provide a quantitative estimate of the likelihood of vulnerable populations suffering from adverse health effects, they provide an indication level of risk due to contamination.

Wastewater contains municipal as well as industrial effluents. This untreated industrial effluent contains toxic heavy metals which are very harmful for human beings as well as for crops and vegetables. When crops and vegetables are irrigated with this wastewater, crops and vegetables uptake those toxic heavy metals which through food chain enters the human body and causes serious health problems. Heavy metal pollution is a prime problem of our surrounding and it is also one of the dealers to contaminate a large supply of food we have. This problem receives increasingly attention all around the global, in widespread, and in developing nations. The tradition of growing vegetables inside and on the edge of an industrial area in the very old cities. This shows that most of the cultivated land contaminated by heavy metals contributed by the industrial waste water for irrigation. Trace metals in the soil reduces the yield of vegetables because of the inconvenience the metabolic processes of plants (Abdullah and Iqbal, 1991).

This research work was conducted in order to characterize wastewater, groundwater and soil samples for heavy metals, which include Cu, Zn, Cd, Cr, Pb and Ni. Furthermore, it was also aimed to analyze heavy metal concentrations and determine health risk in vegetables which include spinach, okra, green chilli, pumpkin, ridge gourd and beans.

2. Materials and Methods

The study was conducted in different areas of Faisalabad city. Different locations were marked where wastewater irrigation was in practice. The existing sewerage system of the city is divided into two distinct zones (eastern, western) by a canal and railway line which is parallel and close to each other and passes through the centre of the city. Each zone has an independent sewage collection and disposal system. Eastern zone mainly deals with industrial wastewater and the sewage from the existing collection system is discharge untreated into Maduana Drain. Western mainly deals with domestic wastewater and treated and untreated wastewater is discharge into Paharang Drain.

3. Research Methodology

3.1.1 Site Description and Research plan

The study was conducted in Chokera wastewater treatment plant (WASA), Jawad Club road, Narwala Road and Pars Campus UAF Jhang Road, where vegetables are grown with treated and untreated wastewater. 20 Samples of wastewater, 24 groundwater samples, 12 soil samples and 12 vegetable samples were taken from four different sites of district Faisalabad named as Chokera wastewater disposal site, Narwala road wastewater disposal site, Pars Campus UAF wastewater disposal site and Jawad club road wastewater disposal site. 3 soil samples were collected each from three different depths from each site. 6 groundwater samples were collected from the surrounding residential areas from each site. 5 samples of wastewater were collected from each site during different time of interval. 3 vegetable samples were collected from each site. All above data was analysed statistically to determine the effect of wastewater on soil, vegetables (spinach, okra, green chilli, pumpkin, ridge gourd and beans) and groundwater.

Table 1: Description of study sites.

Sr.No	Site	Title
1	Site A	Chokera Wastewater Treatment Plant
2	Site B	Jawad Club Road
3	Site C	Narwala Road
4	Site D	Pars Campus UAF Jhang Road

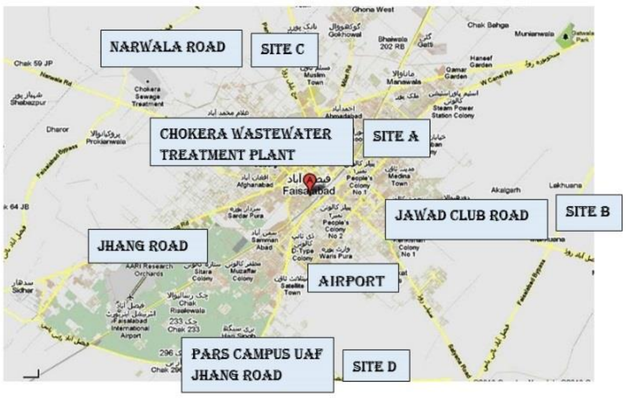

Figure 1: Site Map and Sampling Locations

3.1.2 Sampling plan for wastewater

20 samples of wastewater were collected from the drain during different time of interval and this water irrigate the fields from where I have collected the samples. 5 samples of wastewater were collected from each site. Each wastewater sample had the quantity of 1 liter and kept in plastic bottles with airtight caps. In order to preserve the sample, samples were kept in refrigerator at 5^{o}C throughout the period of analysis. All samples were analysed for pH, Temperature, EC, TSS and heavy metals (Ni, Cd, Cu, Pb, Cr and Zn).

3.1.3 Sampling plan for groundwater

24 samples of groundwater were collected from surrounding area. 6 samples of groundwater were collected from each site. Groundwater

samples were collected from the different fields related to soil, vegetables and wastewater collection sites. Each groundwater sample had the quantity of 1 liter and kept in plastic bottles with airtight caps and noted the reading with the help of GPS receiver. In order to preserve the sample, samples were kept in refrigerator at 5^{o}C throughout the period of analysis. All samples were analysed for pH, Temperature, EC, TSS and heavy metals (Ni, Cd, Cu, Pb, Cr and Zn).

3.1.4 Sampling plan for Soil

12 soil samples were taken from above four sites related to wastewater collection sites from three different depths. 3 samples of soil were collected from each site. Each soil sample had the quantity of 1/2 kg and stored in polythene bags. These samples were air-dried, ground, sieved and were analysed for heavy metals (Ni, Cd, Cu, Pb, Cr and Zn).

3.1.5 Sampling plan for Vegetables

12 vegetable samples were taken from above four sites related to wastewater collection sites. 3 samples of vegetables were collected from each site. Each vegetable sample had the quantity of 1/2 kg. Each sample was air-dried and then dried in oven at 70ºC for 48 hours. The dried samples were grinded into a fine powder using a grinder and then stored in polythene bags. Vegetable analysis was carried out through Standard Digestion Method. In this method vegetable samples were collected from the different fields related to wastewater collection sites.

Table 2: Specific Vegetables.

Sr.no	Local Name	Common Name	Botanical Name	Family
1	Bhindi	Okra	Abelmoschus esculentus	Malvaceae
2	Kadu	Pumpkin	Cucurbita	Cucurbitaceae
3	Phaliyan	Beans	Phaseolus vulgaris	Fabaceae
4	Mirch	Chili	Capsicum annuum	Solanaceae
5	Palak	Spinach	Spinacia oleracea	Amaranthaceae
6	Kali tori	Ridge gourd	Luffa	Cucurbitaceae

4. RESULTS AND DISCUSSIONS

Samples of wastewater, groundwater, soil and vegetables were taken from four different sites in district Faisalabad. Physical and chemical parameters of all these samples were determined and analyzed to determine the effect of wastewater on groundwater, soil and vegetables. Six vegetables which were most commonly used for eating purposes, were selected for the study.

4.1 Analytical Approach

4.1.1 Concentration of Metals in Wastewater

Table 3: Average Concentration of metals in wastewater from Site A, B, C and D

	Sr. No	Copper (Cu)	Nickel (Ni)	Lead (Pb)	Zinc (Zn)	Cadmium (Cd)	Chromium (Cr)
Site A	1	0.23	0	0	0	0	0.2
	2	0.12	0	0	0	0	0.2
Site B	3	0.18	0.1	0	0	0.01	0.21
	4	0.27	0	0	0.02	0	0.21
Site C	5	0.13	0.02	0.19	0.01	0	0.23
	6	0.23	0	0	0.01	0	0.25
Site D	7	0.05	0.03	0.01	0	0	0.25
	8	0.15	0	0	0.02	0	0.28

4.1.2 Concentration of Metals in Groundwater

Table 4: Concentration of metals in Ground water (mg/L) from four Sites.

Sr.no	Copper (Cu)	Nickel (Ni)	Lead (Pb)	Zinc (Zn)	Cadmium (Cd)	Chromium (Cr)
1	0.02	0.02	0.01	0	0.06	0.02
2	0.04	0	0	0	0.01	0.02
3	0	0.08	0	0	0	0.02
4	0.01	0.1	0	0.1	0.12	0.05
5	0.03	0	0.02	0.13	0	0.05
6	0.21	0.12	0.06	0	0.01	0.06
7	0.17	0	0	0.18	0	0.05
8	0	0	0.05	0	0.05	0.05
9	0	0.15	0	0.1	0.01	0.05
10	0.11	0	0.02	0.01	0	0.05
11	0.05	0.06	0.07	0.02	0	0.06
12	0.09	0	0	0	0.12	0.1
13	0.02	0	0	0	0.06	0.07
14	0.01	0.15	0.13	0	0	0.1
15	0.12	0.07	0	0.01	0.09	0.17
16	0.15	0	0	0.01	0	0.13
17	0.11	0	0.04	0	0.04	0.18
18	0.22	0	0.02	0	0.01	0.16
19	0.19	0.05	0	0	0.01	0.18
20	0.2	0	0	0	0	0.17
21	0.2	0	0.06	0	0	0.16
22	0.1	0	0.04	0	0.01	0.19
23	0	0	0.02	0.08	0	0.19
24	0.04	0	0.01	0	0	0.2

4.1.3 Concentration of Metals in Soil

Table 5 (a): Average Concentration of Metals mg^{-kg} in Soil samples of Vegetables from four sites.

Vegetables	Cu		Ni		Pb	
	Mean	STDEV	Mean	STDEV	Mean	STDEV
Beans	22.08	11.86	39.98	8.44	22.10	9.71
Chili L(1)	12.63	0.51	28.21	1.37	10.75	0.36
Chili L(2)	9.88	0.67	32.01	2.52	10.60	0.58
Ridge gourd	11.14	0.22	48.96	0.46	11.53	0.12
Okra	11.71	0.58	49.97	2.39	14.32	0.75
Pumpkin	12.54	0.04	56.00	3.86	16.00	0.56
Spinach(1)	12.82	0.27	48.95	0.49	10.21	0.47
Spinach(2)	24.81	1.87	45.79	2.11	28.40	2.74
Spinach(3)	9.52	0.63	31.37	0.52	11.75	1.91
Spinach(4)	24.34	0.25	45.58	4.16	23.95	2.23
Spinach(5)	10.65	2.12	43.06	5.29	9.45	3.10

Table 5 (b): Average Concentration of Metals mg^{-kg} in Soil samples of Vegetables from four sites.

Vegetables	Zn		Cd		Cr	
	Mean	STDEV	Mean	STDEV	Mean	STDEV
Beans	204.92	98.84	0.73	0.24	19.57	2.38
Chili L(1)	53.97	2.98	0.48	0.03	16.50	0.96
Chili L(2)	177.59	34.67	0.46	0.04	16.71	0.41
Ridge gourd	56.02	1.54	1.00	0.04	19.50	0.33
Okra	51.40	6.04	0.96	0.04	21.00	1.09
Pumpkin	43.31	0.56	0.92	0.02	21.50	0.63
Spinach(1)	61.08	1.22	0.95	0.02	19.89	0.31
Spinach(2)	316.58	42.69	1.56	2.20	21.95	1.29
Spinach(3)	320.05	57.26	0.48	0.03	16.94	0.55
Spinach(4)	438.44	257.52	0.64	0.10	22.68	0.78
Spinach(5)	95.18	32.61	1.87	0.01	15.41	1.01

4.1.4 Concentration of Metals in Vegetables.

Table 6 (a): Average Concentration of Metals mg^{-kg} in Vegetables in four sites.

Vegetables	Cu		Ni		Pb	
	Mean	STDEV	Mean	STDEV	Mean	STDEV
Beans	4.32	0.07	9.11	0.06	1.53	0.11
Chili L(1)	7.28	0.11	6.74	0.41	1.09	0.09
Chili L(2)	7.94	0.29	5.90	0.42	0.52	0.04
Ridge gourd	11.12	0.37	5.36	0.31	0.09	0.03
Okra	7.69	0.43	11.30	9.84	1.95	1.84
Pumpkin	10.78	0.27	9.56	0.75	0.00	0.00
Spinach(1)	5.61	0.21	7.96	0.41	2.53	0.22
Spinach(2)	9.91	0.12	30.69	0.43	6.65	0.21
Spinach(3)	9.14	0.30	10.84	1.89	2.71	0.23
Spinach(4)	8.31	0.15	14.20	1.13	3.24	0.37
Spinach(5)	6.51	0.17	8.90	0.01	1.02	0.62

Table 6 (b): Average Concentration of Metals mg-kg in Vegetables in four sites.

Vegetables	Zn		Cd		Cr	
	Mean	STDEV	Mean	STDEV	Mean	STDEV
Beans	32.98	0.32	0.22	0.04	4.39	0.23
Chili L(1)	34.30	0.50	0.22	0.04	7.26	0.21
Chili L(2)	38.12	1.02	0.19	0.03	5.49	0.04
Ridge gourd	35.99	0.84	0.24	0.06	6.11	0.76
Okra	40.91	1.92	0.76	0.54	9.53	5.10
Pumpkin	39.72	0.87	0.08	0.02	7.79	0.31
Spinach(1)	26.88	1.68	0.66	0.03	5.39	0.35
Spinach(2)	50.46	0.67	0.76	0.03	15.99	2.00
Spinach(3)	54.09	2.51	1.00	0.05	10.82	0.29
Spinach(4)	34.16	0.33	0.98	0.05	10.78	0.29
Spinach(5)	31.02	0.45	0.09	0.01	9.57	0.13

4.1.5 Overall concentration of Metals

4.1.5.1 Copper

Result showed in Figure 2 Consequences showed that Copper concentration is varying significantly in wastewater, groundwater, soil and vegetables and Copper awareness is also varying from area to area. Highest mean Cu concentration is in soil, after which in vegetables after in groundwater and wastewater respectively. All four means are notably different from each other. Graphical representation showed that Cu concentration is maximum in soil.

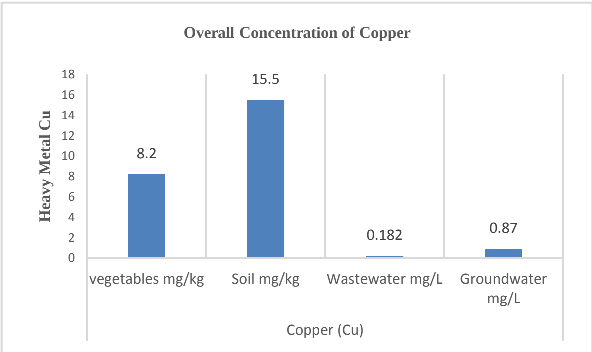

Figure 2: Overall Concentration of Copper

4.1.5.2 Zinc

Results showed in Figure 3 Consequences showed that Zinc concentration is varying considerably in wastewater, groundwater, soil and vegetables. Highest mean Zn concentration is in soil, then in vegetables and after which in groundwater and wastewater respectively. All four means are notably different from each other. Graphical illustration showed that Zn concentration is maximum in soil.

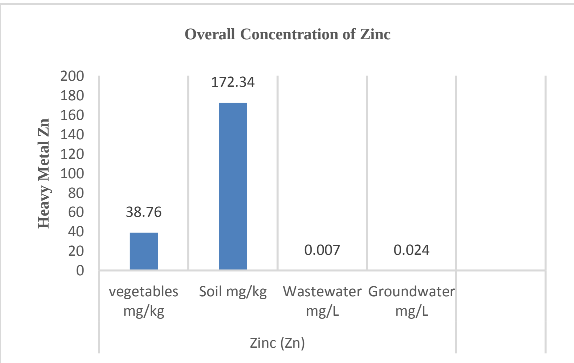

Figure 3: Overall Concentration of Zinc

4.1.5.3 Cadmium

Results in Figure 4 Consequences showed that Cadmium concentration is varying considerably in wastewater, groundwater, soil and vegetables. Cadmium concentration is also varying from area to area. Highest mean Cd concentration is in soil, then in vegetables and after which in groundwater and wastewater respectively. All four means are not notably various from one another. Graphical illustration showed that Cd awareness is maximum in soil.

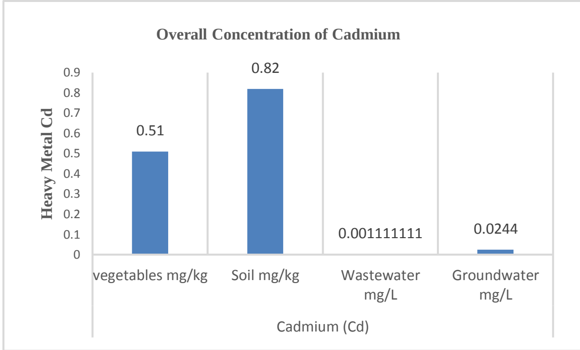

Figure 4: Overall Concentration of Cadmium

4.1.5.4 Lead

Results in Figure 5 Consequences showed that Lead concentration is varying considerably in wastewater, groundwater, soil and vegetables. Lead concentration is also varying from area to area. Highest mean Pb concentration is in soil, then in vegetables and after which in wastewater and groundwater respectively. All four means are notably different from one another. Graphical illustration showed that Pb awareness is maximum in soil.

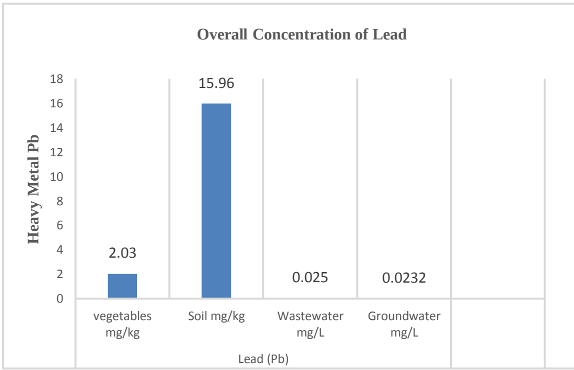

Figure 5: Overall Concentration of Lead

4.1.5.5 Nickel

Results in Figure 6 Consequences showed that Nickel concentration is varying considerably in wastewater, groundwater, soil and vegetables. Nickel concentration is also varying from area to area. Highest mean Ni concentration is in soil, after that, in vegetables and then in groundwater and wastewater respectively. All four means are significantly various from each other. Graphical representation showed that Ni concentration is maximum in soil.

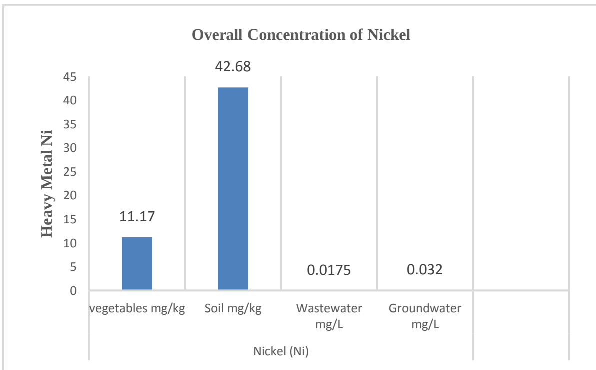

Figure 6: Overall Concentration of Nickel

4.1.5.6 *Chromium*

Results in Figure 7 Consequences showed that Chromium concentration is varying considerably in wastewater, groundwater, soil and vegetables. Chromium concentration is also varying from area to area. Highest mean Cr concentration is in soil, then in vegetables and after which in wastewater and groundwater respectively. All four mean considerably different from one another. Graphical representation showed that Cr awareness is maximum in soil.

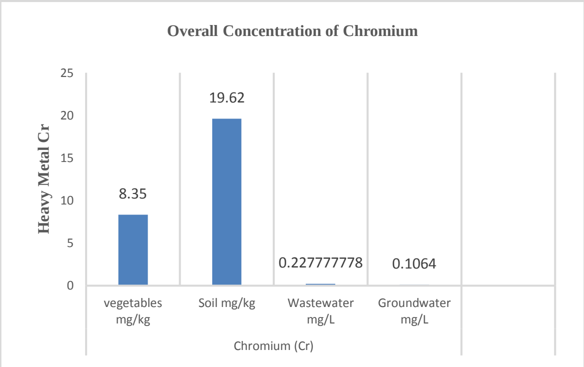

Figure 7: Overall Concentration of Chromium

4.2 Health risk Analysis

4.2.1 *Soil-to-Plant Transfer Quotient (TF)*

As the vegetables are the source of human consumption so soil-to-plant transfer quotient is the main source of human exposure. A suitable way for measuring the relative difference of bioavailability of metal to plant is transfer quotient. In order to determine Health Risk Index (HRI) transfer factor should be known (Khan et al., 2009). The higher transfer quotient of heavy metal indicates the stronger accumulation of the respective metal by that vegetable. The soil-to-plant transfer Quotient (TF) was calculated as bellow (Cui et al., 2005). In Table 7 transfer quotient of Cu in all the vegetables was highest while Pb and Ni were having small values. The soil-to-plant transfer Quotient (TF) was calculated as bellow:

$$TF=CPLANT/CSOIL$$

Table 7: Soil-to-Plant Transfer Quotient (TF).

Vegetables	Cu	Ni	Pb	Zn	Cd	Cr
Beans	0.196	0.228	0.069	0.161	0.300	0.224
Chili L-1	0.576	0.239	0.102	0.636	0.456	0.440
Chili L-2	0.804	0.184	0.049	0.215	0.404	0.329
Ridge gourd	0.998	0.110	0.008	0.642	0.237	0.313
Okra	0.657	0.226	0.136	0.796	0.795	0.454
Pumpkin	0.859	0.171	0.000	0.917	0.081	0.362
Spinach (1)	0.399	0.670	0.234	0.159	0.484	0.728
Spinach (2)	0.437	0.163	0.248	0.440	0.697	0.271
Spinach (3)	0.959	0.346	0.231	0.169	2.085	0.639
Spinach (4)	0.341	0.312	0.135	0.078	1.524	0.475
Spinach (5)	0.729	0.241	0.012	0.364	1.204	0.327

4.2.2 *Daily Intake of Metals*

As vegetables are contaminated by heavy metals so their daily intake needs to be estimated for comparison. The concentrations of metals in plants was calculated in mg kg^{-1}. Conversion factor was taken as 0.085 (Mehmood et al., 2015). The average daily food intake for adults and children was considered to be 0.345 and 0.232 kg $person^{-1}$ day^{-1}, respectively, while the average adult and child body weights were considered as 73 (FAO, 2000) and 32.7 kg, respectively (Ge, 1992; Wang et al., 2005). In table 3.5 daily intake of metals was described it showed that daily intake of Zn was high in all the vegetables. Daily intake of metal was calculated by the equation given bellow:

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

Table 8: Daily intake of metals kg/person/day.

Vegetables	Cu	Ni	Pb	Zn	Cd	Cr
Beans	0.01	0.02	0.01	0.08	0.00	0.01
Chili (1)	0.01	0.01	0.00	0.02	0.00	0.01
Chili (2)	0.00	0.01	0.00	0.07	0.00	0.01
Ridge gourd	0.00	0.02	0.00	0.02	0.00	0.01
Okra	0.00	0.02	0.01	0.02	0.00	0.01
Pumpkin	0.01	0.02	0.01	0.02	0.00	0.01
Spinach (1)	0.01	0.02	0.01	0.13	0.00	0.01
Spinach (2)	0.01	0.02	0.00	0.02	0.00	0.01
Spinach (3)	0.00	0.01	0.00	0.13	0.00	0.01
Spinach (4)	0.01	0.02	0.01	0.18	0.00	0.01
Spinach (5)	0.00	0.02	0.01	0.12	0.00	0.01

4.2.3 *Health Risk Index (HRI)*

By using Daily Intake of Metals (DIM) and reference oral dose we find the health risk index. The following formula is used for the calculation of HRI. Rfd for Cr, Ni, Cu, Pb, Cd, Mn and Zn is 1.5, 0.02, 0.04, 0.004, 0.001, 0.033 and 0.30 (mg/kg bw/day) respectively (US-EPA, 2006) If the value of HRI is less than 1 then the exposed population is said to be safe.
Table 9 showed that which HRI for Pb and Ni was maximum or above from the safe limit in all selected vegetables and HRI for Cu, Cr, Cd and Zn was minimum or in the safe limit. The following formula is used for the calculation of HRI:

$$HRI=DIM/R\ fd$$

Table 9: Health risk Index.

Vegetables	Cu	Ni	Pb	Zn	Cd	Cr
Beans	0.29	1.05	2.90	0.36	0.38	0.01
Chili (1)	0.17	0.74	1.41	0.09	0.25	0.01
Chili (2)	0.13	0.84	1.39	0.31	0.24	0.01
Ridge gourd	0.15	1.28	1.51	0.10	0.53	0.01
Okra	0.15	1.31	1.88	0.09	0.50	0.01
Pumpkin	0.16	1.47	2.10	0.08	0.48	0.01
Spinach(1)	0.33	1.20	3.72	0.55	0.82	0.01
Spinach(2)	0.17	1.28	1.34	0.11	0.50	0.01
Spinach(3)	0.12	0.82	1.54	0.56	0.25	0.01
Spinach(4)	0.32	1.20	3.14	0.77	0.34	0.01
Spinach(5)	0.19	1.14	2.30	0.65	0.51	0.01

4.2.4 *Health Risk Assessment (HQ)*

Risk of intake of metal-contaminated vegetables to human health was characterized by Hazard Quotient (HQ). This is a ratio of determined dose to the reference dose (RD). The population will pose no risk if f the ratio is less than 1 and if the ratio is equal or greater than 1 then population will experience health risk. Table 10 showed that Health risk assessment for Pb, Cu, Cd and Ni was maximum or above from the safe limit in all selected vegetables and Health risk assessment for Cr and Zn was minimum or in the safe limit. The following equation is used

$$HQ = [W] \times [M] / R_{fD} \times B$$

Table 10: Health Risk Assessment (HQ).

Vegetables	Cu	Ni	Pb	Zn	Cd	Cr
Beans	0.5	2.2	1.8	0.5	1.0	0.0
Chili (1)	0.9	1.6	1.3	0.5	1.0	0.0
Chili (2)	0.9	1.4	0.6	0.6	0.9	0.0
Ridge gourd	1.3	1.3	0.1	0.6	1.1	0.0
Okra	0.9	2.7	2.3	0.6	3.6	0.0
Pumpkin	1.3	2.3	0.0	0.6	0.4	0.0
Spinach (1)	1.2	7.3	7.9	0.8	3.6	0.1
Spinach (2)	0.7	1.9	3.0	0.4	3.1	0.0
Spinach (3)	1.1	2.6	3.2	0.9	4.7	0.0
Spinach (4)	1.0	3.4	3.8	0.5	4.6	0.0
Spinach(5)	1.2	6.3	4.1	0.7	2.9	0.1

4.3 Review of Health Risk through contaminated Vegetables

4.3.1 Site A: Chokera Wastewater Treatment Plant

4.3.1.1 Spinach (1)

Table 11 showed that heavy metals in Spinach vegetable was in the order of Zn>Ni>Cr>Cu>Pb>Cd. Transfer factor for spinach ranges from 0.159 (Zn) to 0.728 (Cr). The trend for DIM in spinach vegetable grown was in the order of Zn > Ni>Cr >Cu>Pb >Cd. HRI was maximum for Pb in spinach (3.72) and Ni (1.20) minimum or out of danger for Cr (0.01) in which HRI for Pb and Ni was maximum or above from the safe limit and HRI for Cu, Cr, Cd and Zn was minimum or in the safe limit. HQ was maximum for nickel, lead and cadmium and harmful for human health. Copper are almost close to the safe limit, zinc and chromium are in the safe limit.

Table 11: Heavy metal Concentration in Vegetable Spinach (1).

Metals	Average concentration	Transfer Factor	HRI	HQ	DIM
Cu	9.91	0.399	0.33	1.2	0.01
Ni	30.69	0.670	1.20	7.3	0.02
Pb	6.65	0.234	3.72	7.9	0.01
Zn	50.46	0.159	0.55	0.8	0.17
Cd	0.76	0.484	0.82	3.6	0.00
Cr	15.99	0.728	0.01	0.1	0.01

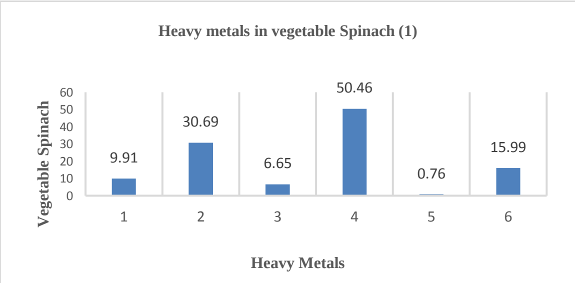

Figure 8: Average Concentration in vegetable Spinach (1)

4.3.1.2 Spinach (2)

Table 12 showed that heavy metals in spinach vegetable was in the order of Zn>Ni>Cu>Cr>Pb>Cd. Transfer factor for spinach ranges from 0.163 (Ni) to 0.697 (Cd) . The trend for DIM in spinach vegetable grown was in the order of Zn > Ni>Cr >Cu>Pb >Cd. HRI was maximum for Pb (1.34) and Ni (1.28) in spinach and minimum or out of danger for Cr (0.01) in which HRI for Pb and Ni was maximum or above from the safe limit and HRI for Cu, Cr, Cd and Zn was minimum or in the safe limit. HQ was maximum in zinc, nickel, lead and cadmium. Copper and chromium were minimum or in the safe limit.

Table 12: Heavy metal Concentration in Vegetable Spinach (2).

Metals	Average concentration	Transfer Factor	HRI	HQ	DIM
Cu	5.61	0.437	0.17	0.7	0.01
Ni	7.96	0.163	1.28	1.9	0.03
Pb	2.53	0.248	1.34	3.0	0.01
Zn	26.88	0.440	0.11	3.4	0.03
Cd	0.66	0.697	0.50	3.1	0.00
Cr	5.39	0.271	0.01	0.03	0.01

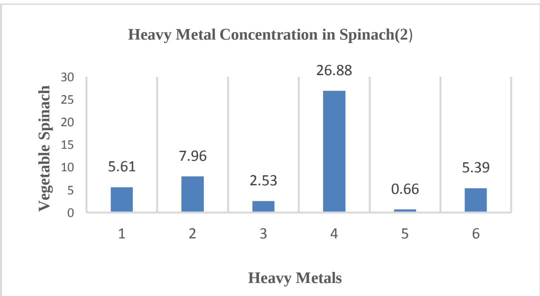

Figure 9: Average Concentration in vegetable Spinach (2)

4.3.1.3 Green Chilli (1)

Table 13 showed that heavy metals in green chilli vegetable was in the order of Zn>Cu>Cr>Ni>Pb>Cd. Transfer factor for green chilli ranges from 0.102 (Pb) to 0.636 (Zn). The trend for DIM in chilli vegetable grown was in the order of Zn > Ni>Cr >Cu>Pb >Cd. HRI was maximum for Pb in chilli (1.41) and minimum or out of danger for Cr (0.01) in which HRI for Pb was maximum or above from the safe limit and HRI for Ni Cu, Cr, Cd and Zn was minimum or in the safe limit. HQ for nickel, lead and cadmium are almost close to the safe limit, copper, zinc and chromium was minimum or in the safe limit.

Table 13: Heavy metal Concentration in Vegetable Green Chilli (1).

Metals	Average concentration	Transfer Factor	HRI	HQ	DIM
Cu	7.28	0.576	0.17	0.9	0.01
Ni	6.74	0.239	0.74	1.6	0.01
Pb	1.09	0.102	1.41	1.3	0.01
Zn	34.30	0.636	0.09	0.5	0.03
Cd	0.22	0.456	0.25	1.0	0.00
Cr	7.26	0.440	0.01	0.0	0.01

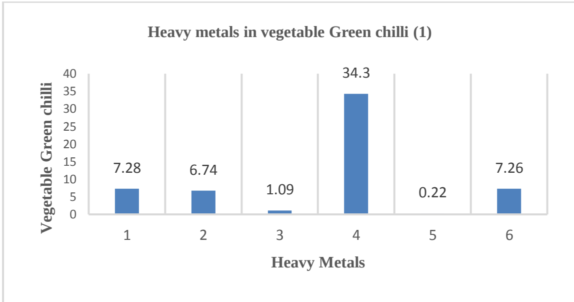

Figure 10: Average Concentration in vegetable Green chilli (1)

4.3.2 Jawad Club Road

4.3.2.1 Spinach (4)

Table 14 showed that heavy metals in spinach vegetable was in the order of Zn>Ni>Cr>Cu>Pb>Cd. Transfer factor for spinach ranges from 0.078 (Zn) to 1.524 (Cd). The trend for DIM in spinach vegetable grown was in the order of Zn > Ni>Cr >Cu>Pb >Cd. HRI was maximum for Pb (3.14) and Ni (1.20) in spinach and minimum or out of danger for Cr (0.01) in which HRI for Pb and Ni was maximum or above from the safe limit and HRI for Cu, Cr, Cd and Zn was minimum or in the safe limit. HQ was maximum for nickel, lead and cadmium. Copper was in the safe limit, zinc and chromium was minimum or in the safe limit.

Table 14: Heavy metal Concentration in Vegetable Spinach (4).

Metals	Average concentration	Transfer Factor	HRI	HQ	DIM
Cu	8.31	0.341	0.32	1.0	0.01
Ni	14.20	0.312	1.20	3.4	0.02
Pb	3.24	0.135	3.14	3.8	0.01
Zn	34.16	0.078	0.77	0.5	0.23
Cd	0.98	1.524	0.34	4.6	0.00
Cr	10.78	0.475	0.01	0.0	0.01

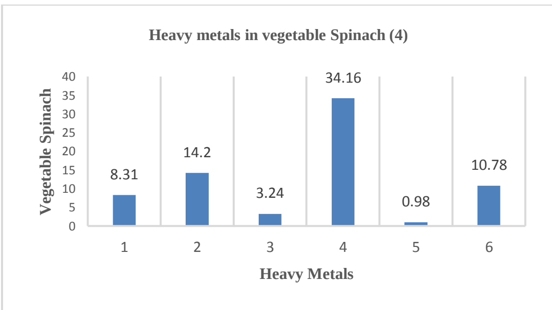

Figure 11: Average Concentration in vegetable Spinach (4)

4.3.2.2 Pumpkin

Table 15 showed that heavy metals in pumpkin vegetable was in the order of Zn>Cu>Ni>Cr>Cd>Pb. Transfer factor for pumpkin ranges from 0.00 (Pb) to 0.917 (Cu). The trend for DIM in pumpkin vegetable grown was in the order of Ni >Zn >Cr >Cu>Pb >Cd. HRI was maximum for Pb (2.10) and Ni (1.47) in pumpkin and minimum or out of danger for Cr (0.01) in which HRI for Pb and Ni was maximum or above from the safe limit and HRI for Cu, Cr, Cd and Zn was minimum or in the safe limit. HQ was maximum in nickel and cadmium Copper was almost close to the safe limit, lead zinc and chromium was minimum or in the safe limit.

Table 15: Heavy metal Concentration in Vegetable Pumpkin.

Metals	Average concentration	Transfer Factor	HRI	HQ	DIM
Cu	10.78	0.859	0.16	1.3	0.01
Ni	9.56	0.171	1.47	2.3	0.03
Pb	0.00	0.000	2.10	0.0	0.01
Zn	39.72	0.917	0.08	0.6	0.02
Cd	0.08	0.081	0.48	2.4	0.00
Cr	7.79	0.362	0.01	0.0	0.01

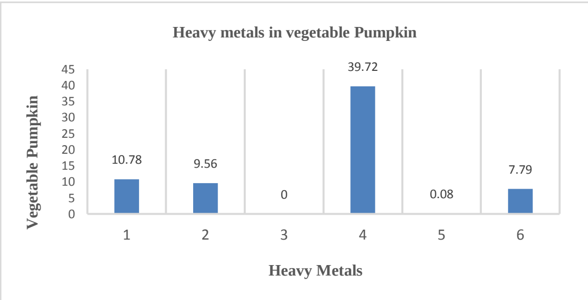

Figure 12: Average Concentration in vegetable Pumpkin

4.3.3 Narwala Road

4.3.3.1 Green Chili (2)

Table 16 showed that heavy metals in chili vegetable was in the order of Zn>Cu>Ni>Cr>Pb>Cd. Transfer factor for chili ranges from 0.049 (Pb) to 0.804 (Cu). The trend for DIM in chili vegetable grown was in the order of Zn > Ni>Cr >Cu>Pb >Cd. HRI was maximum for Pb (1.34) in chili and minimum or out of danger for Cr (0.01) in which HRI for Pb was maximum or above from the safe limit and HRI for Ni, Cu, Cr, Cd and Zn was minimum or in the safe limit. HQ for nickel was almost close to safe limit, lead, cadmium, copper, zinc and chromium was minimum or in the safe limit.

Table 16: Heavy metal Concentration in Vegetable Green Chilli (2).

Metals	Average concentration	Transfer Factor	HRI	HQ	DIM
Cu	7.94	0.804	0.13	0.9	0.01
Ni	5.90	0.184	0.84	1.4	0.02
Pb	0.52	0.049	1.39	0.6	0.01
Zn	38.12	0.215	0.31	0.6	0.09
Cd	0.19	0.404	0.24	0.9	0.00
Cr	5.49	0.329	0.01	0.0	0.01

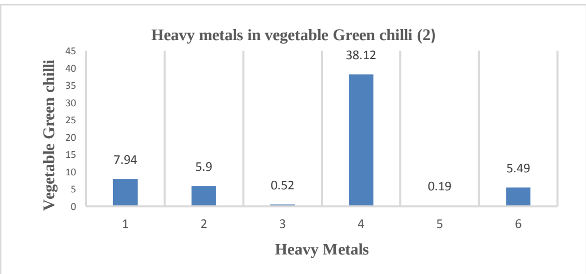

Figure 13: Average Concentration in vegetable Green chilli (2)

4.3.3.2 Okra

Table 17 showed that heavy metals in okra vegetable was in the order of Zn>Ni>Cr>Cu>Pb>Cd. Transfer factor for okra ranges from 0.136 (Pb) to 0.796 (Zn). The trend for DIM in okra vegetable grown was in the order of Zn > Ni>Cr >Cu>Pb >Cd. HRI was maximum for Pb (1.88) and Ni (1.31) in okra and minimum or out of danger for Cr (0.01) in which HRI for Pb and Ni was maximum or above from the safe limit and HRI for Cu, Cr, Cd and Zn was minimum or in the safe limit. HQ was maximum in nickel, lead and cadmium. Copper, zinc and chromium was minimum or in the safe limit.

Table 17: Heavy metal Concentration in Vegetable Okra.

Metals	Average concentration	Transfer Factor	HRI	HQ	DIM
Cu	7.69	0.657	0.15	0.9	0.01
Ni	11.30	0.226	1.31	2.7	0.03
Pb	1.95	0.136	1.88	2.3	0.01
Zn	40.91	0.796	0.09	0.6	0.03
Cd	0.76	0.795	0.50	3.6	0.00
Cr	9.53	0.454	0.01	0.0	0.01

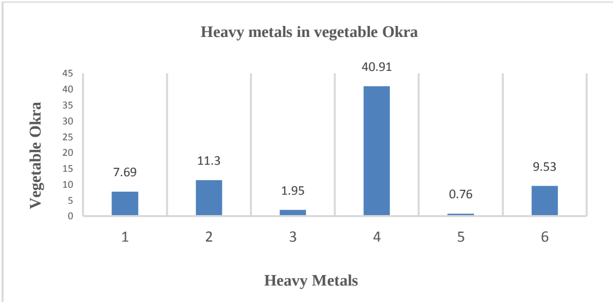

Figure 14: Average Concentration in vegetable Okra

4.3.3.3 Spinach (3)

Table 18 showed that heavy metals in spinach vegetable was in the order of Zn>Ni>Cr>Cu>Pb>Cd. Transfer factor for spinach ranges from 0.169 (Zn) to 2.085 (Cd). The trend for DIM in spinach vegetable grown was in the order of Zn > Ni>Cr >Pb >Cd>Cu. HRI was maximum for Pb (1.54) in spinach and minimum or out of danger for Cr (0.01) in which HRI for Pb was maximum or above from the safe limit and HRI for Ni, Cu, Cr, Cd and Zn was minimum or in the safe limit. HQ was maximum for nickel, lead and cadmium. Copper are almost close to the safe limit, zinc and chromium was minimum or in the safe limit.

Table 18: Heavy metal Concentration in Vegetable Spinach (3).

Metals	Average concentration	Transfer Factor	HRI	HQ	DIM
Cu	9.14	0.959	0.12	1.1	0.00
Ni	10.84	0.346	0.82	2.6	0.02
Pb	2.71	0.231	1.54	3.2	0.01
Zn	54.09	0.169	0.56	0.9	0.17
Cd	1.00	2.085	0.25	4.7	0.00
Cr	10.82	0.639	0.01	0.0	0.01

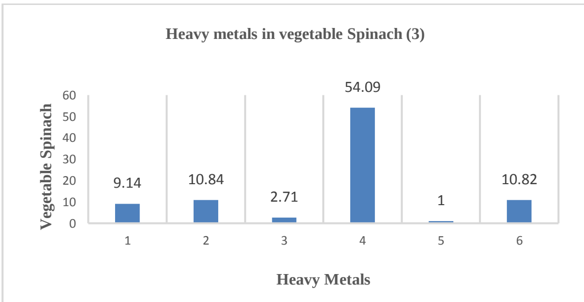

Figure 15: Average Concentration in vegetable Spinach (3)

4.3.4 Pars Campus UAF Jhang Road

4.3.4.1 Beans

Table 19 showed that heavy metals in beans vegetable was in the order of Zn>Ni>Cr>Cu>Pb>Cd. Transfer factor for beans ranges from 0.069 (Pb) to

0.300 (Cd). The trend for DIM in beans vegetable grown was in the order of Zn > Ni>Cr >Cu>Pb >Cd. HRI was maximum for Pb (2.90) and Ni (1.05) in beans and minimum or out of danger for Cr (0.01) in which HRI for Pb and Ni was maximum or above from the safe limit and HRI for Cu, Cr, Cd and Zn was minimum or in the safe limit. HQ was maximum in nickel, lead and cadmium are almost close to the safe limit, copper, zinc and chromium was minimum or in the safe limit.

Table 19: Heavy metal Concentration in Vegetable Beans.

Metals	Average concentration	Transfer Factor	HRI	HQ	DIM
Cu	4.32	0.196	0.29	0.51	0.01
Ni	9.11	0.228	1.05	2.15	0.02
Pb	1.53	0.069	2.90	1.81	0.01
Zn	32.98	0.161	0.36	0.52	0.11
Cd	0.22	0.300	0.38	1.03	0.00
Cr	4.39	0.224	0.01	0.01	0.01

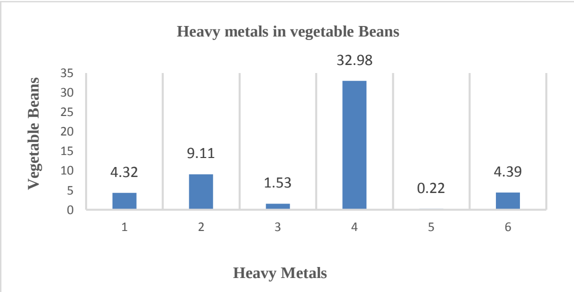

Figure 16: Average Concentration in vegetable Beans

4.3.4.2 Ridge gourd

Table 20 showed that heavy metals in ridge gourd vegetable was in the order of Zn>Ni>Cr>Cu>Pb>Cd. Transfer factor for ridge gourd ranges from 0.008 (Pb) to 0.998 (Cu). The trend for DIM in ridge gourd vegetable grown was in the order of Zn > Ni>Cr >Cu>Pb >Cd. HRI was maximum for Pb (1.51) and Ni (1.28) in kali tori and minimum or out of danger for Cr (0.01) in which HRI for Pb and Ni was maximum or above from the safe limit and HRI for Cu, Cr, Cd and Zn was minimum or in the safe limit. HQ of nickel, copper and cadmium are almost close to the safe limit, chromium, zinc and lead was minimum or in the safe limit.

Table 20: Heavy metal Concentration in Vegetable Ridge gourd.

Metals	Average concentration	Transfer Factor	HRI	HQ	DIM
Cu	11.12	0.998	0.15	1.3	0.01
Ni	5.36	0.110	1.28	1.3	0.03
Pb	0.09	0.008	1.51	0.1	0.01
Zn	35.99	0.642	0.10	0.6	0.03
Cd	0.24	0.237	0.53	1.1	0.00
Cr	6.11	0.313	0.01	0.0	0.01

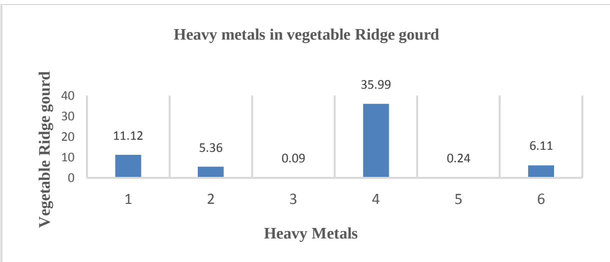

Figure 17: Average Concentration in vegetable Ridge gourd Spinach (5)

Figure 18 showed that heavy metals in pumpkin vegetable was in the order of Zn>Ni>Cu>Cr>Pb>Cd. Transfer factor for spinach ranges from 0.10 (Pb) to 0.206 (Cu). The trend for DIM in spinach vegetable grown was in the order of Pb >Zn >Cr >Cu>Cd>Ni. HRI was maximum for Pb (2.10) and Ni (1.06) in pumpkin and minimum or out of danger for Cr (0.01) in which HRI for Pb and Ni was maximum or above from the safe limit and HRI for Cu, Cr, Cd and Zn was minimum or in the safe limit. HQ was maximum for nickel and cadmium. Lead was almost close to the safe limit, copper, zinc and chromium was minimum or in the safe limit.

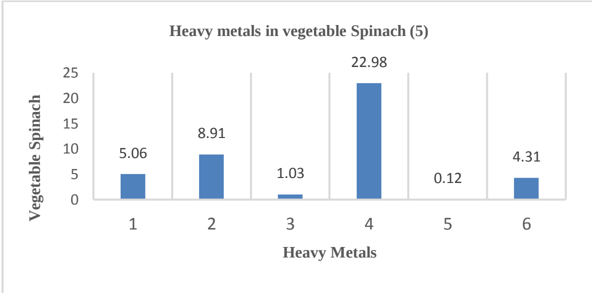

Figure 18: Average Concentration in vegetable Spinach

4.4 Analysis and Discussion

4.4.1 Chokera Wastewater Treatment Plant

Wastewater analysis for heavy metals showed all values within permissible limits except Copper. Copper concentration in wastewater was 0.21 mg/L as compared to permissible limit of 0.1 mg/L. Soil analysis for heavy metals showed highly significant results. Copper concentration in soil was 1.73 mg/kg at 30 cm depth while its permissible limit is 0.50 mg/kg. Lead concentration in soil was 4.20 mg/kg at the depth of 15 cm as compared to permissible limit of 1.00 mg/kg. Zinc concentration in soil was 16.99 mg/kg at the depth of 30 cm while its permissible limit is 1.5 mg/kg. Vegetable analysis showed three heavy metals in excess i.e. Nickel, copper and zinc. Cadmium concentration in vegetables were 0.16 mg/kg while its permissible limit is 0.01 mg/kg. Copper concentration in vegetables were 12.27 mg/kg as compared to permissible limit of 10.00 mg/kg. Zinc concentration in vegetables were 9.12 mg/kg while its permissible limit is 5.00 mg/kg. HRI for Pb and Ni was maximum or above from the safe limit and HRI for Cu, Cr, Cd and Zn was minimum or in the safe limit. HQ was maximum for nickel, lead and cadmium and harmful for human health. Copper are almost close to the safe limit, zinc and chromium are in the safe limit.

4.4.2 Jawad Club Road

Wastewater analysis for heavy metals showed all values within permissible limits except Copper concentration in wastewater was 0.25 mg/L as compared to permissible limit of 0.1 mg/L. Soil analysis for heavy metals showed significant results. Copper concentration in soil was 0.82 mg/kg at 25 cm depth while its permissible limit is 0.50 mg/kg. Nickel concentration in soil was 2.6 mg/kg at 25 cm depth as compared to permissible limit of 1.00 mg/kg. Zinc concentration in soil was 2.76 mg/kg at the depth of 15 cm while its permissible limit is 1.5 mg/kg. Vegetables analysis of heavy metals showed three heavy metals in excess i.e. Nickel, copper and zinc. Cadmium concentration in vegetables were 0.28 mg/kg as compared to permissible limit of 0.01 mg/kg. Copper concentration in vegetables were 10.78 mg/kg while its permissible limit is 10.00 mg/kg. Zinc concentration in vegetables were 6.55 mg/kg as compared to permissible limit of 5.00 mg/kg. HRI for Pb and Ni was maximum or above from the safe limit and HRI for Cu, Cr, Cd and Zn was minimum or in the safe limit. HQ was maximum for nickel lead and cadmium. Copper was in the safe limit, zinc and chromium was minimum or in the safe limit.

4.4.3 Narwala Road

Wastewater analysis for heavy metals showed all values within permissible limits except Cadmium. Copper concentration in wastewater was 0.20 mg/L as compared to permissible limit of 2 mg/L and Cadmium concentration in wastewater was 0.23 mg/L while its permissible limit is 0.1 mg/L. Soil analysis for heavy metals showed significant results. Nickel concentration in soil was 1.5 mg/kg at 10 cm depth while its permissible limit is 0.50 mg/kg. Lead concentration in soil was 2.5 mg/kg at 15 cm depth while its permissible limit is 1.00 mg/kg. Zinc concentration in soil was 2.1 mg/kg at 30 cm depth as compared to permissible limit of 1.5 mg/kg. Vegetables analysis showed three heavy metals in excess i.e. Nickel, Chromium and zinc. Cadmium concentration in vegetables were 0.075 mg/kg as compared to permissible limit of 0.01 mg/kg and Zinc concentration in vegetables were 6.13 mg/kg while its permissible limit is 5.00 mg/kg. . HRI was maximum for Pb (1.34) in chili and minimum or out of danger for Cr (0.01) in which HRI for Pb was maximum or above from the safe limit and HRI for Ni, Cu, Cr, Cd and Zn was minimum or in the safe limit. HQ for nickel was almost close to safe limit, lead, cadmium, copper, zinc and chromium was minimum or in the safe limit.

4.4.4 Pars Campus UAF Jhang Road

Wastewater analysis for heavy metals showed all values within permissible limits except Chromium. Chromium concentration in wastewater was 0.28 mg/L while its permissible limit is 0.1 mg/L. Soil analysis for heavy metals showed highly significant results. Copper concentration in soil was 15.5 mg/kg at 25 cm depth while its permissible limit is 0.50 mg/kg. Lead concentration in soil was 3.27 mg/kg at 25 cm depth as compared to permissible limit of 1.00 mg/kg. Zinc concentration in soil was 72.88 mg/kg at 25 cm depth as compared to permissible limit of 1.5 mg/kg. Vegetables analysis showed three heavy metals in excess i.e. Nickel, Chromium and zinc. Cadmium concentration in vegetables were 0.14 mg/kg as compared to permissible limits of 0.01 mg/kg and Zinc concentration in vegetables were 32.86 mg/kg while its permissible limit is 5.00 mg/kg. HRI was maximum for Pb (2.90) and Ni (1.05) in beans and minimum or out of danger for Cr (0.01) in which HRI for Pb and Ni was maximum or above from the safe limit and HRI for Cu, Cr, Cd and Zn was minimum or in the safe limit .HQ was maximum in nickel, lead and cadmium are almost close to the safe limit, copper, zinc and chromium was minimum or in the safe limit.

5. Conclusion

In case of wastewater, almost all parameters except heavy metals under study were exceeding permissible limits in all sites. The water of Chokara drain containing excessive amounts of certain heavy metals, should not be used for irrigation of those vegetables which are directly consumed uncooked by human beings e.g. spinach, pumpkin, beans, green chili, ridge gourd and okra etc. These sources of water should not be used for drinking purpose of livestock as the heavy metals present in it may cause a number of abnormalities in animals and human beings. All wastewater disposal site was found affected by wastewater for soil and not only on the top of the surface but in the different depths of soil. Heavy metals uptake by soil was also observed. So it is concluded that the majority the heavy metal concentrations in soil are deteriorated because of wastewater. Vegetables was observed up taking heavy metals in larger concentrations which when consumed by human beings created a lot of health problems. At last, it is concluded that wastewater is not fit for irrigation purposes and this practice should be stopped before no time otherwise human health will be damaged with the passage of time.

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