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Heavy Metal Contamination in Vegetables, Soil and Water and Potential Health Risk Assessment

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Abstract: The practice of using wastewater for irrigation is very common especially in developing countries attributed mainly to scarcity of fresh water resources. The presence of toxic metals in wastewater poses serious contamination hazard to soil, crops and vegetables and hence human health. The study was designed to evaluate degree of metal pollution in soil and vegetables irrigated with untreated wastewater of Rohi Drain. Wastewater, vegetables and soil samples, collected from different sites along Rohi Drain, were analyzed for Cd, Cr, Zn, Cu, Fe and Pb. The bio concentration factor was calculated to assess the potential exposure hazard from wastewater irrigation and metal buildup in the edible parts of vegetables. All heavy metals, except Zn, were found much higher than permissible limit in all waste water samples. Vegetables samples were contaminated with metals except Cu and Fe while soil samples showed higher concentrations of metals compared to control but, except Cd, all were less than applicable soil standards. Bio concentration factor was higher for Zn & Cr while HRI was higher for Zn & Pb in different vegetables. It is concluded that agricultural land & vegetables thereof along Rohi drain are contaminated with heavy metals.

Key words: Heavy Metals · Contamination · Soil · Vegetables · Bio Concentration · Health Risk

INTRODUCTION

Pakistan is suffering from shortage of surface supplies therefore there is greater reliance on use of waste water for agricultural activities, especially growing vegetables in urban and peri -urban areas. In different cities of Punjab, Pakistan wastewater is rampant. Higher organic matter in waste water can no doubt enhances the productivity and yield of crops. Nonetheless, occurrence of heavy metals in the waste water, as a consequence of release from untreated industrial effluents, could be potentially toxic due to their persistence, bioaccumulation and bio magnification attributes which poses a threat to human health and environment [1].

Untreated wastewater use for agricultural practices is a widespread practice in the developing countries [2, 3]. A multitude of adverse impacts are associated with toxic constituents present in waste water above the permissible limit as reported in literature. Long term irrigation with wastewater containing heavy metals not only results in metal accumulation in soil but also is a source of contamination of the crops grown therein. The metal buildup in crops results in affecting the safety of crops for human consumption.

Factors such as atmospheric deposition, climate, soil characteristics, extent of plant growth at the time of harvest and irrigation frequency of wastewater affect the extent of heavy metals contamination while processes like adsorption and precipitation also contribute to the mobility and bioavailability of heavy metals in the soil. In the longer run soil accumulates heavy metals to the extent that it becomes deleterious to plants [4]. Apart from toxicity to plants and animals, heavy metals in soil also affect the fundamental biological and chemical processes which in turn change the stability of ecosystem. Besides, heavy metals accumulation impedes N fixation process and biological degradation of organic matter so essential for the transformation of natural nutrient cycles. Studies reported the increased concentration of various heavy metals in soil and crops irrigated with wastewater [5-9]. In many instances the bio concentration factor exceeded the allowable limits for human health.

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Trace metals like Chromium (Cr), lead (Pb) and cadmium (Cd) are important environmental pollutants while iron (Fe), copper (Cu) and zinc (Zn) constitute essential micro nutrient. Release of untreated effluents in water resources have resulted in the buildup of trace metals in the environment and their transport in soil and food produce. Recent studies in Pakistan have focused on contamination of different vegetables, fruits, cereals etc. for determination of metal content.

The problem is more aggravated due to escalating food demands coupled with scarcity of fresh water resources for use in agriculture. As such, regular monitoring of food produce; crops, fruits and vegetables, is integral for timely management strategies for safe guarding human health and environment.

In view of the ever increasing evidence and significance of heavy metal contamination, the current work reported heavy metal concentration in water, soil and selected vegetables irrigated with the waste water of Rohi Nullah only, as the Nullah receives large volumes of effluent from industries at Kasur and Kasur is considered as one of the most polluted city in the world owing to being a hub of tanneries. Human risk assessment has also been undertaken using Health Risk Index (HRI) Bio concentration factor (BF) and Daily intake of metals (DIM).

MATERIALS AND METHODS

Study Area: Kasur is located about 55 km southeast of Lahore, Punjab, near River Sutlej Pakistan with the total district area of 981,702 acres of which 705,224 acres is cultivated land. Rice, cotton, various fodder, sugarcane, maize, wheat and vegetables are the major crops. The cultivated land is partly irrigated from Rohi Nullah which has a length approximately 9.4km and passes through the town from Kashmir Chowk to south western part of the town. This Nullah is fed by municipal sewage and industrial effluents of Kasur [10]. The Nullah, being a storm water drain, has transformed into a permanent drain as a result of unmanaged and untreated industrial and domestic wastewater discharges. Moreover, there is a hub of tanneries and textile industries in Kasur which also discharge their waste directly into Rohi Nullah [11, 12].

There are approximately 44 tube wells around each side of the drain and farmers living nearby use this water for irrigation purpose. The heavy metals from the wastewater accumulate in the surface soil which would be toxic to both soil fauna and flora and it may get into the food chain.

Sampling Methodology: The study was conducted along Rohi Nullah. Wastewater, soil and vegetable samples were collected from the site using standard sampling protocols. Figure 1 illustrates the study area map along with the sampling points.

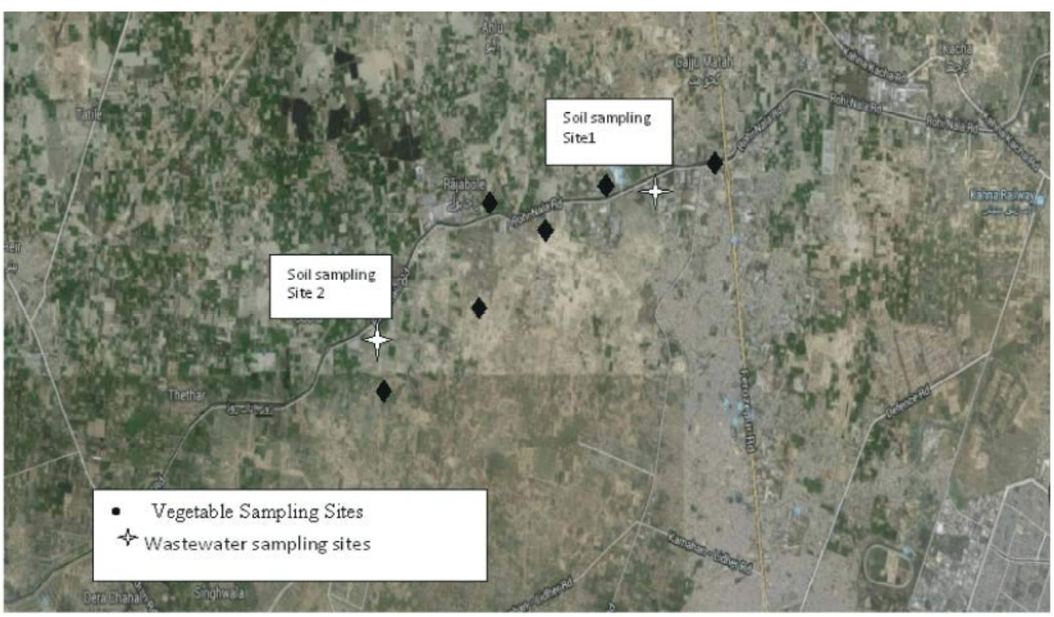

Fig. 1: Study Area Map
Source: Google Maps

Water Samples: Wastewater samples were collected from two different points along Rohi Nullah. pH, temperature and DO of the wastewater were measured onsite before preserving them in different sampling bottles. The sampling bottles were firstly sterilized with sodium thiosulphate ($Na_2S_2O_3$) and then washed thrice with double distilled water and labeled accordingly [13]. The cross contamination of the samples were avoided in all cases and for this purpose bottles were sealed and dried from outside immediately after the preparation of a composite sample at the site. The samples were stored in the laboratory for further analysis.

Soil Samples: Wastewater irrigated soil samples were collected randomly from the upper horizon (0-15 cm) in plastic bags and sealed. Soil samples, after drying in open air, were crushed, passed through 2 mm mesh sieve, sealed in envelopes and stored until analysis. Soil pH and EC was determined using pH meter and EC meter respectively. For extractable heavy metals, 10g of air dried soil in 250ml flask was extracted with 20ml of ammonium bicarbonate- diethylene triamine penta acetic acid AB-DTPA. The contents were shaken for 15 minutes [14]. The mixture was filtered and filtrate was stored in clean plastic bottles and analyzed for selected metals (Cd, Cr, Zn, Cu, Fe, Pb).

Vegetable Samples: Eggplant *Solanum melongena;* Spinach *Spinacia oleracea;* Green Chillies *Capsicum annuum;* Cabbage *Brassica oleracea capitata;* Pumpkin *Cucurbita maxima* and Colocasia Leaves Arvi Colocasia antiquorum were taken randomly from fields along the stretch of Rohi Nullah, from Padoki to Bahadurabad in Kasur.

Vegetable samples were washed with distilled water, dried and then finely chopped. These were taken in ceramic dishes and heated in an electric furnace (Carbonated Electric Furnace with ceramic Lining) at 100 °C for half an hour, then at 300 °C in a Petri dish followed by heating in covered crucibles at 450 °C for 2 hours in an electric furnace. Temperature was increased gradually to avoid the loss of analyte by volatilization. After drying & ashing, organic matter digestion was done adding 2 ml hydrogen peroxide to 0.5g sample and heating for half an hour. Subsequently Multi-Acid Digestion was carried out with 10ml HNO_3 + 3ml $HClO_4$ (Per chloric acid) +5ml HF (hydrofluoric acid) and placed on a hot plate. Again 5ml HNO_3 was added in the sample. Leaching of samples was done by adding 1portion HNO_3 and 1 portion (30ml each) distilled water in the samples, beaker was covered with watch glass and placed on hot plates for 2 hours. Samples were filtered, dried and volume was made (50ml) with distilled water [15]. The parameters analyzed and instruments /Standard methods used for each sample type were as follows: EC (Conductivity Meter/ pH meter, Eutech Instrument Pc 510/HACH Method 8160, 8156), DO & BOD (DO meter, Jenway 970/HACH Method 8215 & 8043 resp), COD (COD meter, Lovibond RD 125/HACH Method 8000), TDS (Filtration, Eutech Instrument Pc 510/ HACH Method 8163), TSS (Filtration/HACH Method 8006), Na^{1+}, K^{1+} and Ca^{2+} (Flame photometer, Sherwood 410/HACH Methods 8131, 8049, 8129 resp), CO_3^{2-} / HCO_3^{1-}, Cl^{1-}, SO_4^{2-} and Mg^2+ (Digital Titration, Schott Instrument/ HACH Methods 8023, 8207, 8051, 8010 respectively), Cu, Pb, Fe, Zn, Cr and Cd (Atomic Absorption spectrophotometer, Buck Model 210 VGP/ HACH Methods 8143,1001, 8008, 8009,8023,8017 respectively)

Human Risk Assessment: The potential of heavy metals to transport from the soil to vegetable can be established by use of accumulation/Bio concentration factor and is useful to assess the risk of exposure and metal accumulation in the edible parts of the selected vegetables.

Bio concentration Factor (BF), Daily intake of metals (DIM) & Health risk index (HRI) were calculated using following formulae [16].

BF = Concentration of metal in vegetable / Concentration of metal in soil

$$DIM= (C_{metal} *C_{factor} *D_{intake})/B_{weight}$$

Where C_{metal} = Metal concentration in food crop, C_{factor} = Conversion factor (0.085), D_{intake}= Average Daily intake of food crop (Estimated as 0.585kg/person/day for the selected area), B_{weight} =Average body weight for adult population (Estimated as 52.7kg average male/female of the area)

HRI refers to ratio of daily metal intake in food crops to the oral reference dose. RfD, the oral reference dose (mg/Kg/day), is an estimate of human daily exposure, as given by US EPA [17].

$$HRI = DIM / RfD$$

RESULTS AND DISCUSSIONS

The results of analysis of wastewater, soil and vegetables are given in Tables 1 and 2.

Table 1: Results of Wastewater Analysis

Parameters	Wastewater Site 1	Wastewater Site 2	Mean	NEQS [18]	WHO [3] Irrigation water Standard
Temperature °C	32	38.6	35.3	40	-
pH	8.84	8.30	8.57	6-9	5.0-9.0
DO (mg/L)	0.52	0.7	0.61	NA	-
COD (mg/L)	294	249	271	150	100-500
BOD (mg/L)	190	120	155	80	30
TDS (mg/L)	1734	3200	2467	3500	450-2000
TSS (mg/L)	3987	1832	2909.5	200	50-150
Na^{1+} (me/L)	2.36	2.47	2.415		3-9
K^{1+}(mg/l)	0.4	0.5	0.45		-
Ca^{2+}(me/L)	0.85	1.13	0.99		-
CO_{32-}(mg/L)	8	11.6	9.8		-
HCO_{31-} (me/L)	0.24	0.27	0.255		1.5-8.5
Cl^{1-}(mg/l) (me/L)	22.79/0.64	19.8/0.56	21.3/0.6	1000	4-10
Mg^{1+}(me/L)	1.483	1.975	1.729		
SO_{42-} (mg/l)/(me/L)	460/4.79	520/5.41	490/5.1	6006.25	500/5.2
SAR	2.48	1.70	2.09		<6
RSC (me/L)	-1.964	-2.65	-2.307		<40
Cu (mg/L)	2.0	1.6	1.8	1.0	0.20
Pb (mg/L)	4.2	5.4	4.8	0.5	5.0
Fe (mg/L)	9.5	7.2	8.35	8	5.0
Zn (mg/L)	2.0	4.0	3	5.0	2.0
Cr (mg/L)	0.9	0.7	0.8	1	0.10
Cd (mg/L)	0.03	0.4	0.215	0.1	0.01

Table 2: Heavy Metals Concentrations in Soil and Edible Parts of Vegetables Irrigated With Wastewater

Samples	Cu (mg/Kg)	Pb (mg/Kg)	Fe (mg/Kg)	Zn (mg/Kg)	Cr (mg/Kg)	Cd (mg/Kg)
Soil Sample 1	32.1	13.4	66.2	100.4	3.4	5.6
Soil Sample 2	52.6	24.6	68.6	155.6	5.4	10.6
Mean	42.35	19	67.4	128	4.4	8.1
Control Sample	6.20	1.2	34.10	18.4	1	0.1
Maximum Limits	*100	*84		*300		*4
	**140	**300	-	**300	**150	**3
Egg Plant	3.9	4.2	3.5	285	3.8	0.4
Green Chili	8.0	1.0	6.5	350	2.0	0.4
Pumpkin	10	2.0	0	260	4.0	0.30
Arvi Leaves	13	4.4	13	236	3.5	0.4
Spinach	14	4.0	9	320	4.2	1.0
Cabbage	16	2.0	11	360	4.4	0.2
ML's						
FAO/WHO (Codex) [20]						
EU [21]	40	0.05-0.3	425.5	60	2.3	0.05- 0.2

*WHO [3] Maximum tolerable soil concentrations of various toxic chemicals based on human health protection.
**EU [19].

Wastewater: Two composite waste water samples were collected from each of the selected points along Rohi Nullah and the results (Table 1) showed pH, temperature and TDS within the permissible limits. The sodium adsorption ratio (SAR) was 2.48 and 1.70 which terms water as good for irrigation while Residual sodium carbonate (-1.96 and -2.65) being less than 2.5 is also considered good for irrigation as the negative value show less hazard owing to sodium buildup due to counteraction of calcium and magnesium. However, TSS, BOD and COD values were higher than the permissible limits. Low DO values and high BOD and COD values illustrate that there are high organic loads in Rohi Nullah which may be attributed to the excessive input of industrial waste water in the drain. Industrial effluents, being released in Nullah, contain chemicals, organic solvents, catalysts and reactants which results in the deterioration of water quality and hence high TSS, BOD and COD. Elevated levels of these parameters have an adverse effect on plant growth. Moreover, Suspended solids decrease the soil permeability resulting in oxygen availability to roots [22].

Waste water investigations for selected trace heavy metals were also carried out in order to determine suitability of its use for agriculture purposes. All metals exceeded the WHO permissible limits.

Average Cu concentration was 1 mg/L; higher than NEQS (1.0 mg/L) [18] and WHO (0.20 mg/L) irrigation guidelines. Chromium is not considered as an essential metal for growth of plants while it is toxic to humans and animals. According to FAO standards Cr is toxic to a number of plants at concentration of 0.1ppm to 1.0ppm [23]. The concentration of Cr in wastewater samples exceeded permissible limits of WHO (0.10 mg/L) guidelines. Chromium concentration is expected to be higher due to release of untreated effluents from tanning units and chemical industries located near the Rohi Nullah; also supported by the fact that Cr is also present in well water of Kasur residential area at an average concentration of 2.12 mg/L [24].

Health effects of Lead in humans, especially children, are well documented. According to the findings of the study, the average Pb level (4.8 mg/L) in samples far exceeds NEQS (0.5 mg/L) but was on threshold level according to WHO irrigation water guidelines (5.0 mg/L). Elevated Lead levels can hamper plant cell growth, in addition to its much reported toxic effects on humans. Numerous studies report excessive Pb levels especially in industrial effluents [1, 25].

Fe concentration in water samples also exceeded NEQS (8 mg/l) and is also above WHO/FAO guidelines (i.e. 5 mg/L) for irrigation [3]. Similarly, Zn concentration in sample-2 (4 mg/ L) was higher than WHO but lower than the NEQS i.e. 5 mg/L [18].

Cd concentration i.e., 0.03 and 4 mg/l was higher than WHO standards, consistent with other studies carried out in Pakistan which show varied and exceeding concentration of Cd in wastewater used for agriculture. One such study reports Cd levels in the range 0.18 to 0.37 mg/L in Lahore [26]. In another study mean Cd concentration in irrigation water was 0.75 mg/l [6]. Numerous studies around the world establish the translocation of heavy metals to food crops or vegetables from contaminated soil and irrigation water [1, 11, 27, 28].

Heavy Metals Concentration in Soil and Edible Part of Vegetables: Analysis of the physico-chemical properties of soil, irrigated with wastewater, showed that average soil pH values for the two sites were 7.8 and 7.6 respectively. Waste water irrigation tends to decrease the pH of soil and increase Na, Ca, Mg and K [29]. The electric conductivity values were 0.96 mS cm^{-1} and 5.58 mS cm^{-1} while organic matter in the soil of sample-1 was 0.7 mg kg^{-1}, while in sample-2 it was 1.1 mg kg^{-1}.

Heavy metal concentration showed variation in wastewater, soil and selected vegetables (Tables 1 & 2). It is noteworthy that metal concentrations in wastewater were high compared to soil which could be related to the relative insolubility of metals at high soil pH. Metal adsorption and retention in soil is affected by factors like soil pH, amount of organic matter and input rate of metals. The wastewater application leads to transformation of physico-chemical characteristics of soil and heavy metals concentrations [6]. According to the results wastewater application reduces soil pH by 0.5 to 1 units. Furthermore, the wastewater application enhances the level of heavy metals in the soil which is linked with organic matter of soil and negatively linked with pH of the soil.

As regards metal content, soil samples were within safe limits except for Cd which exceeded all standards; concentration determined was 5.6 and 10.6 mg/Kg which were more than the range (1.29-5.18 mg/Kg) reported by Mahmood and Malik in soil irrigated with waste water [26]. Reportedly, Cd levels in soil in Pakistan vary between 0.02 (Normal) and 184 mg/Kg for polluted soil [30].

As anticipated, Cd levels in all vegetables samples also exceeded WHO & CODEX Alimentarius standards [20], with highest concentration observed in Spinach. In Pakistan average Cd concentration as 0.24-2.1 mg/Kg has been reported in vegetables [31]. Also it has been concluded that Cd buildup in aerial parts tends to be more compared to roots and as such vegetables whose stems and leaves are mostly consumed should not specifically grown in areas irrigated with waste water [32, 33]

Cr concentrations in vegetables ranged from 2 mg/Kg -4.4 mg/Kg. The highest chromium content (4.4 mg/Kg) was present in the Cabbage followed by Spinach as heavy metals tend to accumulate more in roots and leaves. Different plants and vegetables have different tendency of heavy metal absorption. Chromium has more absorption tendency in soil but it does not retain in soil for very long time and is taken up by plants. In the present study also, Cr concentration in soil was well below the standards while it is high in vegetables. This is consistent with majority of studies which report Cr content in soil within the tolerable range of 100–150 mg/Kg with global mean soil concentration recognized as 60 mg/Kg [34] while in vegetables it exceeds the Codex limits, being in concurrence to similar studies; one such study reports Cr content as 3.74 and 7.56 mg/Kg in leaf and edible portion of vegetables [9]. Similarly, waste water irrigated spinach has been observed, by Lone *et al.* [35] to show considerably elevated Cr concentration (3.93 mg/Kg) in comparison to spinach grown using, clean water (0.004 mg/Kg).

Lead concentration range between 1.0 -4.2 mg/Kg, with Arvi leaves having the highest concentration. Comparison with WHO / CODEX Alimentarius limits in which maximum level of Pb in green leafy vegetables excluding spinach (0.3 mg/Kg), fruiting vegetable and cucurbits vegetables (0.1 mg/Kg) revealed that Pb concentration was higher than the safe limits in all the vegetables. The concentration of Pb in Arvi leaves was more because heavy metals accumulation, as stated earlier, is more in roots and leaves than in other parts as per CODEX standards. Studies elsewhere in Pakistan showed vegetable Pb levels in the range of 0.03–44 mg/Kg [31]. Likewise, Farooq *et al.* demonstrated Pb amount in edible and leafy portions of vegetables as 27.49 mg/Kg and 15.58 mg/Kg, respectively with 83% of the vegetable samples (edible portion) were found well above the EU (2006) limits [36].

Even though Zinc, constituent of protein, is an important micronutrient due to its role in catalyzing enzyme activity and regulation of gene expression [37] it can pose toxicity at higher exposure. In Gilgit, elevated Zn concentration (271 mg/Kg) was present in *B. campestris* and *M. Sylvestris* (247 mg/Kg) vegetable samples [31]. In present study, all vegetable samples exceeded the Zn permissible limits with highest concentration in cabbage.

While Iron is nontoxic to plants, its presence in excess may render the soil acidic and inhibit the availability of phosphorous and molybdenum. The concentration of Fe was within the safe limits in all the vegetables.

The trends of heavy metals observed in selected vegetables were as follows:

Cu = Cabbage>Spinach>Arvi Leaves>Pumpkin>Green Chili>Egg Plant

Pb = Arvi Leaves>Egg Plant> Spinach> Cabbage>Pumpkin>Green Chili

Fe = Arvi Leaves> Cabbage>Spinach> Green Chili>Egg Plant>Pumpkin

Zn = Cabbage>Green Chili>Spinach>Egg Plant>Pumpkin>Arvi Leaves

Cr = Cabbage>Spinach>Pumpkin>Egg Plant>Arvi Leaves>Green Chili

Cd = Spinach>Cabbage>Pumpkin>Egg Plant>Green Chili>Arvi Leaves

Transfer/ BF of metals from soil to vegetables (Table 3) were found to be in the sequence as follows:

Solanum melongena **(Egg Plant):** Zn (2.226)> Cr (0.863)>Pb (0.221)>Cu (0.092)> Fe (0.051)> Cd (0.049)

Capsicum frutescens **(Green Chilli):** Zn (2.734)> Cr (0.454)> Cu (0.188) > Fe (0.096) >Pb (0.052) > Cd (0.049)

Cucurbita pepo (Pumpkin): Zn (2.031)> Cr (0.909)> Cu (0.236) >Pb (0.105) > Cd (0.037) > Fe (0.0)

Colocasia esculenta **(Arvi Leaves):** Zn (1.843)> Cr (0.795)> Cu (0.306) >Pb (0.231) > Fe (0.192)> Cd (0.049)

Spinacia oleracea **(Spinach):** Zn (2.5)> Cr (0.954)> Cu (0.330) >Pb (0.210) > Fe (0.133)> Cd (0.123)

Brassica oleracea var. capitata **(Cabbage):** Zn (2.812)> Cr (1)> Cu (0.377) > Fe (0.163) >Pb (0.105) > Cd (0.024)

Bio concentration factor (Table 3) depends on vegetable species and nature of soil and it changes due to human and environmental factors. Values greater than 1 shows efficient transfer system of plants [38] while values higher than 0.5 show greater probability of metal accumulation attributed to human interventions [39].

DIM and HRI calculated for study area population (Average 52.7 years), are shown in Table 4. Data showed that DIM in case of vegetables grown along Rohi Nullah was found to be the highest for Zn and lowest for Fe.

The Health risk index for adult population was calculated (Table 4), with maximum HRI (1.18675) for Pb in Arvi leaves and min HRI for Fe in pumpkin. Lead & Zn showed HRI >1 for different vegetables

Results of the present and previous studies demonstrated that heavy metals accumulate in vegetables irrigated with drainage water.

Table 3: Bio concentration factor for the selected vegetables in the soil system irrigated with wastewater.

		Bio concentration/Transfer factor Heavy Metals					
S. No.	Vegetable Samples	Cu	Pb	Fe	Zn	Cr	Cd
1.	Egg Plant	0.092	0.221	0.051	2.226	0.863	0.049
2.	Green Chilli	0.188	0.052	0.096	2.734	0.454	0.049
3.	Pumpkin	0.236	0.105	0.000	2.031	0.909	0.037
4.	Arvi Leaves	0.306	0.231	0.192	1.843	0.795	0.049
5.	Spinach	0.330	0.210	0.133	2.500	0.954	0.123
6.	Cabbage	0.377	0.105	0.163	2.812	1	0.024

Table 4: Estimated DIM (mg / person/day) and HRI of metal concentrations via intake of selected vegetables from the study area

	Egg plant		Pumpkin		Arvi Leaves		Spinach		Cabbage	
Metals	DIM	HRI	DIM	HRI	DIM	HRI	DIM	HRI	DIM	HRI
Cr	003585	0.00239	0.003774	0.002516	0.003302	0.002202	0.003963	0.002642	0.004152	0.002768
Cd	0.000377	0.377419	0.000283	0.283065	0.000377	0.377419	0.000944	0.943548	0.000189	0.18871
Cu	0.00368	0.091996	0.009435	0.235887	0.012266	0.306653	0.01321	0.330242	0.015097	0.377419
Fe	0.003302	0.004718	0	0	0.012266	0.017523	0.008492	0.012131	0.010379	0.014827
Pb	0.003963	1.132258	0.001887	0.539171	0.004152	1.186175	0.003774	0.001887	0.001887	0.539171
Zn	0.268911	0.896371	0.245323	0.000861	0.222677	0.742258	0.301935	1.006452	0.339677	1.132258

*Green Chilies: Daily intake not estimated as it is used *primarily* as spice and/or garnishing purpose only

CONCLUSIONS

It can be concluded that continuous release of agricultural runoff, untreated industrial discharges and drainage of various tributaries carrying municipal and industrial wastewater in Rohi Nullah has profound effect on metal contents and physical properties of Nullah's water, soil and vegetation of the area.

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