Environment Conservation Journal 15(3)157-164, 2014
ISSN 0972-3099 (Print) 2278-5124 (Online)
Abstracted and Indexed

Impact of trace elements pollution of treated industrial effluent and its effect on soil and agriculture produce

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Received: 25.01.2014 Revised: 15.07.2014 Accepted: 02.11.2014

Abstract

In the present study investigation on impact of treated and partially treated industrial effluents on soil and agriculture produce has been carried out. The study find out that parameters (pH, TSS, TDS, BOD, COD, Chloride, Sulphate, Zn, Cu, Pb, Ni, Cr, Cd) of channel water of sampling station-I (8.12, 404 mgl^{-1}, 2624 mgl^{-1}, 122 mgl^{-1}, 331.45 mgl^{-1}, 808 mgl^{-1}, 32.4 mgl^{-1} , 0.36 mgl^{-1} , 0.05 mgl^{-1}, 0.03 mgl^{-1}, 0.04 mgl^{-1}, 4.55 mgl^{-1}, 0.03 mgl^{-1}) was higher than station-II (7.82, 215 mgl^{-1}, 1737 mgl^{-1}, 105 mgl^{-1}, 265 mgl^{-1}, 788 mgl^{-1}, 29.7 mgl^{-1} , 0.31 mgl^{-1}, 0.04 mgl^{-1}, 0.03 mgl^{-1}, 0.03 4.12 mgl^{-1}, 0.02 mgl^{-1}) . Waste water quality of stations I and II meet to exceed the Indian standard (IS: 2490) for BOD- 30 mgl^{-1}, COD-250 mgl^{-1} and Cr- 2 mgl^{-1} for safe disposal of effluents into the surface water. During the course of study soil and agricultural produce has been collected from irrigation of treated or partial treated industrial effluent and analyzed for trace elements i.e. Fe, Zn, Cu, Pb, Ni, Cr and Cd. The trace elements showed different enrichment factor for soil as Cd 8.75(max), Cr 8.6, Zn 5.73, Ni 4.08, Fe 3.16, Cu 2.41, Pb 1.58(min). For plant samples collected at polluted site showed different enrichment factor of trace elements - 6.87 (Cr)> 6.04 (Zn)> 3.34 (Pb)> 3.05 (Cu)> 2.78 (Fe)> 2.30 (Ni)> BDL (Cd). The levels of trace elements concentration in spinach (max) (Fe821, Zn145, Cu19.84, Pb 18.04, Ni 10.1, Cr38.32, Cd0.88 µg/g) and in wheat (min) (Fe326, Zn102, Cu8.23, Pb 12.6, Ni 5.9, Cr21.5, Cd0.21 µg/g) grown on polluted soil were found more than the reference value of control sites in spinach (Fe257, Zn25, Cu6.98, Pb7.43, Ni4.13, Cr5.6, Cd BDL) , which may create chronic health problem to living being through food chain . The highest enrichment factor of agricultural produce (Efp- Fe-2.78,Zn-6.04,Cu-3.05,Pb-3.34,Ni-2.3,Cr-6.87,Cd-0) was found for the element of Cr and for soil, the highest enrichment factor (Efs- - Fe-3.16,Zn-5.73,Cu-2.41,Pb-1.58,Ni-4.08,Cr-8.6,Cd-8.75) was found for element of Cd respectively.

Keywords:*agriculture produce, effluent, enrichment factor, pollution, soil, trace elements*

Introduction

Large numbers of tanneries were located at Jajmau, Kanpur which is one of the major centers for the processing of raw hides. These industries and sewage wastewater is being treated in treatment plant. The treated wastewater is being used for more than two decades for the irrigation of crops and vegetable. According to local information all the plants are adversely affected by contaminated irrigation water. Complaints have been made regarding the deterioration of health of the local inhabitants consuming the local plants produce and using ground water for drinking. There are frequent complaints of water born diseases among people using water from Jajmau area. According to Raj *et al.*,(1996) tanneries, oil refineries and metal industries are causing depletion of surface and ground water quality. Khwaja *et al*., (2001) stated that the major components of the tannery effluents are the toxic trace metals. Presence of heavy metals in soil is known to have potential toxic impact on environmental quality and on human health via ground water and surface water (Mishra and Pandey, 2005; Akinola and Ekiyoyo, 2006). The use of wastewater is now a big problem due to the presence of pollutants particularly heavy metals, however, it is being used for the irrigation of agricultural produce. Long-term irrigation can changes the quality of agricultural soil and trace element inputs which sustained over long period (Barman *et al.*, 2001*;* Gothberg *et al.*, 2002*;* Sinha *et al.*, 2005, 2006). More over concentration of heavy metals in soil may render soils non productive because of phytotoxicity and may cause bioaccumulation of heavy metals in human beings (Abdel-Sahab *et al.*, 1994; Memon *et al.* ,2001; Singh *et al*., 2006). Polluted water, in addition to other effects, directly affects soil not only in

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industrial area but also in agricultural fields as well as the beds of rivers, creating secondary sources of pollution (De *et al*., 1980, 1985; Ray and Banerjee., 1983; Ray *et al*., 1988; Barman and Lal., 1994; Kisku *et al*., 2000; Barman *et al*., 2001). Temmerman *et al*., (1984) reported the upper limit of metals (μgg^{-1}) in non polluted sandy soil; Cd (1.00), Cr (15), Co (5), Cu (15), Hg (0.15), Mn (500), Mo (5), Ni (1), Pb (50), Zn (100).The unregulated use of chromium in many industries has led to the contamination of soil, sediments, surface, and ground water (Barnhart, 1997; Kotas and Stasicka, 2000; Singh and Sinha., 2004a) which causes several environmental problems due to its extreme toxicity to living organism. Similar to other metals, Cr in trace amounts is beneficial to humans, animals, plants and microorganism (Nielsen, 1998). However, at higher concentrations, it is detrimental to health. Keeping this objective in mind the present study was undertaken to assess the trace elements in the treated effluents discharged from tanneries and their impact on soil and plants irrigated with waste water for a long time.

Material and methods

Samples of effluent water were taken from two locations- Station-1 (confluence point of channel receiving effluent), and Station-2 which is 5 km downstream from the first location and analyzed for their quality.The control sites was irrigated by ground water which is situated near about 16 km distance from Station I & II (Fig. 1). The physico-chemical parameters were estimated as per standard procedure (APHA, 2005). Agriculture produce and soil samples were collected during March-April, 2010 from wastewater irrigated area in Jajmau. The wastewater is being used for more than two decades for the irrigation of crops and vegetable. Six edible plants of different species and top productive soil (0-30 cm) samples were collected randomly from polluted site. Soil samples were free from extraneous matter (stones, pebbles etc) and air-dried. After air-drying, the samples were ground and sieved through 2 mm sieve to ensure uniform particle size. The soil samples were analyzed for pH, electrical conductivity, bulk density, porosity, organic matter, nitrite, nitrate, inorganic phosphate

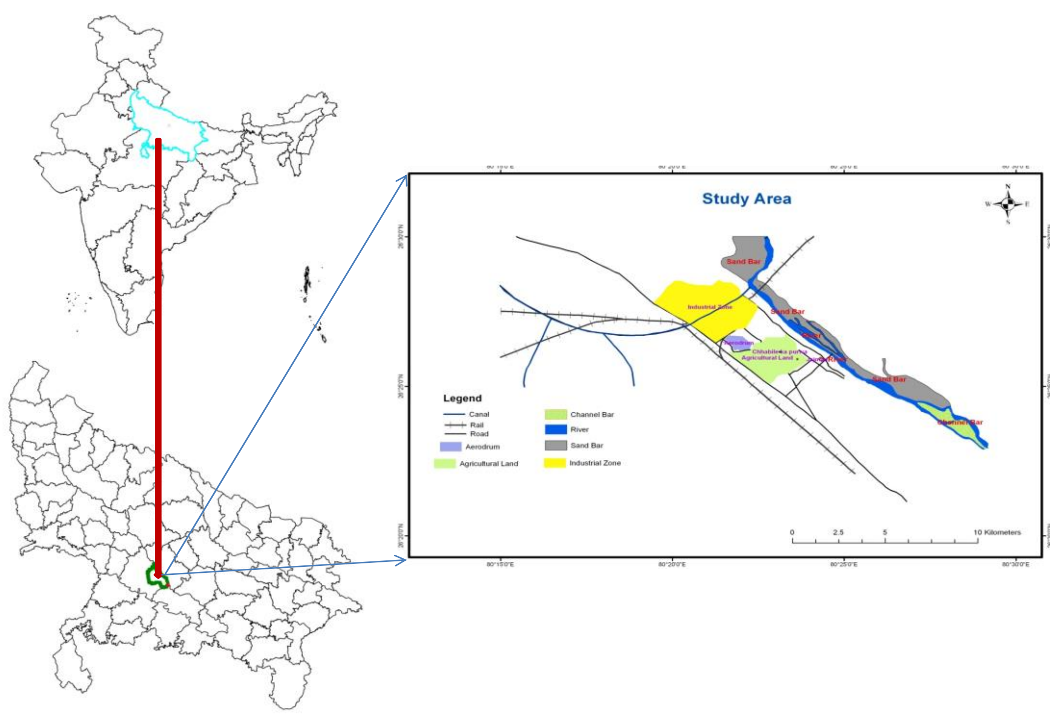

Fig. 1: Map of the study area

and chloride which have a bearing on the availability of trace elements to the plants (Sahu*et al*., 2007). Soil and plant samples were analyzed for the trace elements- Fe, Zn, Cu, Pb, Ni, Cr and Cd using Atomic Absorption Spectrophotometer (AAS). Samples were digested with HNO_3-$HClO_4$ mixture following the method of Barman and Lal (1994). Plant samples were taken in mature stage. For each sample, nine plants were collected and 70^oC for 24 h, grind and mixed thoroughly for metal analysis. All analyses were done in triplicate.

Control soil and plant samples receiving ground water irrigation from deep bore well were also collected at a distance of near about 16 km from polluted site having similar soil profile and climate condition. This area is free from industry. Enrichment factors (Efs/Efp) (Kisku *et al*., 2000) were calculated by fallowing formula:

$$\text{Efs/Efp} = \frac{\textbf{Concentration of the metal in soil or plant at contaminated site}}{\textbf{Concentration of the metal in soil or plant at uncontaminated site}}$$

Results and discussion

Water analysis: The average value of pH, TSS, TDS, BOD, COD, Chloride, Sulphate were found 8.12, 404 mg/l, 2624 mg/l, 122 mg/l, 331.45 mg/l, 808 mg/l, 32.4 mg/l at Station-I and 7.82, 215 mg/l, 1737 mg/l, 105 mg/l, 265 mg/l, 788 mg/l, 29.7 mg/l at Station-II and control area (Tubell water) pH-7.82, TSS-38 mg/l, TDS-314 mg/l, Chloride- 45 mg/l, Sulphate-13 mg/l at respectively (Table-1).

The chemical parameters of station-I was showed higher concentration (pH-8.12, TSS- 404 mg/l, TDS-2624 mg/l, BOD-122 mg/l, COD-331.45 mg/l, Chloride-808 mg/l, Sulphate- 32.4 mg/l) than at Station-II (pH-7.82, TSS-215 mg/l, TDS-1737 mg/l, BOD-105 mg/l, COD- 265 mg/l, Chloride-788 mg/l, Sulphate- 29.7 mg/l) this may be because Station-I was near to outlet. The control site irrigation water qualities were found under the permissible limit. The analysed parameters of irrigation water like TSS, TDS, BOD and COD were found much higher (404 mg/l, 2624 mg/l, 122 mg/l, 331.45 mg/l,) than their respective standards 100 mg/l, 2100 mg/l, 30 mg/l, and 250 mg/l for the final discharged of the industrial effluent water into the inland surface water (IS: 2490, 1981). Irrigation channel water at both sampling station were not found suitable for irrigation, our result are in agreement with several workers who reported that because of improper treatment high chemical load was found in the discharged tannery effluents (Karagul *et al*.,2005; Malaviya and Rathore, 2007).

The average concentrations of trace elements likes Zn, Cu, Pb, Ni, Cr, and Cd were found 0.36 mg/l, 0.05 mg/l, 0.03 mg/l, 0.04 mg/l, 4.55 mg/l, 0.03 mg/l at Station-I, at Station-II were found 0.31 mg/l, 0.04 mg/l, 0.03 mg/l, 0.03 mg/l, 4.12 mg/l, 0.02 mg/l and 0.094 mg/l, 0.012 mg/l, 0.012 mg/l, 0.007 mg/l, 0.016 mg/l, BDL mg/l at control site respectively (Table-I). Except Cr, other observed values i.e Zn, Cu, Pb, Ni, Cr and Cd are found lower than their prescribed standard 5.0 mg/l, 3.0 mg/l, 0.1 mg/l, 3.0 mg/l, 2.0 mg/l, 2.0 mg/l respectively for safe disposal of treated effluent into the inland surface water (IS : 2490,1981). However, chromium concentrations approach the higher limit for disposal (Kannan *et al.*, 2005).

Soils analysis: The average value of pH in polluted soil was found as 7.97 and 7.35 in unpolluted soil. The natures of polluted soil was alkaline this may be due to the continuous receiving of tannery effluents. Average concentrations of chloride and nitrate were found 80.2 mg/g and 0.66 mg/g in polluted soil while 26.2 mg/g and 0.33 mg/g respectively in unpolluted soil (Table-2).

The porosity and organic matter percentage differ from polluted soil (34.9% & 9.8%) in comparison to unpolluted soil (50.1% and 15.6%) (Table-2). These two soil fertility parameters; porosity which collect enough water and air for plant growth and organic matter were markedly decreased due to the receiving of contaminated wastewater (Sahu*et al.*,2007). Bulk density of polluted soil was found as 1.21gm/cc and for unpolluted soil it was observed as 1.1. According to Kolay, 2000 the sandy soil and clay soil should not be more than 1.4 gm/cc and 1.2 gm/cc respectively for optimum crop growth.The average trace elements concentrations of polluted soil were found in Fe (737.4 $\mu g\ g^{-1}$), Zn (212 $\mu g\ g^{-1}$), Cu (34.75 $\mu g\ g^{-1}$), Pb (24.45 $\mu g\ g^{-1}$), Ni (16.73 $\mu g\ g^{-1}$), Cr (164.43 $\mu g\ g^{-1}$), Cd (1.75 $\mu g\ g^{-1}$) d.w. where as in case of unpolluted soil it was found almost in the same sequence of Fe (233 $\mu g\ g^{-1}$), Zn (37 $\mu g\ g^{-1}$), Cu (14.4 $\mu g\ g^{-1}$), Pb (15.5 $\mu g\ g^{-1}$), Ni (4.1 $\mu g\ g^{-1}$), Cr (19.12 $\mu g\ g^{-1}$), Cd (0.2 $\mu g\ g^{-1}$) d.w. respectively in unpolluted soil (Table-2). Polluted soil showed different enrichment factor- 8.75 (Cd)> 8.6 (Cr)> 5.73 (Zn)> 4.08 (Ni)> 3.16 (Fe)> 2.41 (Cu)> 1.58 (Pb) times higher trace

Table-1: Study of water quality at station I, station II and control area

S.N.	Parameter	Unit	Study Area		
			Station-I	Station-II	Control Area
1	Color	Visual	Light Gray	Light Gray	Colorless
2	Odor	---	Unpleasant	Unpleasant	Odorless
3	TSS	mgl^{-1}	404	215	38
4	TDS	mgl^{-1}	2624	1737	314
5	TS	mgl^{-1}	3028	1952	352
6	pH		8.12	7.82	7.57
7	BOD	mgl-1	122	105	-----
8	COD	mgl-1	331.45	265	-----
9	Chloride	mgl-1	808	788	45
10	Sulphate	mgl-1	32.4	29.7	13
11	Zn	mgl-1	0.36	0.31	0.094
12	Cu	mgl-1	0.05	0.04	0.012
13	Pb	mgl-1	0.03	0.03	0.012
14	Ni	mgl-1	0.04	0.03	0.007
15	Cr	mgl-1	4.55	4.12	0.016
16	Cd	mgl-1	0.03	0.02	BDL

Table2: Average concentrations of different parameter of unpolluted soil and polluted soil

S.N.	Parameters	Unit	Control Area	Study Area
1	pH		7.35	7.97
2	Electrical Conductivity	µS cm-1	212	387
3	Bulk density	gm/cc	1.1	1.21
4	Porosity	%	50.1	34.9
5	Organic matter	%	15.6	9.8
6	Chloride	$mg\ g^{-1}$	26.2	80.2
7	Nitrate	$mg\ g^{-1}$	0.33	0.66
8	Fe	$\mu g\ g^{-1}$	233	737.4
9	Zn	$\mu g\ g^{-1}$	37	212
10	Cu	$\mu g\ g^{-1}$	14.4	34.75
11	Pb	$\mu g\ g^{-1}$	15.5	24.45
12	Ni	$\mu g\ g^{-1}$	4.1	16.73
13	Cr	$\mu g\ g^{-1}$	19.12	164.43
14	Cd	$\mu g\ g^{-1}$	0.2	1.75

elements level than unpolluted soil. Increases of the such trace elements in soil irrigated with industrial effluent may be the source of bioaccumulation in agriculture plant grown on this land which not only affect the yield/ hectare but also fare chance to pass on to food web (Nath *et al.*, 2005; Hooda, 2007).

Agriculture produce: The Plant samples of polluted site also showed different enrichment factor (metal vies) - 6.87 (Cr)> 6.04 (Zn)> 3.34 (Pb)> 3.05 (Cu)> 2.78 (Fe)> 2.30 (Ni)>BDL (Cd).

The levels of trace elements concentration in spinach (max) (Fe821 $\mu g\ g^{-1}$, Zn145 $\mu g\ g^{-1}$, Cu 19.84$\mu g\ g^{-1}$, Pb 18.04 $\mu g\ g^{-1}$, Ni 10.1 $\mu g\ g^{-1}$, Cr 38.32 $\mu g\ g^{-1}$, Cd 0.88 $\mu g\ g^{-1}$) and in wheat (min) (Fe 326 $\mu g\ g^{-1}$, Zn 102 $\mu g\ g^{-1}$, Cu 8.23 $\mu g\ g^{-1}$, Pb 12.6 $\mu g\ g^{-1}$, Ni 5.9 $\mu g\ g^{-1}$, Cr 21.5 $\mu g\ g^{-1}$, Cd 0.21 $\mu g\ g^{-1}$) grown on polluted soil were found more than the reference value of control sites, These results shows that irrigation channel water enriches the trace elements content. Enrichment of the trace elements content in water and soil shows greater uptake (Fig. 2,3), translocation and retention of metal in different tissues (Li *et al*., 2003; Greger and Lofstedt, 2004; Boularbah *et al*., 2006).The trace elements level of Fe 821 µg g^{-1}spinach (whole plant), Zn 145 µg g^{-1}spinach (whole plant), Cr 38.32 µg g^{-1}spinach (whole plant), Ni 10.1 µg g^{-1}spinach (whole plant), Pb 18.04 µg g^{-1} spinach (whole plant), Cd 0.88 µg g^{-1}spinach (whole plant), Cu 19. 84 µg g^{-1}spinach (whole plant) of metalswere found in plant on polluted site (Table-3,4).

Table3: Average concentration (µg $g^{-1)}$ of trace elements in different plants grown on polluted soil

Plant name	Fe (µg g^{-1})	Zn (µg g^{-1})	Cu (µg g^{-1})	Pb (µg g^{-1})	Ni (µg g^{-1})	Cr (µg g^{-1})	Cd (µg g^{-1})
Spinach (*Spinacia oleracea*)	821	145	19.84	18.04	10.1	38.32	0.88
Wheat (*Triticum aestivum*)	326	102	8.23	12.6	5.9	21.5	0.21
Black Musterd (*Brassica campestries*)	690	121	13.43	17.1	7.81	29.2	0.63
Potato (*Solanum tuberosum*)	495	125	16.2	25.3	7.09	22.34	0.41
Cabbage(*Brassica oleracea*)	750	130	14.2	16.6	8.3	33.02	0.61
Cucumber (*Cucumus melo*)	474.5	105	17.61	14.01	4.12	27.94	0.52
Cultivated plant Avg	592.8	121.3	14.92	17.28	7.22	28.72	0.54

Table 4: Average concentration (µg g^{-1}) of trace elements in different plants grown at control site.

Plant name	Fe (µg g^{-1})	Zn (µg g^{-1})	Cu (µg g^{-1})	Pb (µg g^{-1})	Ni (µg g^{-1})	Cr (µg g^{-1})	Cd (µg g^{-1})
Spinach (*Spinacia oleracea)*	257	25	6.98	7.43	4.13	5.6	BDL
Wheat (*Triticum aestivum*)	159	12	3.7	3.1	1.81	3.1	BDL
Black Musterd (*Brassica campestries*)	240	20	4.02	6.1	4.03	4.16	BDL
Potato (*Solanum tuberosum*)	210	18.5	4.34	4.5	4.25	4.1	BDL
Cabbage (*Brassica oleracea*)	228	26	5.38	5.9	2.5	4.32	BDL
Cucumber (*Cucumus melo*)	185	19	4.88	4	2.1	3.8	BDL
Cultivated plant Avg.	213.17	20.08	4.88	5.17	3.14	4.18	--

(n= 3, BDL= Below Detection Limit)

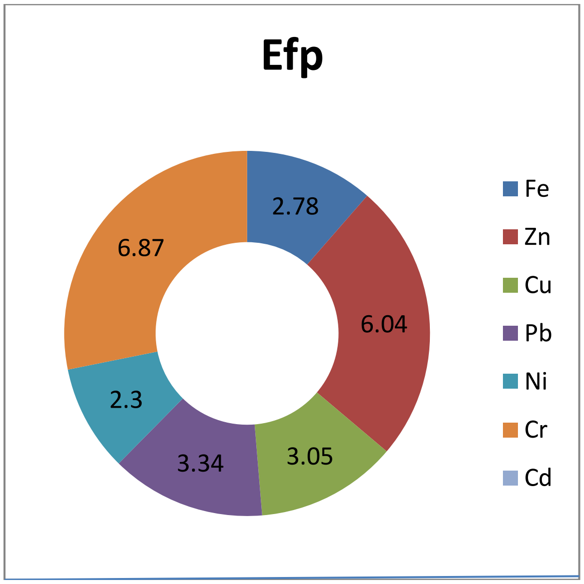

Fig.2: Enrichment factor of agriculture produce (Efp) of different trace elements

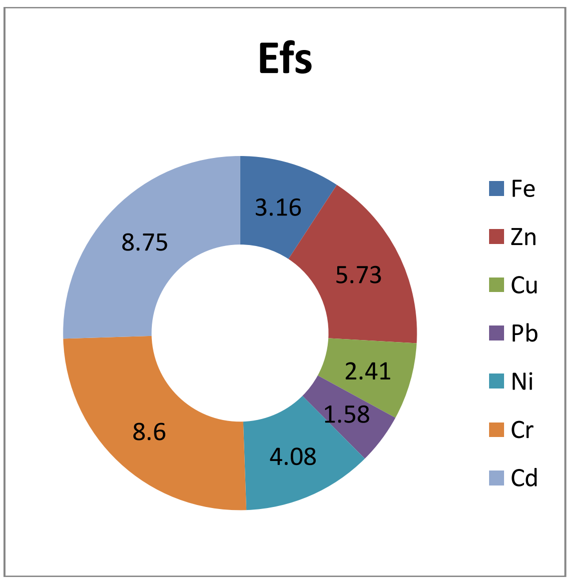

Fig.3: Enrichment factor of soil (Efs) of different trace elements

The consumption of cereal/ grains or leafy plants has high content of Cr for a long period, shows to cause the fetal disease (Sinha *et al.*, 2006). Chromium is regarded as priority pollutant by USEPA due to its carcinogenicity and mutagencity (Cohen *et al.*, 1993, Cieslak- Golonka, 1995). When such metals laden plants and their foodstuffs are consumed they pose a serious health hazard to human being through food-chain biomagnifications resulting into catastrophic episodes (Nriagu, 1988). The daily intake of such plants that accumulate more toxic elements should be avoided for consumption. Mostly this is very important in the case of edible species particularly leafy vegetables (spinach) and root/tuber vegetables (potato). Whatever the amount accumulated by leafy and root/tuber vegetable, there is a more chance of direct entery into human diet (Kisku *et al*., 2000). There are many studies where the significantly high accumulation of metal in leaf of the plants was observed (Voutsa *et al*., 1996). Similarly, Farooq *et al*. (1999) also observed the accumulation in the vegetables collected from dry bed River in the city of Kanpur and found more accumulation in leafy vegetables than fruit bearing vegetables. Sinha *et al.*(2006) studied the accumulation of different metals in edible parts of plants and found that accumulation was high in leafy vegetables in comparison to non-leafy vegetable/crops, they also reported that the leafy vegetables were unfavorable to grow in this contaminated agriculture area. Our studies found that the Spinach showed high accumulation of trace elements (Fe821 µg g^{-1}, Zn145 µg g^{-1}, Cu19.84µg g^{-1}, Pb 18.04 µg g^{-1}, Ni 10.1 µg g^{-1}, Cr 38.32 µg g^{-1}, Cd 0.88 µg g^{-1}) and Wheat showed low accumulation of trace elements (Fe 326 µg g^{-1}, Zn 102 µg g^{-1}, Cu 8.23 µg g^{-1} , Pb 12.6 µg g^{-1}, Ni 5.9 µg g^{-1}, Cr 21.5 µg g^{-1}, Cd 0.21 µg g^{-1}). Plants sample showed higher enrichment factor of chromium 87 (Cr)> 6.04 (Zn)> 3.34 (Pb)> 3.05 (Cu)> 2.78 (Fe)> 2.30 (Ni)>BDL (Cd) because tanneries and lather industries situated in polluted area. The result of this study was found that leafy plants may cause high exposure risk than grain. So, leafy vegetables are not suitable to grow in this type of polluted area.

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