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Assessment of metals in vegetables irrigated with biomethnated textile effluent at Haridwar (Uttarakhand), India

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ABSTRACT

The present study showed that irrigation of soil with biomethnated textile effluent (BMTE) resulted in significant ($P<0.01$) changes in chlorides (Cl^-), organic carbon (OC), sodium (Na^+), potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), total Kjeldahl nitrogen (TKN), phosphate (PO_4^{3-}), sulphate (SO_4^{2-}), iron (Fe), zinc (Zn), cadmium (Cd), copper (Cu), chromium (Cr), nickel (Ni) and cobalt (Co) of the soil. The significant ($P<0.05$) accumulation of metals viz. Fe, Zn, Cd, Cu, Cr, Co, and Ni were also recorded in the different parts (shoot, root, leaves, and fruit) of P. vulgaris, V. radiata, V. faba and L. usitatissimum crops after irrigation with BMTE in comparison to bore well water (BWW). The maximum content of metals was observed in the root of P. vulgaris, shoot of V. radiata, fruit of V. faba and leaves of L. usitatissimum after irrigation with BMTE. The contamination factor was observed to be crop specific. The maximum contamination factor was found of Ni for P. vulgaris, Co for V. radiata and L. usitatissimum and Cr for V. faba after irrigation with BMTE.

Keywords: Textile effluent, Metals, Vegetables, Contamination factor.

INTRODUCTION

The untreated wastewater irrigation on urban and sub-urban lands has long been practiced in several parts of the world due to its high contents of plant nutrients and due to lack of infrastructure and facilities for safe disposal [17; 18]. The urban agricultural soils are often irrigated with city effluents for growing vegetables [10; 16]. Farmers used it as a source of irrigation and nutrients [8; 15; 21] while the administrators consider it a viable practice for disposal. Trace elements are the essential part of rock and soil, natural waters and living matters. It is well known that the biomass uptakes trace metals naturally available to them through soil and have even stored them in their tissues. Pollution of soil and water with metals is currently of great concern to human health. Among 90 naturally occurring elements, 53 are heavy metals, but only 17 are bioavailable and important for ecosystems. Despite Mo, Cu, Cr and Co are essential micronutrients; however some of them are toxic in slightly higher concentrations. In contrast, Ni, As, Hg, Ag, Sb, Cd, Pb and U are toxic elements for living organisms [7; 19; 22]. The nature of soil is considered one of the most important factors that determine metal content of food plants [11; 17]. Metals accumulation in agricultural soils pose long-term problem of up-take, accumulation with its negative human and animal health implications [5; 20]. Around the world where farming activities and land utilization especially for industrial purposes are regulated, the major anthropogenic sources of metal contamination of agricultural soils are via fertilizer application, sewage sludge or irrigation with wastewater [6; 16; 22]. It is believed that in most cases, the metals in these soils are taken up by plants via the roots and later accumulated in the stem and other edible portions of plants which eventually lead to poisoning when consumed [14; 18]. Some plant species have developed strategies for avoiding toxic concentrations build up of heavy metals at sensitive sites within the cell. If metals are absorbed by the plants, they may be stored away from metabolically active compartments, thus preventing phytotoxic effects [13; 19; 23]. Thus the present investigation was undertaken to assess the contamination of metals in vegetables irrigated with biomethnated textile effluent at Haridwar (Uttarakhand), India.

MATERIALS AND METHODS

Experimental design

A field study experiment was conducted in the Experimental Garden of the Department of Zoology and Environmental Sciences, Faculty of Life Sciences, Gurukula Kangri University Haridwar (29°55'10.81" N and 78°07'08.12" E), for studying the effect of biomethnated textile effluent (BMTE) on *Phaseolus vulgaris*, *Vigna radiata, Vica faba* and *Linum usitatissimum* during the year 2009 and 2010. Pots (dia-30cm.) were used for growing the crop plants. The pots were arranged in a completely randomized design. The experiment was replicated by six times in both the years.

Effluent collection and analysis

The Rishabh Velveleen (Pvt.) Ltd. Haridwar located at Delhi Dehradun National Highway (NH-58) near Haridwar city was selected for the collection of effluent. The effluent was collected in the plastic containers from the outlet of the biomethanation unit of effluent treatment plant situated in the campus of the textile mill. The effluent was brought to the laboratory and then analyzed for various parameters viz. total dissolved solids (TDS), pH, electrical conductivity (EC), dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), chlorides (Cl^-), bicarbonate (HCO_3^-), carbonates (CO_3^{2-}), sodium (Na^+), potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), total Kjeldahl nitrogen (TKN), nitrate (NO_3^{2-}), phosphate (PO_4^{3-}), sulphate (SO_4^{2-}), iron (Fe), zinc (Zn), cadmium (Cd), copper (Cu), chromium (Cr), cobalt (Co) and nickel (Ni) content following standard methods [1; 4].

Soil sampling and analysis

The soil was analyzed before crop sowing and after crop harvesting for various physico-chemical parameters viz. moisture content, bulk density, and water holding capacity, EC, pH, OC, Na^+, K^+, Ca^{2+}, Mg^{2+}, Fe^{2+}, TKN, PO_4^{3-}, SO_4^{2-}, Zn, Cd, Cu, Cr, Co and Ni were determined by using standard methods adopted by [4].

Sowing of seeds, irrigation pattern and collection of crop parameters data

The seeds of *P. vulgaris*, *V. radiata*, *V. faba* and *L. usitatissimum* were procured from ICAR, Pusa, New Delhi and sterilized with 0.01 mercuric chloride and was soaked for 12 hrs. Seven seeds of each crop were sown at equal distance of 7.5 cm. Five plants were maintained in each pot by thinning out of the seven. 500 ml BMTE per 5 kg soil was applied twice in a week for irrigation and no drainage was allowed. The plant materials were collected to determine metals content after harvesting the crops [3].

Digestion process for metals analysis

For the extraction of metals, 5-10 ml sample of effluent, 0.5-1.0 g sample of air dried soil/plant was taken in digestion tube. 3 ml conc. HNO_3 was added and digested the sample on electrically heated block for 1 hour at 145° C. Then added 4 ml of $HClO_4$ and heated to 240° C for an additional hour. Aliquot was cooled, filtered through Whatman # 42 filter paper and made the volume 50 ml with double distilled water and used for analysis. The metals were analyzed by using Atomic absorption spectrophotometer (PerkinElmer Analyst 800 AAS) following standard methods [1; 4]. The contamination factor (Cf) for metals accumulated in BMTE irrigated soil and in crop plants was calculated by following [9].

$$\text{Contamination factor (Cf)} = \frac{\text{Mean content of metal in the sample}}{\text{Mean metal content in the control}}$$

Statistical analysis

The values reported here are means of twelve values (two years). Data were tested at different significant levels using student t-test to measure the variations between the soil parameters before and after irrigation of these crops with BMTE. One way analysis of variance (ANOVA) was used for data analysis to measure the variations of metals in different parts of these crops before and after effluent irrigation. Mean standard deviation of soil and crop parameters with effluent were calculated with the help of MS Excel, 2003. The graphical work was carried out using Sigma plot, 2000.

RESULTS AND DISCUSSION

Characteristics of textile effluent

The characteristics of BMTE (Table 1) showed that it was slightly acidic in nature pH (6.87). Among various parameters, BOD, COD, Cl^-, Ca^{2+}, TKN, NO_3^{2-}, SO_4^{2-}, Fe^{2+}, Zn, Cd, Cu, Co, Cr, Ni, MPN and SPC were found beyond the prescribed limit of Indian Irrigation Standards [15].

Table 1. Physico-chemical and heavy metal characteristics of control (Bore well water) and biomethnated textile effluent of Rishabh Velveleen (Pvt.) Ltd. Haridwar

Parameters	0 (BWW)[a]	Textile effluent	BIS for irrigation water
TDS(mg L^{-1})	221.50±10.75	4396.80±8.41	1900
EC(dS m^{-1})	0.34±0.12	6.87±1.42	-
pH	7.52±0.24	6.87±0.31	5.5-9.0
DO(mg L^{-1})	8.24±2.65	1.18±0.14	-
BOD(mg L^{-1})	3.83±0.59	2462.50±11.82	100
COD(mg L^{-1})	5.88±1.37	6495.50±11.82	250
Cl^-(mg L^{-1})	15.68±2.50	1298.00±10.95	500
HCO_3^-(mg L^{-1})	282.00±13.95	1884.50±8.39	-
CO_3^{2-}(mg L^{-1})	105.75±5.91	285.25±9.57	-
Na^+ (mg L^{-1})	9.65±1.25	217.00±5.29	-
K^+ (mg L^{-1})	5.54±2.25	408.75±7.72	-
Ca^{2+} (mg L^{-1})	23.46±4.16	1425.00±10.00	200
Mg^{2+}(mg L^{-1})	12.15±1.50	231.00±5.29	-
TKN (mg L^{-1})	24.27±5.08	456.00±10.77	100
NO_3^{2-} (mg L^{-1})	25.17±4.16	1139.50±7.72	100
PO_4^{3-} (mg L^{-1})	0.04±0.01	476.50±9.71	-
SO_4^{2-} (mg L^{-1})	17.64±2.57	954.50±5.97	1000
Fe (mg L^{-1})	0.28±0.04	52.75±4.27	1.0
Zn (mg Kg^{-1})	0.06±0.02	29.24±2.41	15
Cd (mg Kg^{-1})	0.1±0.01	35.99±3.76	2.00
Cu (mg Kg^{-1})	0.04±0.01	29.50±2.60	3.00
Co (mg Kg^{-1})	0.02±0.01	36.30±2.88	1.00
Cr (mg Kg^{-1})	0.04±0.02	47.54±4.37	2.00
Ni (mg Kg^{-1})	0.02±0.02	25.64±2.11	1.00
SPC(SPC ml^{-1})	98±6.20	$4.36x10^8$±245	10000
MPN(MPN100 ml^{-1})	$2.96x10^1$±15.25	$8.62x10^5$±882	5000

Mean ±SD of twelve values
a-Borewell water

Characteristics of soil

The characteristics of the soil before and after irrigation with BMTE are given in Table 2. The student t-test analysis showed that BMTE irrigation had significant (P<0.01) change in Cl^-, OC, Na^+, K^+, Ca^{2+}, Mg^{2+}, TKN, PO_4^{3-}, SO_4^{2-} of the soil used in the cultivation of *P. vulgaris, V. radiata, V. faba* and *L. usitatissimum*. More significant (P<0.001) change was recorded in OC, Fe, Zn, Cd, Cu, Cr, Ni and Co of the soil after irrigation with BMTE. The BMTE showed no significant change in moisture content, water holding capacity (WHC), bulk density (BD), pH and EC in the soil used for the cultivation of all the crops. The BMTE irrigation increased the metals, Fe. Zn, Cd, Cu, Ni, Cr and Co in the soil used for the cultivation of *P. vulgaris, V. radiata, V. faba* and *L. usitatissimum* respectively (Table 2). The contamination of metals in the soil were observed in order of Cd>Ni>Cr>Co>Zn>Cu>Fe for *P. vulgaris, V. faba* and Cd>Ni>Cr>Co>Zn>Fe>Cu for *V. radiata* and *L. usitatissimum* after irrigation with BMTE (Table 3). Among metals the maximum contamination factor was found of Cd (538.00, 708.00, 417.00 and 321.50) for the soil used for *P. vulgaris, V. radiata, V. faba* and *L. usitatissimum* cultivation with BMTE (Table 3). Kaushik et al. [12] also reported that the distillery effluent irrigation increase the EC, pH, OC, TKN, available phosphorus, exchangeable Na, K, Ca, Mg of the soil. Vinod and Chopra [15] observed earlier that distillery effluent irrigation increased the EC, Cl^-, TOC, HCO_3^-, CO_3^{2-}, Na^+, K^+, Ca^{2+}, Mg^{2+}, TKN, NO_3^{2-}, PO_4^{3-} and SO_4^{2-}, Fe, Zn, Cd, Cu, Pb and Cr of the soil. Among the metals the maximum enrichment factor was shown by Cd (31.33) while the minimum by Fe (4.59) and it was in order of Cd>Cr>Pb>Zn>Cu>Fe after irrigation with distillery effluent. The findings are much accordance with Vinod and Chopra (2012).

Table 2. Changes in physico-chemical and heavy metals characteristics of soil used in the cultivation of *P. vulgaris*, *V. radiata*, *V. faba* and *L. usitatissimum* after irrigation with biomethnated textile effluent

Parameters	Before effluent irrigation (Control)	After irrigation with textile effluent			
		P. vulgaris	***V. radiata***	***V. faba***	***L. usitatissimum***
Soil moisture (%)	43.81±4.88	35.55^{NS} ±2.37 (-18.85)	37.23^{NS} ±3.43 (-15.01)	36.76^{NS} ±3.21 (-16.09)	39.55^{NS} ±2.87 (-9.72)
WHC (%)	48.76±1.08	45.04^{NS} ±2.20 (-7.62)	44.74^{NS} ±2.34 (-8.24)	45.66^{NS} ±2.20 (-6.35)	41.24^{NS} ±2.54 (-15.42)
BD (gm cm^{-3})	1.53±0.06	1.47^{NS}±0.02 (-3.92)	1.48^{NS} ±0.04 (-3.26)	1.46^{NS} ±0.07 (-4.57)	1.45^{NS} ±0.06 (-5.22)
EC (dS m^{-1})	2.10±0.09	3.04^{NS} ±0.14 (+44.76)	3.14^{NS} ±0.17 (+49.52)	2.94^{NS} ±0.12 (+40.00)	2.74^{NS} ±0.19 (+30.47)
pH	8.21±0.24	8.15^{NS} ±0.07 (-0.73)	8.16^{NS} ±0.06 (-0.60)	8.20^{NS} ±0.04 (-0.12)	8.19^{NS} ±0.08 (-0.24)
OC(mg Kg^{-1})	0.45±0.10	7.62***±0.66 (+1593.33)	8.82***±0.34 (+1860.00)	6.94***±0.57 (+1442.22)	7.87***±0.64 (+1648.88)
Cl^- (mg Kg^{-1})	89.05±1.82	162.22**±2.11 (+82.16)	164.52**±2.46 (+84.75)	156.34**±2.65 (+75.56)	152.64**±2.42 (+71.40)
Na^+ (mg Kg^{-1})	18.32±3.09	31.49**±5.15 (+71.88)	34.56**±5.76 (+88.64)	30.42**±3.15 (+66.04)	29.34**±4.15 (+60.15)
K+ (mg Kg -1)	154.09±6.70	217.78** ±3.47 (+41.33)	227.74** ±3.56 (+47.79)	211.22** ±3.45 (+37.07)	220.74** ±3.48 (+43.25)
Ca^{2+} (mg Kg^{-1})	14.40±2.79	133.31**±2.60 (+825.76)	153.48**±2.76 (+965.83)	123.64**±2.66 (+758.61)	143.44**±2.64 (+896.11)
Mg^{2+}(mg Kg^{-1})	1.68±0.60	15.55**±2.79 (+825.59)	18.67**±2.43 (+1011.30)	13.23**±2.56 (+687.50)	12.50**±2.75 (+644.04)
TKN(mg Kg^{-1})	29.22±3.85	242.36**±3.60 (+729.43)	252.22**±3.34 (+763.17)	232.36**±3.56 (+695.20)	248.12**±2.89 (+749.14)
PO_4^{3-} (mg Kg^{-1})	52.45±3.64	115.94**±2.23 (+121.04)	125.45**±2.67 (+139.18)	110.96**±2.27 (+111.55)	120.32**±2.68 (+129.39)
SO_4^{2-} (mg Kg^{-1})	73.05±6.57	103.15**±3.30 (+41.20)	119.35**±3.36 (+63.38)	113.13**±2.30 (+54.86)	116.25**±3.13 (+59.13)
Fe (mg Kg^{-1})	2.63±0.99	18.58***±1.15 (+606.46)	23.98***±2.15 (+811.78)	12.67***±2.15 (+381.74)	16.58***±2.15 (+530.41)
Zn (mg Kg^{-1})	0.78±0.16	12.61***±2.02 (+1516.66)	18.94***±3.23 (+2328.20)	8.65***±3.24 (+1008.97)	10.51***±2.42 (+1247.43)
Cd (mg Kg^{-1})	0.02±0.01	10.76***±2.56 (+53700.00)	14.16***±2.11 (+70700.00)	8.34***±2.37 (+41600.00)	6.43***±1.01 (+32050.00)
Cu (mg Kg^{-1})	1.99±0.33	14.56***±3.50 (+631.65)	16.07***±2.16 (+707.53)	10.09***±2.29 (+407.03)	8.76***±2.11 (+340.20)
Ni (mg Kg^{-1})	0.06±0.02	10.31***±2.25 (+17083.33)	13.51***±2.04 (+22416.66)	7.65***±1.08 (+12650.00)	8.21***±1.14 (+13583.33)
Cr (mg Kg^{-1})	0.11±0.06	7.85***±1.32 (+7036.36)	8.98***±1.06 (+8063.63)	5.15***±1.03 (+4581.81)	6.80***±1.00 (+6081.81)
Co (mg Kg^{-1})	0.10±0.06	6.25***±1.13 (+6150.00)	7.75***±0.03 (+7650.00)	3.45***±1.65 (+3350.00)	5.25***±1.07 (+5150.00)

*Mean ±SD of twelve values; Significant t-***P>0.01% level: **P>1% level; *P>5% level; NS-not significant; %increase and decrease in comparison to control given in parenthesis.*

Metals in vegetables

The content of various metals in *P. vulgaris, V. radiata, V. faba* and *L. usitatissimum* after irrigation with BMTE are shown in Table 4 and Figs. 1, 2, 3, 4. BMTE irrigation affected the accumulation of various metals in the entire crop plants viz. *P. vulgaris, V. radiata, V. faba* and *L. usitatissimum* differently. The concentration of Cd, Cu, Cr, Co and Ni were found to be significantly ($P<0.05$) different in various plant parts viz. shoot, root, leaves and fruits of *P. vulgaris, V. radiata, V. faba* and *L. usitatissimum* after irrigation with BMTE in comparison to their respective control (BWW). The content of Fe and Zn were also recorded to be significantly ($P<0.05$) different in the shoot, root, leaves and fruit of *V. radiata, V. faba* and *L. usitatissimum* whereas these were found to be insignificantly ($P>0.05$) different in shoot, root, leaves and fruit of *P. vulgaris* after irrigation with BMTE in comparison to control.

Table 3. Contamination factor of various heavy metals in the soil after irrigation of different crops plants with biomethnated textile effluent

Crop plants	Fe	Zn	Cu	Cd	Cr	Co	Ni
P. vulgaris	7.06	16.16	7.31	538.00	71.36	62.50	171.83
V. radiata	9.11	24.28	8.07	708.00	81.63	77.50	225.16
V. faba	4.81	11.08	5.07	417.00	46.81	34.50	127.50
L. usitatissimum	6.30	13.47	4.40	321.50	61.81	52.50	136.83

Table 4. Content of heavy metals in *P. vulgaris, V. radiata, V. faba* and *L. usitatissimum* after irrigation with biomethnated textile effluent

Crop plant	Plant parts	Content of heavy metals (mg Kg^{-1}) in vegetables after irrigation with control (BWW) and biomethnated textile effluent													
		Fe		Zn		Cd		Cu		Cr		Co		Ni	
		BWW	TE	BWW	TE	BWW	TE	BWW	TE	BWW	TE	BWW	TE	BWW	TE
P. vulgaris	Shoot	2.66±0.10	3.44±0.15	2.54±0.99	4.56±0.95	1.04±0.08	2.34a±0.01	1.04±0.05	3.65a±0.20	0.88±0.04	1.23a±0.06	0.33±0.03	1.75a±0.09	0.22±0.05	1.43a±0.15
	Root	3.78±0.16	4.98±0.16	3.77±0.76	5.78±0.56	1.12±0.07	2.98a±0.02	1.23±0.06	3.99a±0.23	1.02±0.03	1.98a±0.11	0.42±0.01	1.96a±0.08	0.34±0.01	1.57a±0.10
	Leaf	1.87±0.08	2.65±0.13	2.66±0.65	3.59±0.68	1.01±0.04	1.45a±0.03	1.05±0.05	2.87a±0.32	0.67±0.01	1.13a±0.09	0.29±0.00	1.01a±0.03	0.12±0.03	1.24a±0.11
	Fruit	1.23±0.05	1.75±0.09	2.34±0.58	2.87±0.78	0.34±0.08	1.01a±0.04	0.54±0.00	2.14a±0.65	0.21±0.00	0.87a±0.03	0.08±0.00	0.76a±0.06	0.09±0.04	0.75a±0.03
	Mean	2.39	3.21	2.83	4.20	0.88	1.95	0.97	3.16	0.70	1.30	0.28	1.37	0.19	1.25
	F-stat.	CD-4.10; CF-2.11NS		CD-2.33; CF-1.52NS		CD-0.12; CF-1.36*		CD-1.40; CF-2.03*		CD-0.16; CF-1.78*		CD-0.25; CF-6.83**		CD-0.50; CF-4.65**	
V. radiata	Shoot	4.63±0.99	6.93a±0.90	3.98±0.12	5.67a±0.89	1.09±0.05	2.63a±0.99	1.63±0.08	4.69a±0.01	1.33±0.23	6.93a±0.89	1.08±0.05	5.67a±0.95	1.05±0.49	5.13a±0.99
	Root	2.45±0.12	5.87a±0.10	2.87±0.09	4.64a±0.07	0.86±0.03	1.98a±0.01	1.12±0.08	3.76a±0.00	0.98±0.06	5.48a±0.13	0.65±0.02	4.88a±0.12	0.45±0.08	4.11a±0.21
	Leaf	2.33±0.06	5.43a±0.13	2.23±0.12	3.28a±0.04	0.65±0.07	1.44a±0.09	0.54±0.06	2.67a±0.02	0.67±0.02	4.39a±0.15	0.22±0.00	3.85a±0.15	0.21±0.05	3.09a±0.10
	Fruit	1.28±0.03	3.44a±0.11	1.78±0.04	2.76a±0.09	0.43±0.02	1.09a±0.05	0.10±0.02	1.88a±0.04	0.13±0.04	3.98a±0.17	0.08±0.00	2.76a±0.18	0.06±0.01	2.05a±0.12
	Mean	2.67	5.42	2.72	4.09	0.76	1.79	0.85	3.25	0.78	5.20	0.51	4.29	0.44	3.60
	F-stat.	CD-1.10; CF-2.45*		CD-0.33; CF-3.12*		CD-0.12; CF-1.36*		CD-0.11; CF-2.43*		CD-2.16; CF-9.78**		CD-2.45; CF-9.80**		CD-2.56; CF-8.61**	
V. faba	Shoot	4.52±0.51	8.98a±1.20	3.44±0.54	5.67a±1.08	1.14±0.06	4.30a±0.37	1.21±0.02	4.98a±0.65	1.03±0.09	7.88a±1.11	1.12±0.07	6.43a±1.02	1.08±0.07	4.56a±0.77
	Root	4.12±0.99	7.45a±1.27	3.22±0.23	5.21a±1.01	1.01±0.08	3.63a±0.45	1.10±0.04	4.54a±0.34	0.85±0.00	6.54a±1.06	1.01±0.04	5.46a±1.06	0.65±0.04	4.11a±0.84
	Leaf	4.22±0.56	6.56a±1.34	3.87±0.40	5.99a±1.02	1.12±0.05	4.45a±0.66	1.34±0.09	4.77a±0.65	1.12±0.03	7.12a±1.00	1.09±0.05	5.98a±1.03	0.98±0.05	4.32a±0.49
	Fruit	5.67±1.01	9.43a±1.23	4.51±0.62	6.21a±1.06	1.77±0.03	4.89a±0.56	1.86±0.05	5.63a±0.77	1.33±0.07	8.66a±1.03	1.21±0.02	7.32a±1.02	1.21±0.08	5.22a±0.67
	Mean	4.63	8.11	3.76	5.77	1.26	4.32	1.38	4.98	1.08	7.55	1.11	6.30	0.98	4.55
	F-stat.	CD-0.20; CF-6.34**		CD-0.64; CF-5.15**		CD-0.22; CF-4.39*		CD-0.61; CF-4.67*		CD-0.16; CF-8.33**		CD-0.67; CF-9.00**		CD-1.56; CF-6.98**	
L. usitatissimum	Shoot	1.59±0.33	5.32a±0.92	1.09±0.08	4.21a±0.19	1.05±0.02	5.76a±0.23	1.05±0.04	4.32a±0.33	0.98±0.03	6.10a±1.23	0.77±0.01	5.59a±0.93	0.97±0.04	3.14a±0.22
	Root	1.44±0.12	4.30a±0.76	1.01±0.02	4.05a±0.09	1.00±0.03	5.21a±0.45	0.78±0.07	4.08a±0.21	0.76±0.01	5.43a±1.20	0.54±0.00	5.03a±0.67	0.78±0.07	2.85a±0.19
	Leaf	1.66±0.23	5.99a±0.56	1.13±0.03	4.51a±0.10	1.21±0.06	6.12a±0.76	1.14±0.03	4.67a±0.20	1.08±0.05	6.77a±1.19	0.96±0.02	5.80a±0.87	1.23±0.05	3.82a±0.12
	Fruit	1.32±0.08	4.21a±0.69	0.77±0.01	3.87a±0.11	0.86±0.06	4.30a±0.45	0.54±0.01	3.75a±0.25	0.54±0.00	5.10a±1.16	0.43±0.00	4.88a±0.60	0.67±0.02	2.16a±0.11
	Mean	1.50	4.96	1.00	4.16	1.03	5.35	0.88	4.21	0.84	5.85	0.68	5.33	0.91	2.99
	F-stat.	CD-0.60; CF-2.11*		CD-0.54; CF-4.18*		CD-0.29; CF-7.34**		CD-0.64; CF-3.67*		CD-0.98; CF-5.33**		CD-0.34; CF-4.34*		CD-0.56; CF-2.23*	

*Mean ±SD of twelve values; a-significantly different to control; Significant F -**P>1% level; *P>5% level; NS-not significant: CD-critical difference; CF-Calculated-F.*

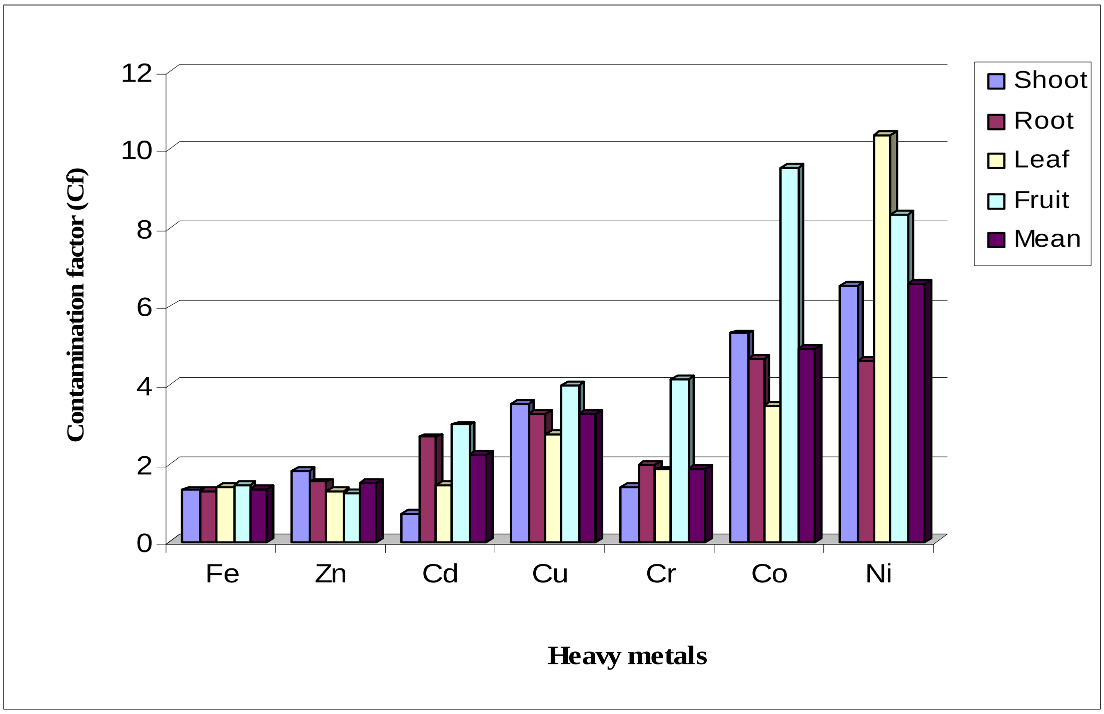

Fig. 1 Contamination factor of heavy metals in various parts of *P. vulgaris* after irrigation with biomethnated textile effluent

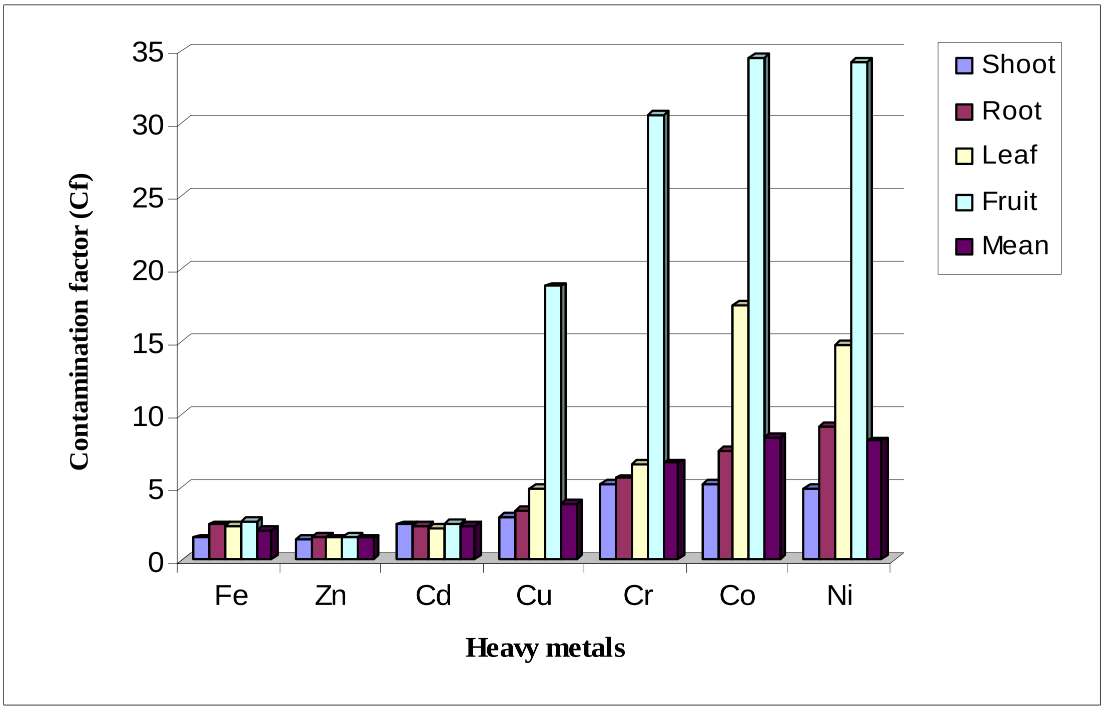

Fig. 2 Contamination factor of heavy metals in various parts of *V. radiata* after irrigation with biomethnated textile effluent

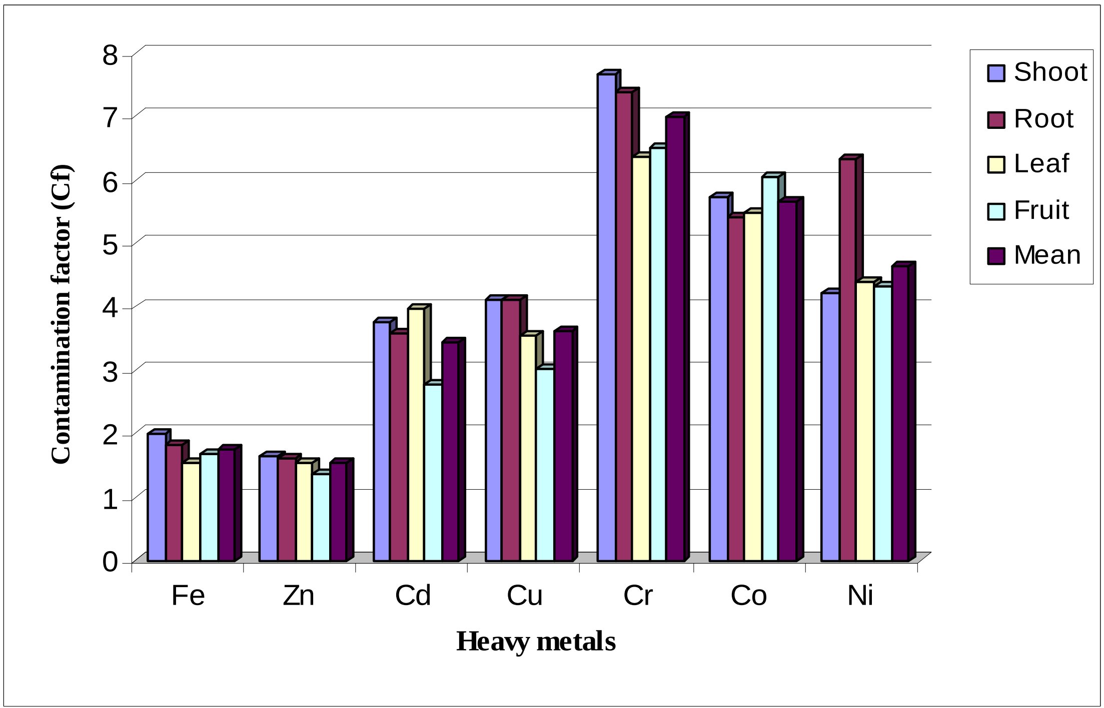

Fig. 3 Contamination factor of heavy metals in various parts of *V. faba* after irrigation with biomethnated textile effluent

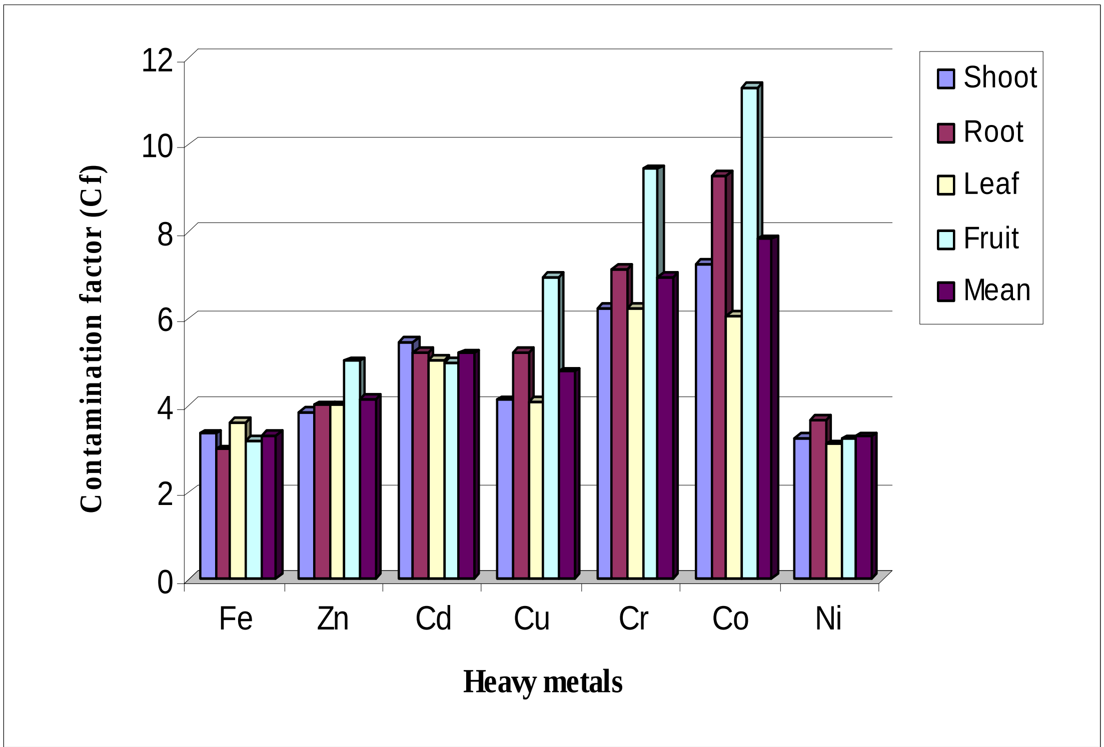

Fig. 4 Contamination factor of heavy metals in various parts of *L. usitatissimum* after irrigation with biomethnated textile effluent

More significant (P<0.01) accumulation was observed in the content of Co and Ni in the shoot, root, leaves and fruit of *P. vulgaris, V. radiata* and *V. faba* after irrigation with BMTE irrigation in comparison to control. The content of Cr was also observed to be more significantly (P<0.01) different in the shoot, root, leaves and fruit of *V. radiata, V. faba* and *L. usitatissimum*. Fe and Zn content were also recorded to be more significantly (P<0.01) different in the shoot, root, leaves and fruit of *V. faba* after irrigation with BMTE in comparison to control. The maximum content of various metals were recorded in the root of *P. vulgaris,* shoot of *V. radiata,* fruit of *V. faba* and leaves of *L. usitatissimum* after irrigation with BMTE (Table 4). The maximum contamination factor was found of Ni for *P. vulgaris,* Co for *V. radiata* and *L. usitatissimum* and Cr for *V. faba* after irrigation with BMTE. The contamination factor of metals were recorded in order of Ni>Co>Cu>Cd>Cr>Zn>Fe for *P. vulgaris,* Co>Ni>Cr>Cu>Cd>Fe>Zn for *V. radiata,* Cr>Co>Ni>Cu>Cd>Fe>Zn for *V. faba* and Co>Cr>Cd>Cu>Zn>Fe>Ni for *L. usitatissimum* after irrigation with BMTE (Figs. 1, 2, 3, 4). Though, content of metals in *P. vulgaris, V. radiata, V. faba* and *L. usitatissimum* were slightly higher in the BMTE irrigated plants as compared to control. Chandra et al. [2] also reported the accumulation and distribution of toxic metals (Cu, Cd, Cr, Zn, Fe, Ni, Mn, and Pb) in wheat and mustard plants irrigated with mixed distillery and tannery effluents. Vinod and Chopra [15] also reported the accumulation of metals (Fe, Zn, Cd, Cu, Pb and Cr) in soil and *Trigonella foenum-graecum* irrigated with distillery effluent.

In conclusion, biomethnated textile effluent increased the metals in the soil as well as cultivated vegetable crops. The maximum content of metals was recorded in the root of *P. vulgaris,* shoot of *V. radiata,* fruit of *V. faba* and leaves of *L. usitatissimum* after irrigation with BMTE. Thus the accumulation of metals in plant parts of these vegetable crops were observed to be crop specific, differ from crop to crop it may be due to the diverse uptake efficiency and tolerance limit against different metals of these crop plants. Further studies on the accumulation of metals and changes in biochemical composition of these crops after BMTE irrigation are required for the ethnobotanical importance of these vegetable crops.

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