Bull. Environ. Contam. Toxicol. (2005) 74:210–218

DOI: 10.1007/s00128-004-0570-2

Bulletin of Environmental Contamination and Toxicology

Accumulation of Metals in Vegetables and Crops Grown in the Area Irrigated with River Water

S. Sinha, K. Pandey, A. K. Gupta, K. Bhatt

Ecotoxicology and Bioremediation, Environmental Sciences Division, National Botanical Research Institute, Lucknow 226 001 (U.P.), India

Received: 12 March 2004/Accepted: 23 September 2004

The use of polluted river water for irrigation is a matter of major concern due to the presence of toxic metals and other pollutants, which ultimately contaminate the soil. There are few reports on the concentration of heavy metals in the soil, water and plants growing in the effluent receiving areas (Armienta et al. 2001; Barman et al. 2000; Farooq et al. 1999; Fytianos et al. 2001; Oudeh et al. 2002; Pichtel et al. 2000; Singh et al. 2004; Samantaray et al. 2001). These authors reported that the main source of the metals in the plants is their growth media from which these are taken up by the roots of the plants and translocated to upper parts. The translocation of metals varies from one plant to another and depends on element mobility and plant availability, which consequently results in varied levels of accumulation (Mench et al. 1994). The essential metals (Fe, Cu, Mn and Zn) are required in small quantities for the growth and development of the plants, however, excessive concentrations could be toxic. In addition, toxic metals, Cr and/or Ni may lead to severe health hazards. Metals ingested in excess from plant-based foodstuff grown on polluted soil. These are excreted by the body through urine and faeces; otherwise, their accumulation in various body tissues can lead to serious health outcomes (UNEP/FAO/WHO 1988). The present study was planned to assess the status of metal accumulation in different parts of the vegetables/crops grown at different sites of river Gomti that receives the maximum pollution load at Lucknow. A total number of 26 drains in Lucknow discharge the urban domestic treated wastewater (about 21.26 million gallons per day) into the Gomti river, which deteriorate the water quality of the river. The river water is being used for the irrigation and drinking purposes. Excessive accumulation of metals in agriculture soils may results in environmental contamination; elevated uptake by vegetables/crops may also affect food quality and safety.

MATERIALS AND METHODS

Five sites, S-1, S-2, S-3, S-4 and S-5 from Lucknow were selected in both up-stream and down-stream of Gomti River. Five composite soil samples from each site were collected randomly with an average depth of 5-20 cm, where the plants were growing. These samples were air dried, mixed thoroughly and sieved to desired particle size for analysis. The sampling of water of selected sites was done; five samples from each site were collected separately to analyze physico-chemical parameters. Different plant species, namely mustard (*Brassica nigra*), egg plant (*Solanum melongena*), chilli (*Capsicum frutescens*), fenugreek (*Trigonella foenum-graecum*), okra (*Abelmoschus*

Correspondence to: S. Sinha

esculentus), snake cucumber (*Cucumis melo* var. *utilissimus*), corn (*Zea mays*), spinach (*Spinacia oleracea*), sponge gourd (*Luffa aegyptiaca*), sugarcane (*Saccharum officinarum*), tomato (*Lycopersicon esculentum*) beet root (*Beta vulgaris*), mint (*Mentha arvensis*), radish (*Raphanus sativus*), dill (*Anethum graveolens*), turnip (*Brassica rapa*), elephant's ear (*Colocasia antiquorum*) cabbage (*Brassica oleracea* var. *capitata*), knol-khol (*Brassica caulorapa*) and guava (*Psidium guajava*) grown at various sites were collected at maturity stage. For each species five plants were collected randomly. The plant samples were thoroughly washed dried in oven at 80^0 C for 24 h and ground for metal analysis.

The physico-chemical properties of soil and water were analyzed by the method of Kalra and Maynard (1991) and APHA, AWWA, WPCF (1996), respectively. Soil, water and plant samples were digested using 70% nitric acid in Microwave Digestion System 2000. The solution was filtered and analysed for different metals by using an Atomic Absorption Spectrophotometer (GBC, Avanta Sigma). Coefficient of variance (cv) was calculated (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

The physico-chemical properties of soil (Table 1) and water (Table 2) have shown variation from one location to the other. Among all the sites, the level of metals, namely, Mn, Fe and Cr in the soil was found maximum at S-4, while rest of the metals (Cu and Zn) at S-1. The maximum organic carbon, OC (0.78%) was found at S-3, whereas, maximum electrical conductivity, EC (1.916) was found at S-1. Among the metals estimated in the soil samples, Fe was found more at all the sites as compared to other metals, being maximum at S-1 (23087 $\mu g\ g^{-1}$ dw). pH of water varied from 6.80-8.09 at different sites and found more than 8.03 at S-1 and S-5. Among all the sites, S-5 was found to have maximum total dissolved solid, TDS (0.90%) and salinity (1.05 PPT), however, maximum EC (0.801 $dS\ m^{-1}$) and dissolved oxygen, DO (3.80 ppm) were found at S-2 and S-3, respectively. Among the various sites, the analysis of metal content in water samples revealed that S-2 and S-4 are most contaminated sites. The level of the metals was found low in water samples at site S-1 and S-5, which may be due to high pH and salinity in water samples.

The concentration of heavy metals in the different parts of the plants from selected sites is presented in Tables 3-7. The analysis of the data showed that the metal translocation vary from one plant to another.

Among the leafy vegetables, the results showed significant accumulation of metals in leaf of the plants. The results of metal accumulation were compared in all the leafy vegetables, which showed maximum accumulation ($\mu g\ g^{-1}$ dw) of Fe (2701) in mustard, Cr (11.21) in cabbage, Zn (192.00) in mint, Mn (209.91) in spinach and Cu (31.67) in dill.

Among the plants with edible roots, raddish collected from S-1 and S-5 was found to have elevated concentration of all the metals ($\mu g\ g^{-1}$ dw), in the edible part, i.e., 703.13 and 429 (Fe), 80.75 and 49.55 (Zn), 24.50 and 18.25 (Mn) and 14.00 and 7.76 (Cu), respectively at both the sites. However, elephant's ear has shown maximum accumulation of Fe and Zn in edible part at all the sites, except at S-2, where Zn was maximum in leaf (29.26 $\mu g\ g^{-1}$ dw). Mn and Cu were also found high in edible part of

Table 1. Physicochemical properties of soil collected from different sites.

Parameters	Sites				
	S-1	S-2	S-3	S-4	S-5
pH	7.22±0.14	7.81±0.62	8.15±0.84	7.82±0.49	6.94±0.57
OC (%)	0.54±0.001	0.06±0.001	0.78±0.05	0.13±0.002	0.52±0.002
EC (dSm^{-1})	1.916±0.18	1.838±0.19	0.887±0.02	1.029±0.17	0.673±0.07
Metals ($\mu g\ g^{-1}$ dw)					
Cu	43.12±2.66	23.44±3.2	13.74	28.40±1.84	16.32±1.59
Mn	245.3±10.0	307.49±22	82.02	342.86±21	146.05±5.4
Zn	135.40±6.6	80.29±0.7	54.11	95.83±1.74	80.70±7.81
Fe	23087±1545	32158±3247	15357±1043	38872±3571	14410±1074
Cr	4.79±0.25	17.46±0.7	8.31	18.15±1.44	2.59±0.13
Ni	28.75±2.20	bdl	bdl	bdl	16.74±1.91

bdl- below detection limit. All values are means of five replicates ± S.D.

Table 2. Physicochemical properties of water collected from different sites.

Parame-ters	Sites				
	S-1	S-2	S-3	S-4	S-5
pH	8.03±0.77	7.20±0.62	6.90±0.66	6.80±0.51	8.09±0.56
TDS (%)	0.40±0.02	0.37±0.04	0.33±0.03	0.31±0.01	0.90±0.04
EC (dSm^{-1})	0.792±0.05	0.801±0.07	0.664±0.07	0.648±0.05	0.792±0.02
Salinity (PPT)	0.750±0.03	0.60±0.03	0.50±0.01	0.50±0.01	1.05±0.11
DO (ppm)	3.35±0.31	2.70±0.29	3.80±0.22	3.50±0.19	3.45±0.28
Metals ($\mu g\ ml^{-1}$)					
Cu	0.028±0.00	0.195±0.02	0.076±0.001	0.177±0.05	0.021±0.001
Mn	0.042±0.001	1.34±0.02	0.112±0.01	0.474±0.02	0.065±0.00
Zn	0.095±0.002	0.775±0.03	0.159±0.01	0.934±0.09	0.07±0.00
Fe	3.31±0.25	5.53±0.62	6.35±0.42	5.96±0.45	2.54±0.16
Cr	0.025±0.001	0.161±0.02	0.045±0.001	0.295±0.06	0.045±0.001
Ni	bdl	bdl	bdl	bdl	bdl

bdl- below detection limit. All values are means of five replicates ± S.D.

elephant's ear. Beet root and turnip (S-1) were found to accumulate maximum Fe followed by Zn>Mn>Cu.

Knol-khol and sugarcane (edible stem) accumulated the metals in order; Fe>Zn>Mn>Cu. In knol-khol, accumulation of Fe and Cu was maximum in root > stem > leaf, whereas, Zn and Mn was found maximum in leaf (142.65 $\mu g\ g^{-1}$ dw) and root (79.00 $\mu g\ g^{-1}$ dw), respectively. Plants of sugarcane have shown maximum accumulation of all the metals in leaf followed by stem.

The other fruit bearing plants (egg plant, chilli, and guava) collected from S-5 were found to accumulate all the metals maximum in root part, except Mn

Table 3. Metal accumulation (μg g^{-1} dw)* in different parts of the vegetable/crops collected from Site, S-1.

Name of plants	Plant parts	Accumulation of metals (μg g^{-1} dw)			
		Fe	**Zn**	**Mn**	**Cu**
Beet root	R (E)	1033±222.39	95.08±8.13	71.37±8.30	20.75±1.41
	L S	1228±131.67	95.34±2.74	56.62±3.38	12.78±1.01
	L	1767±412.17	102.25±2.15	182.58±10.3	26.08±1.70
Fenu-greek	R	3362±141.12	101.08±10.3	66.69±7.31	33.34±2.97
	S	1465±112.27	138.92±5.19	39.62±3.63	28.14±1.06
	L (E)	1281±113.22	122.60±7.64	49.60±2.50	21.78±2.44
Mint	R	3143±18.06	86.94±9.02	66.75±5.12	30.03±2.24
	S	1496±111.06	129.75±1.41	52.08±4.97	24.51±2.41
	L (E)	2197±254.60	192.00±6.24	97.30±3.58	17.34±1.19
Mustard	R	1213±123.67	63.63±7.25	57.12±4.77	21.50±2.54
	S	399±3.52	66.42±5.03	29.30±2.86	12.75±0.43
	L (E)	1504±5.52	90.92±3.36	119.75±4.24	25.91±2.96
	F	552±25.44	109.75±2.83	61.55±1.89	18.33±2.67
Raddish	R P	1403±83.44	75.08±7.94	53.25±3.77	32.38±3.83
	R (E)	703.13±70.20	80.75±5.23	24.50±1.77	14.00±1.06
	L S	1066±26.86	63.50±1.52	53.00±3.88	10.77±0.88
	L	971±5.66	71.25±3.89	47.42±4.51	7.00±0.77
Dill	R	1691±83.77	132.75±1.06	46.42±1.60	34.25±3.20
	S	426±46.72	71.25±5.63	20.33±3.45	10.08±0.76
	L (E)	1498±136.88	97.42±5.57	49.25±2.59	31.67±3.12
Spinach	R	1402±108.30	84.50±2.47	84.25±6.71	26.87±3.36
	L S	1446±110.30	68.13±0.88	106.12±6.89	16.00±1.06
	L (E)	2685±343.12	91.42±1.53	209.91±23.6	23.42±1.28
Turnip	R P	1473±117.43	156.75±8.53	63.33±6.87	39.43±3.18
	R (E)	574±63.44	173.50±5.43	29.71±2.05	30.17±1.11
	L S	829±72.11	72.94±0.99	54.67±5.22	24.72±2.22
	L	241±21.95	192.08±2.79	89.69±8.88	18.22±1.11
cv (%) Edible		50.09	35.61	75.27	26.07

*- Cr was found below detection limit in the plants. bdl- below detection limit. All values are means of five replicates ± S.D. RP- root peel, R – root, S- stem, LS- leaf stalk, L- leaf, F- flower, E- edible. cv = Coefficient of variation.

(94.05 μg g^{-1} dw in leaf of guava). However, the egg plant collected from other site (S-3), has shown different trend. In tomato (S-3 and S-4), Fe accumulated maximum in root and leaf and Mn in stem and root, respectively, while Zn and Cu were found maximum in root at both the sites. High concentrations of all the metals were also found in the edible part of the plant. The results of metal accumulation (μg g^{-1} dw) in sponge gourd collected from S-2 and S-4 has shown 137 and 608.78 of Fe, 59.34 and 91.46 of Zn, 20.03 and 74.59 dw of Mn and 18.80 and 53.88 of Cu at both the sites, respectively in fruit. Plants of snake cucumber collected from S-2 have shown least accumulation of the tested metals (μg g^{-1} dw) in fruit part, i.e., 258.00 (Fe), 18.37 (Mn) and 9.78 (Cu), except Zn, found least in leaf (30.60).

Table 4: Metal accumulation (μg g^{-1} dw) in different parts of the vegetable/crops collected from Site, S-2.

Name of plants	**Plant parts**	**Accumulation of metals (μg g^{-1} dw)**				
		Fe	**Cr**	**Zn**	**Mn**	**Cu**
Elephant's ear	R (E)	532±28.85	8.92±0.92	24.63±2.16	21.02±2.95	15.19±1.4
	S	100±7.46	6.95±0.01	21.32±2.32	17.58±1.53	9.50±0.86
	L	226±22.79	1.97±0.07	29.26±2.86	56.42±4.40	4.64±0.48
Okra	R	257±20.97	5.91±0.04	56.19±0.56	12.88±1.43	10.30±0.1
	S	120±6.36	5.83±0.57	25.45±4.53	15.61±1.36	4.78±0.30
	L	404±29.83	5.58±0.16	56.93±2.82	44.10±0.22	9.02±0.73
	F	160±9.13	6.00±0.57	116.36±9.4	29.22±0.28	11.3±0.05
Snake cucumber	S	424±42.96	7.97±0.56	46.48±3.15	27.86±2.78	16.39±1.5
	L	821±11.05	4.18±0.27	30.60±3.92	59.36±4.62	14.57±1.6
	Fr(E)	258±20.49	9.78±0.96	35.86±3.78	18.37±1.81	9.78±0.37
Corn	R	1521±156	8.98±0.47	40.84±0.91	45.74±4.80	15.10±1.9
	S	186±14.77	1.69±0.10	72.76±5.76	8.58±0.14	3.42±0.15
	L	712±19.98	5.32±0.66	31.04±2.72	61.32±2.89	6.39±0.04
	Fr(E)	554±20.03	11.49±1.8	107.5±10.8	45.03±3.69	10.85±0.9
Spinach	L (E)	538±27.84	3.04±0.34	16.22±1.29	175.3±17.5	12.17±1.6
Sponge gourd	S	291±26.22	5.74±0.40	28.51±2.66	17.43±1.01	11.93±1.7
	L	292±27.80	6.55±0.05	43.42±4.57	67.34±0.94	10.18±0.6
	Fr(E)	137±11.85	6.58±0.58	59.34±5.57	20.03±2.48	18.80±1.2
cv (%) Edible		47.87	41.08	75.22	120.85	27.37

All values are means of five replicates ± S.D. R – root, S- stem, L- leaf, F- flower, Fr- fruit, E- edible. cv = Coefficient of variation.

Among all the metals tested in the plants from the selected sites, Cr, the toxic metal was found only at S-2 and S-5, which was further found below detection limit in most of the plants of S-5. The Cr content (μg g^{-1} dw) in the edible part of different plants were: 11.21 (cabbage), 7.26 (raddish), 8.55 (spinach) at S-5 and 8.92 (elephant's ear), 9.78 (snake cucumber), 3.04 (spinach) and 6.58 (sponge gourd) at S-2.

It is well documented that the level of metals was found high in water due to the wastewater receiving from both natural and anthropogenic sources. The plants growing using this water accumulate significantly high amount of metals (Rai et al. 1996; Rai and Sinha 2001). Similarly, the use of metal contaminated water for irrigation of vegetables/crops may results an enhanced level of metals in soil, which ultimately translocated to plants growing therein (Singh et al. 2004). Plants take up metals via roots, which depend upon physico-chemical characteristics of soil, concentration, solubility, species, cultivar age and organ of the plant. Interaction between metals occurring at the root surface and within the plant can also affect uptake as well as translocation and toxicity (Mench et al. 1994). Solubility and intensity of toxicity of heavy metals largely vary with the soil pH value. When the pH changes from neutral to alkaline state, solubility of Cu, Zn, Mn etc. is reduced which resulted in decrease in absorption of heavy metals by crop and consequently reduction of contamination of crops and feeds produced. As per the report of NIN (Anonymous 1982), on metal levels in Indian leafy vegetables, roots and tubers, metal content (μg g^{-1} dw) in green leafy vegetables ranged from 16 to 95 for Zn, 8 to 96 for Mn, 1.9 to 18 for Cu and 0.52 to

Table 5: Metal accumulation (μg g^{-1} dw)* in different parts of the vegetable/crops collected from Site, S-3.

Name of plants	Plant parts	Accumulation of metals (μg g^{-1} dw)			
		Fe	Zn	Mn	Cu
Egg plant	R	319.94±15.94	94.08±2.88	31.49±2.25	8.12±0.75
	S	159.38±3.68	50.25±5.48	67.61±2.41	8.99±0.56
	L	409.70±27.13	42.25±3.04	43.37±2.57	40.76±4.16
	C	1268.98±63.44	45.14±3.20	57.32±3.32	27.70±1.69
	Fr (E)	280.43±25.02	46.53±4.20	8.85±0.570	11.80±1.68
Elephant's ear	R (E)	1214.60±100.14	65.93±2.85	59.13±5.12	44.89±2.50
	S	575.20±24.60	48.11±4.69	35.66±3.18	26.61±1.90
	L	586.69±58.90	49.41±1.86	108.35±11.41	22.34±2.65
Tomato	R	744.06±37.20	134.48±11.75	23.37±2.10	26.87±1.64
	S	1290.25±25.30	58.72±4.49	57.87±4.11	21.53±2.30
	L	993.36±49.68	58.72±4.49	32.48±2.75	18.06±0.42
	Fr (E)	200.87±21.02	106.95±4.39	30.94±3.50	16.38±1.43
cv (%) Edible		99.72	42.18	25.20	73.61

*- Cr was found below detection limit in the plants. All values are means of five replicates ± S.D. R – root, S- stem, L- leaf, C- calyx, Fr- fruit, E- edible. cv = Coefficient of variation.

Table 6: Metal accumulation (μg g^{-1} dw)* in different parts of the vegetable/crops collected from Site, S-4.

Name of plants	Plant parts	Accumulation of metals (μg g^{-1} dw)			
		Fe	Zn	Mn	Cu
Elephant's ear	R (E)	749.64±26.28	79.33±4.00	19.14±1.27	14.05±0.64
	S	646.00±24.46	70.43±4.06	38.54±3.54	54.18±4.20
	L	689.34±45.28	51.63±5.09	71.73±5.90	21.11±1.66
Sponge gourd	S	381.71±16.89	47.22±4.26	25.03±2.02	15.89±1.75
	L	959.94±17.00	77.31±4.31	99.85±3.63	21.84±2.45
	Fr (E)	608.78±33.38	91.46±1.64	74.59±6.29	53.88±0.20
Sugarcane	S (E)	177.64±1.74	24.62±1.58	4.11±0.44	5.32±0.43
	L	370.95±3.11	25.71±2.27	8.66±0.64	5.94±0.53
Tomato	R	640.83±22.84	66.63±5.78	54.19±0.49	14.68±1.19
	S	489.61±28.52	39.97±2.10	20.22±2.78	14.41±1.57
	L	1574.56±95.04	33.69±2.18	53.47±5.86	13.55±1.16
	Fr (E)	120.87±11.02	56.95±3.39	26.95±1.39	12.38±1.13
cv (%) Edible		75.36	46.54	97.57	102.66

*- Cr was found below detection limit in the plants. All values are means of five replicates ± S.D. R – root, S- stem, L- leaf, Fr- fruit, E- edible. cv = Coefficient of variation.

4.37 for Cr. In case of other vegetables (egg plant, snake cucumber, cow pea, pumpkin, bitter gourd), the values (μg g^{-1} dw) were Zn (5-46), Mn (5-29), Cu (0.87-11) and Cr (0.28-4.80). Metal content (μg g^{-1} dw) in roots and tubers (e.g. sweet potato, elephant's ear, raddish) were Zn (15-58), Mn (7-14), Cu (0.80-9) and Cr (0.20-0.40). In general, Fe content ranged from 50-250 μg g^{-1} dw in the plants. The results of our study have shown that all the tested metals were found higher in the edible parts of the plants with

Table 7: Metal accumulation ($\mu g\ g^{-1}$ dw) in different parts of the vegetable/crops collected from Site, S-5.

Name of plants	Plant parts	Accumulation of metals ($\mu g\ g^{-1}$ dw)				
		Fe	Cr	Zn	Mn	Cu
Egg plant	S	506±2.2	bdl	21.85±1.98	37.29±2.7	42.45±3.7
	L	1865±213.6	bdl	109.8±10.1	70.58±5.0	23.10±2.1
	C	135±10.4	bdl	93.00±2.31	42.94±4.1	18.56±1.1
	Fr (E)	206±14.3	bdl	91.46±5.71	25.90±3.0	23.40±2.6
Cabbage	R	1090±96.1	13.20±1.6	57.95±5.58	66.63±3.0	15.38±1.9
	S	31.68±1.8	bdl	106.4±13.7	45.65±0.4	8.66±0.8
	L (E)	520±53.5	11.21±1.1	66.49±7.36	57.48±4.1	8.19±1.0
Chilli	R	5802±561.9	bdl	112.54±5.3	92.10±5.7	51.87±3.4
	S	871±22.6	bdl	73.10±4.52	28.38±3.5	20.18±2.3
	L	1611±146.6	bdl	91.62±4.50	40.38±5.3	25.32±1.8
	Fr (E)	173±16.2	bdl	65.44±3.09	12.70±1.5	10.95±1.8
Guava	S	580±54.5	bdl	40.09±1.48	38.85±4.4	20.14±2.4
	L	1299±128.6	bdl	62.36±5.38	94.05±9.3	36.15±3.9
	Fr (E)	643±69.3	bdl	34.28±2.36	9.75±1.13	14.93±1.2
Knol-khol	R	4233±410.3	bdl	98.55±4.09	79.00±7.1	23.48±2.6
	S (E)	1879±197.4	bdl	142.65±2.8	34.20±2.8	8.19±0.5
	L	676±62.3	bdl	73.73±5.11	57.11±2.1	5.89±0.2
Mustard	R	2497±248.2	bdl	76.05±7.10	45.53±4.5	15.38±2.2
	S	2562±198.7	bdl	52.24±4.97	83.07±7.2	13.92±1.6
	L (E)	2701±271.8	bdl	84.11±2.98	65.85±6.1	18.64±1.7
Raddish	R P	2110±167.9	6.33±0.63	51.49±5.31	31.61±3.1	4.69±0.4
	R (E)	429±41.2	7.26±0.53	49.56±3.00	18.25±1.7	7.76±0.8
	L S	485±48.7	10.65±1.2	32.79±3.14	23.19±1.1	6.95±0.4
	L	1106±107.7	5.47±0.69	65.72±4.50	49.69±2.8	8.71±0.2
Spinach	R	2621±23.8	7.17±0.72	48.36±4.57	82.32±5.3	6.90±0.7
	L S	448±49.5	11.03±1.5	63.45±2.76	76.28±6.1	15.1±0.3
	L (E)	2068±31.0	8.55±0.57	85.08±4.28	155.6±1.6	23.0±1.4
cv (%) Edible		91.19	42.19	101.53	45.99	22.36

bdl- below detection limit. All values are means of five replicates ± S.D. RP- root peel, R – root, S- stem, LS- leaf stalk, L- leaf, C- calyx, Fr- fruit, E- edible. cv = Coefficient of variation.

few exceptions of different sites, which are in conformity with other findings (Farooq et al. 1999; Fytianos et al. 2001). Iron, one of the essential metals was found in excess in all plants except egg plant and chilli (S-2), tomato (S-3) and sugarcane stem and tomato (S-4). Except spinach leaf at S-5, Cr was also found in the toxic range in all the edible parts of the plant.

Singh et al. (2004) reported the impact of metals and pesticides in all the environmental media, suggesting a definite adverse impact on the environmental quality of Kanpur (India). The levels of metals were recorded high in the samples of human blood and urine of the different population groups. The major intake routes considered are drinking water, food grains, vegetables and milk, which contain high level of metals.

These authors also reported considerable risk and impact of the metals on the human health in the exposed area receiving wastewater. Further, risk quotient (RQ) was also evaluated and the values were 2-4 times higher over their respective unexposed population groups. In the present study, the concentration of metals in edible part of crops/vegetables was found higher than reported by Srikumar (1993) from southern India, Tripathi et al. (1997) from Bombay (India) and Alam et al. (2003) from Samta village (Bangladesh). These authors have also reported that metals could contaminate water, soil, food grains and vegetables. These local food products are the basis of human consumption in the region and of great relevance to human health. Many researches revealed the carcinogenic effects of several heavy metals such as Cd, Co, Cr, Ni, Pb, As and Se (Trichopoulos 1997). Mukherjee et al. (1997) have indicated that Cr has significant clastogenic and genotoxic effects. But reports on the effect of these metals when present in combination with vegetables are very meager. Patra et al. (2001) studied the genotoxic effect of vegetable extracts (cauliflower, spinach, radish) containing combination of various heavy metals after *in vivo* acute exposure in mice and found significant increase in chromosome aberrations when compared to control mice. This dose was relatively much higher than the amount of vegetable a human can consume in a day.

The results of the present study showed that the vegetables and crops growing in such area constitute risk due to accumulation of metals. It is interesting to note that toxic metal, Cr, was found below detection limit in most of the vegetables/crops, whereas, the essential metals (Fe, Zn, Mn and Cu) were in excess amount in plant parts including the edibles. The situation could change in the future depending on the volume of contaminants added to the ecosystem. Thus, it is recommended that the edible plants grown on such area should be monitored periodically before consumption of the edible part.

REFERENCES

Alam MGM, Snow ET, Tanaka A (2003) Arsenic and heavy metal contamination of vegetables grown in Samta village, Bangladesh. Sci Total Environ 308: 83-96

Anonymous (1982) Nutritive value of food. In Annual report, National Institute of Nutrition, Hyderabad, India, 1-3

APHA, AWWA, WPCF (1996) Standard methods for the examination of water and wastewater analysis, American Public Health Association, Washington, DC, USA

Armienta MA, Morton O, Rodriguez R, Cruz O, Aguayo A, Ceniceros N (2001) Chromium in a tannery wastewater irrigated area Lion Valley, Mexico. Bull Environ Contam Toxicol 66: 189-195

Barman SC, Sahu RK, Bhargava SK, Chaterjee C (2000) Distribution of heavy metals in wheat, mustard, and weed grown in field irrigated with industrial effluents. Bull Environ Contam Toxicol 64: 489-496

Farooq M, Hans RK, Viswanathan PN, Joshi PC (1999) Health hazard from dry river bed agriculture. Bull Environ Contam Toxicol 62: 555-562

Fytianos K, Katsianis G, Triantafyllou P, Zachariadis G (2001) Accumulation of heavy metals in vegetables grown in an industrial area in relation to soil. Bull Environ Contam Toxicol 67: 423-430

Gomez KA, Gomez AA (1984) Statistical procedures for Agricultural Research. John Willey & sons, New York.

Kalra YP, Maynard DG (1991) Methods manual for forest soil and plant analysis. Forestry Canada, Northwest Region, Northern forest Centre, Edmonton, Alberta. Information Report NOR-X-319

Gomez KA, Gomez AA (1984) Statistical procedures for Agricultural Research. John Willey & sons, New York.
Kalra YP, Maynard DG (1991) Methods manual for forest soil and plant analysis. Forestry Canada, Northwest Region, Northern forest Centre, Edmonton, Alberta. Information Report NOR-X-319
Mench M, Vangransveld J, Divier V, Clijster D (1994) Evaluation of metal mobility, plant availability and immobilization by chemical agents in a limed-silty soil. Environ Pollut 86: 279-286
Mukherjee P, Sarkar D, Sharma A (1997) Effects of dietary consumption of black tea infusion alone and in combination with known clastogens on mouse bone marrow chromosomes *in vivo*. Food and Chem Toxicol 35: 657-661
Oudeh M, Khan M, Scullion J (2002) Plant accumulation of potentially toxic elements in sewage sludge as affected by soil organic matter level and mycorrhizal fungi. Environ Pollut 116: 293-300
Patra U, Gupta S, Talapatra SN, Giri AK (2001) Genotoxic effects after in vivo exposure of vegetables extracts containing heavy metals from Dhapa area of Calcutta, India. I. Effects of cauliflower, spinach and radish. Food and Chem Toxicol 39: 67-72
Pichtel J, Kuroiwa K, Sawyerr HT (2000) Distribution of Pb, Cd and Ba in soil and plants of two contaminated sites. Environ Pollut 110: 171-178
Rai UN, Sinha S (2001) Distribution of metals in aquatic edible plants: *Trapa natans* (Roxb.) Makino and *Ipomoea aquatica* Forsk. Environ Monit Assess 70: 241-252
Rai UN, Sinha S, Chandra P (1996) Metal Biomonitoring in water resources of eastern ghats, Koraput (Orissa), India by aquatic plants. Environ Monit Assess 43: 125-137
Samantaray S, Rout GR, Das P (2001) Heavy metal and nutrient concentration in soil and plants growing on a mettaliferous chromite minespoil. Environ Technol 22: 1147: 1154
Singh KP, Mohan D, Sinha S, Dalwani R (2004) Impact Assessment of treated/untreated wastewater toxicants discharged by sewage treatment plants on health agricultural and environmental quality in the wastewater disposal area. Chemosphere 55:227-255
Srikumar TS (1993) The mineral and trace element composition of vegetables, pulses and cereals of southern India. Food Chem 46: 163-167
Trichopoulos D (1997) Epidemiology of cancer. In: DeVita, V.T. (Ed.), Cancer, Principles and Practice of Oncology. Lippincott Company, Philadelphia, pp. 231-258
Tripathi RM, Raghunathan R, Krishnamoorthy TM (1997) Dietary intake of heavy metals in Bombay city, India. Sci Total Environ 208: 149-159
UNEP/FAO/WHO (1988) Assessment of chemical contaminants in foods. United Nations Environment Programme, Nairobi, Food and Agriculture Organization, Rome and World Health Organization, Geneva, p109-176