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Heavy Metal Contamination in Soil and Vegetable Crops Irrigated with Varthur Lake Water, Bengaluru

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Abstract

The present study aims at evaluating the heavy metal contents in soil and vegetable crops collected randomly from different agricultural fields irrigated with Varthur lake water of Bengaluru district, Karnataka. The concentration of Cr, Cd, Ni and Pb in soils ranged from 21.34 to 217.25, 2.12-10.9, 13.44-53.63 and BDL-7.39 mg kg^{-1}, respectively. Among the soil samples analysed, mean concentration of Cr and Cd were higher in the soils collected from Immadihalli and lower in Banahalli village. Most of the heavy metal concentration in soils exceeded the permissible limits of European Union (EU) and Indian standards. For the vegetable crops analysed for Cr content, the mean values were 9.06, 14.69, 13.81, 12.67, 18.27 and 12.18 mg kg^{-1} for knol khol, spinach, radish tuber, radish leaves, coriander and amaranthus, respectively. The concentration of Cr in the crop samples exceeded the permissible limits (0.30 mg kg^{-1}) of European Union for vegetables but were below the Indian standard permissible limits.

Keywords: Contamination, Lake water, Heavy metals, Soil, Vegetables, Irrigation

Lakes were once important water resources for domestic needs, animal husbandry and agriculture but recently, in-and-around Bengaluru area, lakes have become part of city drainage system that drain untreated and partially treated domestic sewage and industrial effluents from a number of small scale units like garment factories, electroplating industries, distilleries etc. The unscientific disposal of the waste water has caused immense environmental problems (Kumar and Reddy, 2009). The farmers in peri urban areas use water from these lakes for cultivation of crops. Soils receiving water from lakes accumulate heavy metals to varying degrees depending on their concentration in water and the frequency of irrigation. Waste water irrigation may lead to the accumulation of heavy metals in agriculture soils and plants (Sharma *et al*., 2007) and pose serious problems. Steady increase in the soil contaminated with heavy metals around the urban areas of the world especially in Bengaluru was observed by Jayadev and Puttaih (2013). Water from the contaminated lakes have become the major source of irrigation for agricultural fields in the peri-urban areas and it is being reported for the decades in Bengaluru. Various lakes in Bengaluru (*viz.* Maragondanahalli, Byramangala, Bellandur and Jigani *etc.*) have been reported to be contaminated and among them Varthur lake is one. Vegetables are being grown extensively in areas around the city. The vegetables are rich in important minerals, carbohydrates, proteins, vitamins and trace elements which have marked health effect. The heavy metals are absorbed by crops along with other essential plant nutrients. The consumption of these vegetables is one of the most important pathways by which heavy metals enter the food chain. Contamination of soils and crops with these metals may have adverse effects on soil, plants, animals and human beings. The contaminated leafy vegetables pose a significant health risk to humans. The nature of effects can be toxic, neuro toxic, carcinogenic and becomes apparent only after several years of exposure, as there is no good mechanism for their elimination from the human body (Gupta *et al*., 2012). Earlier research works of Singh *et al.* (2012) and various others have reported contamination of heavy metals in lakes of peri-urban areas and also the sites irrigated with such water beyond the permissible limits. The present research aims to assess the heavy metal contamination in soils and crops irrigated with Varthur lake water of Bengaluru.

Material and Methods

Study area

Varthur lake is located in the eastern periphery of Bangalore city at 12°56'49.50 N and 77°44'10.54 E. The major crops of the area being vegetables, *viz*., kno khol, spinach, radish, coriander and amaranthus. The selected fields for sampling were exclusively irrigated with Varthur lake water for cultivation of these crops.

Soil sampling and processing

The soil samples from agricultural field were collected randomly from five villages and the number of samples from each village depends on the irrigation with lake water and the type of crop under cultivation. A total of 18 soil samples were collected at 0-15 cm depth preferably under cultivation of vegetable crops during post monsoon of 2016. Soil samples were air dried under shade, powdered and sieved through 2.00 mm mesh size sieve. The samples were stored in plastic containers for further use.

Analysis of heavy metal content in soil

One gram of 2.00 mm soil was ground and sieved through 0.2 mm mesh size sieve and was used for microwave digestion and analysed for heavy metal content. 0.05 g of 0.2 mm sieved soil was predigested with 8 ml HNO_3 (70 %) and 2 ml H_2O_2 (30 %). Later, the samples were digested using a microwave digester (Milestone- START D) at 150 ^{0}C with following steps: 1200 w for 15 minutes, 1200 w for 10 minutes and venting for 10 minutes. The digested sample was stored in clean plastic tubes of 50 ml capacity, after making up the volume using double distilled water and the heavy metals were analysed using ICP-OES (Thermofisher-model IC76DC170111) (Dospatliev *et al*., 2012).

Plant sampling and processing

Edible parts of the vegetable crops (knol khol, radish tuber, radish leaves, spinach, coriander and amaranthus) commonly grown in the sites irrigated with Varthur lake water were sampled. A total of 18 plant samples at maturity were collected during post monsoon of 2016 during which soil samples were also collected.

Analysis of heavy metal content in plant samples

Crop plants were washed with running water followed by double distilled water to remove surface contaminants. The samples were dried in the hot air oven at 70 ^{0}C for 72 hours, powdered and analyzed for their heavy metals content following the same method as heavy metal analysis in soil (Dospatliev *et al*., 2012).

Results and Discussion

Total and DTPA extractable heavy metal content in soils

Total and DTPA extractable heavy metal content in soil samples collected from agricultural lands irrigated with Varthur lake water are presented in Table 1 and 2. Concentration of total Cr, Cd, Ni and Pb in soil samples ranged from 21.34 to 217.25, 2.12 to 10.9, 13.44 to 53.63 and BDL to 7.39 mg kg^{-1}, respectively with their mean values of 105.09, 3.77, 30.38 and 2.17 mg kg^{-1}, respectively. Soils irrigated with Varthur lake water recorded 0.04, 0.01, 0.10 and 0.64 mg kg^{-1} of DTPA extractable Cr, Cd, Ni and Pb, respectively. The possible major reason for the contamination of these soils is due to irrigation with contaminated Varthur lake water. According to Aboud and Nandini (2009), Cr concentration in Varthur lake water ranged from 0.57 to 4.07 mg kg^{-1} (Mean: 2.13 mg kg^{-1}) which exceeds the irrigation standards limit by Food and Agriculture Organization (Sharma *et al*., 2007). The mean Cd and Ni concentration in Varthur lake water were 0.12 and 1.03 mg kg^{-1}, respectively. The range for Cd was within the stipulated Central Pollution Control Board tolerance limit for water bodies subject to pollution discharge but Cr and Ni values exceeded the tolerance limits. Cr is used in a variety of applications such as leather tanning, chromium plating, timber preservation, corrosion protection, textiles, *etc.* (Aboud and Nandini, 2009).

The concentration of Cr in soils was 112.29, 96.97, 217.25, 138.81 and 42.86 mg kg^{-1} for Channasandra, Nagondanahalli, Immadihalli, Maddapanahalli and Banahalli village, respectively. The higher concentration of 217.25 mg kg^{-1} was observed in the soil of

TABLE 1

Total content of metals (mg kg^{-1}) in soils of different villages irrigated with Varthur lake water

Sl. No.	Fe	Mn	Cu	Zn	Cr	Cd	Ni	Co	Pb
Channasandra									
1	20,129.3	261.7	23.1	183.0	76.73	3.65	7.53	32.92	3.16
2	24,129.9	121.4	24.0	138.5	87.62	2.62	4.67	26.76	BDL
Mean	22,482.9	283.4	34.0	126.8	112.29	1.68	10.08	34.57	BDL
Nagondanahalli									
3	20,718.3	391.6	31.3	72.2	89.25	3.25	12.86	31.87	3.76
4	28,878.3	262.5	18.2	123.6	80.77	2.28	9.32	34	BDL
5	20,696.5	218.4	15.2	98.3	87.44	3.63	7.92	25.94	BDL
6	29,908.9	302.5	31.9	172.4	102.8	3.06	11.44	50.52	3.52
7	27,430.3	305.2	34.1	107.2	107.74	5.50	8.22	43.4	0.53
8	25,049.9	277.0	17.9	170.8	91.9	4.59	9.87	36.88	BDL
9	21,141.2	242.6	23.3	159.4	98.88	3.55	5.12	18.7	BDL
10	21,761.0	243.6	22.7	111.8	118.25	5.30	12.53	24.89	2.44
Mean	20,350.5	214.4	26.9	118.7	96.67	2.79	4.60	16.47	2.00
Immadihalli									
11	26,724.2	376.5	42.0	137.1	119.06	4.40	6.45	19.78	BDL
12	23,088.1	290.3	23.3	159.6	97.97	3.28	7.24	13.44	BDL
Mean	23,605.5	328.1	44.1	117.8	217.25	10.90	17.89	53.63	7.04
Maddapanahalli									
13	27,301.8	303.2	37.9	202.9	145.42	4.63	7.82	32.41	6.13
14	23,687.6	275.6	44.5	104.9	147.11	4.94	8.15	40.47	4.00
15	25,780.4	310.4	24.6	201.1	149.99	5.53	9.30	38.11	0.02
Mean	26,800.3	249.7	29.4	213.5	138.81	4.76	8.77	29.2	7.39
Banahalli									
16	24,794.7	298.0	33.9	123.2	153.23	5.15	10.62	37.48	5.90
17	20,433.0	48.6	34.5	97.9	21.34	0.74	7.04	19.36	3.44
18	21,904.2	20.7	32.8	178.6	33.58	0.47	5.04	14.82	0.36
Mean	21,091.6	112.1	12.3	105.3	42.86	2.12	13.04	23.11	0.33
Grand Mean	23821.2	249.5	28.8	140.2	105.09	3.77	30.38	8.94	2.17
Range	20129.3-29908.9	20.7-391.6	12.3-44.5	72.2-213.5	21.34-217.25	2.12-10.9	13.44-53.63	4.6-17.89	BDL -7.39
SD	2962.0	93.5	8.9	38.9	42.89	2.23	10.92	3.17	2.55

TABLE II

DTPA-Extractable elemental content (mg kg^{-1}) in soils of different villages irrigated with Varthur lake water

Sl. No.	Fe	Mn	Cu	Zn	Ni	Cr	Cd	Co	Pb
Channasandra									
1	41.0	18.6	2.0	2.12	0.22	BDL	0.02	0.48	1.04
2	51.9	13.1	2.2	3.05	0.22	0.01	0.02	0.42	0.91
Mean	29.1	19.7	2.4	2.31	0.21	0.00	0.02	0.40	0.88
Nagondanahalli									
3	32.4	28.2	2.1	3.7	0.24	0.01	0.01	0.44	0.92
4	44.0	10.1	1.6	1.5	0.18	0.12	0.01	0.13	0.44
5	62.0	22.1	3.6	2.2	0.23	0.11	0.01	0.34	0.62
6	74.0	19.5	2.2	1.2	0.22	0.08	0.01	0.34	0.74
7	63.4	19.9	2.1	1.2	0.24	0.08	0.01	0.34	0.74
8	55.0	17.4	1.4	1.0	0.22	0.01	0.01	0.34	0.55
9	68.8	13.5	1.5	1.6	0.18	0.01	0.01	0.22	0.69
10	60.2	11.2	1.6	1.7	0.15	0.01	0.01	0.21	0.61
Mean	47.5	17.9	2.4	0.8	0.29	0.01	0.01	0.52	0.98
Immadihalli									
11	60.7	13.0	1.8	1.0	0.17	0.10	0.01	0.25	0.61
12	58.0	12.9	1.7	1.0	0.17	0.08	0.01	0.25	0.60
Mean	37.3	14.2	1.5	1.3	0.14	0.11	0.01	0.23	0.37
Maddapanahalli									
13	49.1	14.5	5.4	2.2	0.59	0.06	0.02	0.88	1.49
14	47.7	23.2	2.6	1.6	0.31	0.03	0.01	0.34	0.75
15	29.5	15.6	1.8	1.2	0.21	0.05	0.01	0.23	0.49
Mean	32.1	8.9	1.8	1.8	0.08	0.02	0.01	0.26	0.22
Banahalli									
16	29.2	19.0	3.6	3.4	0.17	0.01	0.02	0.49	0.49
17	39.4	19.1	3.6	3.4	0.17	0.01	0.02	0.49	0.50
18	34.0	0.8	0.8	0.1	0.06	0.01	BDL	BDL	0.03
Mean	25.0	1.0	0.1	0.2	0.08	0.00	BDL	BDL	0.06
Grand Mean	46.6	15.4	2.1	1.7	0.21	0.04	0.01	0.33	0.64
Range	25.0-74.0	0.8-28.2	0.1-5.4	0.1-3.7	0.06-0.59	BDL -0.12	BDL -0.02	BDL -0.88	0.03-1.49
SD	14.3	6.4	1.1	1.0	0.10	0.04	0.01	0.19	0.32

TABLE III

Elemental content (mg kg^{-1}) of different crops irrigated with Varthur lake water

S.No.	Crop	Fe	Mn	Cu	Zn	Cr	Co	Cd	Pb	Ni
1	Spinach	1,033.13	29.98	29.12	22.63	18.13	25.12	BDL	BDL	BDL
2	Spinach	972.31	30.36	27.60	23.01	17.25	27.60	BDL	BDL	BDL
3	Spinach	834.21	30.53	37.00	22.70	18.48	28.74	BDL	BDL	BDL
4	Spinach	812.55	28.63	4.82	21.37	17.09	17.18	BDL	BDL	BDL
5	Spinach	662.16	21.54	13.29	25.87	6.36	23.85	BDL	BDL	BDL
6	Spinach	954.10	45.77	17.99	12.67	10.83	3.55	BDL	BDL	BDL
	Mean	878.08	31.14	21.64	21.38	14.69	21.01	BDL	BDL	BDL
7	Radish tuber	67.93	19.99	3.84	6.40	9.20	5.95	BDL	BDL	BDL
8	Radish tuber	60.80	16.01	6.92	8.17	9.37	5.38	BDL	BDL	BDL
9	Radish tuber	52.10	17.16	9.38	2.07	11.99	4.35	BDL	BDL	BDL
	Mean	65.55	21.18	9.45	10.07	13.81	7.70	BDL	BDL	0.87
10	Radish leaves	64.76	20.99	6.29	10.22	12.70	7.12	BDL	BDL	2.61
11	Radish leaves	76.63	25.38	8.98	15.63	16.75	10.04	BDL	BDL	BDL
12	Radish leaves	63.71	27.37	12.04	16.42	14.89	21.56	BDL	BDL	BDL
	Mean	63.09	21.15	8.13	9.85	12.67	8.87	BDL	BDL	0.65
13	Coriander	721.90	30.37	2.80	21.67	18.59	25.97	BDL	BDL	0.66
14	Coriander	932.90	30.86	4.13	22.56	17.94	28.31	BDL	BDL	0.84
	Mean	827.40	30.62	3.47	22.12	18.27	27.14	BDL	BDL	0.75
15	Knolkhol	96.07	18.04	17.20	31.50	2.86	46.16	BDL	BDL	1.04
16	Knolkhol	96.65	25.83	5.54	14.02	15.26	14.05	0.70	BDL	BDL
	Mean	96.36	21.94	11.37	22.76	9.06	30.11	0.35	BDL	0.52
17	Amaranthus	730.20	30.74	3.33	22.96	19.07	24.55	BDL	BDL	1.22
18	Amaranthus	890.10	20.59	18.18	31.41	5.28	48.14	BDL	BDL	1.47
	Mean	810.15	25.67	10.76	27.19	12.18	36.35	BDL	BDL	1.35
	Grand Mean	388.17	27.06	9.89	18.75	14.61	21.43	0.06	BDL	0.34
	Range	52.1-1033.13	16.01-45.77	0.37-37.0	2.07-31.5	2.86-19.07	3.55-48.14	BDL-0.7	BDL	BDL-2.61
	SD	383.64	6.12	9.39	6.96	4.60	11.39	0.19	BDL	0.66

Immadihalli village and the lower concentration of 21.34 mg kg^{-1} in Banahalli village. According to the permissible limits of heavy metals in soil (Table 4) and among the soil samples collected, three samples recorded higher than the EU limits (150 mg kg^{-1}) for soil that accounted to 14.29 per cent (Fig. 1a) and 11 samples (52.38 %) higher than the Indian standards (100 mg kg^{-1}) (Fig. 1b). This indicated greater accumulation of Cr in these soils.

The concentration of Cd in soils was 1.68, 2.79, 10.9, 4.76 and 2.12 mg kg^{-1} for Channasandra, Nagondanahalli, Immadihalli, Maddapanahalli and Banahalli villages, respectively. The higher concentration of 10.9 mg kg^{-1} was also observed in the soil of Immadihalli village and none of the samples from Banahalli village. As many as 14 samples (66.67%) recorded higher values than the EU limits (Fig. 1a) and Indian standards of 3.0 mg kg^{-1} (Fig. 1b).

TABLE IV

Permissible limits of heavy metals in soil, plants and vegetables

Standard methods adopted	Cd	Cr	Ni	Pb
European Union Standards for soil (mg kg^{-1})	3.0	150	75	300
Indian Standards for soil (mg kg^{-1})	3.0	100	50	300
European Union Standards for vegetables (mg kg^{-1})	0.2	0.3	2.3	0.3
Indian Standards for plant (mg kg^{-1})	1.5	20.0	1.5	2.5

Source: WHO 2007(Aweng *et al*., 2011)

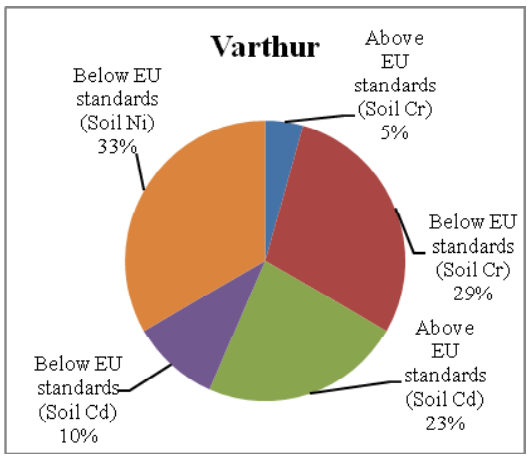

Fig. Ia : Extent of heavy metals in soils as per European Union (EU) standards irrigated with Varthur lake water

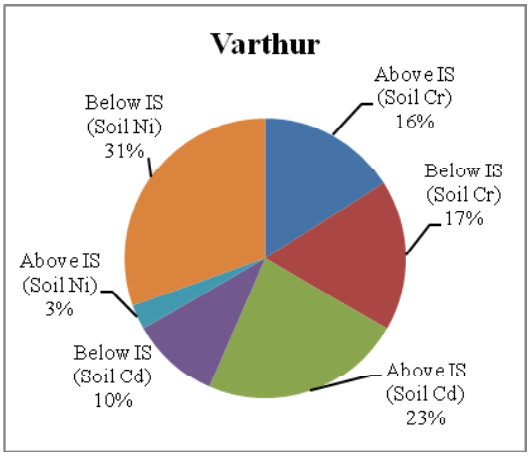

Fig. Ib: Extent of heavy metals in soils as per Indian standards (IS) irrigated with Varthur lake water

The concentration of Ni in soils was 10.08, 4.60, 17.89, 8.77 and 13.04 mg kg^{-1} in Channasandra, Nagondanahalli, Immadihalli, Maddapanahalli and Banahalli village, respectively. Similar to Cr and Cd, the higher concentration of Ni (17.89 mg kg^{-1}) was also observed in the soil of Immadihalli village and the lower value of 4.60 mg kg^{-1} in Nagondanahalli village. Among the soil samples collected, all the samples were below EU limits (75 mg kg^{-1}) (Fig 1a) and two samples recorded higher (9.52 %) than Indian standards (50 mg kg^{-1}) (Fig 1b).

The concentration of Pb in soils was BDL, 2.0, 7.04, 7.39 and 0.33 mg kg^{-1} in Channasandra, Nagondanahalli, Immadihalli, Maddapanahalli and Banahalli village, respectively. All the soil samples were below EU limits (300 mg kg^{-1}) (Fig 1a) and Indian standards (300 mg kg^{-1}) for Pb (Fig 1b).

Although heavy metals like Cd, Cr, Ni and Pb were present in all the samples, few samples recorded higher concentration than the European standards and Indian standards (Fig 2a, b and c). Immadihalli village being very close to Varthur lake, all the heavy metals analysed were higher in these soils. Whereas, Banahalli being a far off village recorded lower values for heavy metal concentration in soils which may be because of dilution of contamination in water with the increase in distance.

The soils that received water from lakes have become point of deposition/ accumulation of heavy metals. Varalakshmi and Ganeshmurthy (2010) studied heavy metal contamination in four different water bodies *viz*, Bellandur, Varthur, Byramangala and Nagavara lakes of peri urban areas of Bengaluru and found higher concentrations of Cd and Cr in waters of all the lakes, exceeding the recommended levels. Among all the lakes, Bellandur and Varthur were found to be highly contaminated with Cd, Pb and Ni. Similar findings were

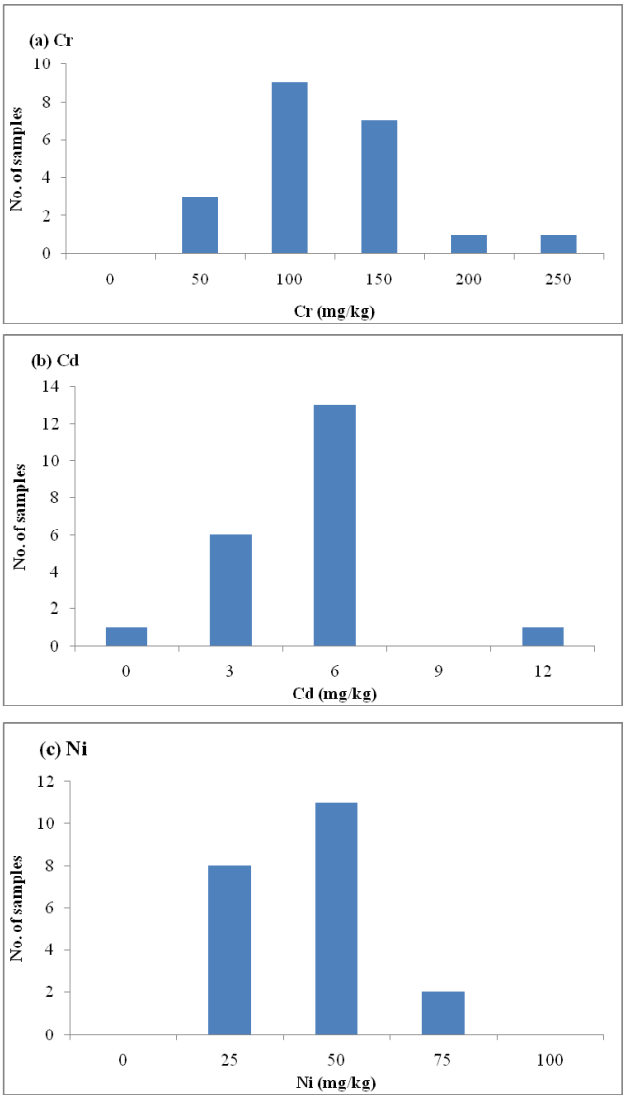

Fig. 2: Frequency distribution histogram of (a) Cr, (b) Cd and (c) Ni (mg kg^{-1}) in soils irrigated with Varthur lake water

noticed by Raj *et al*. (2006), who reported that water and soils collected all along the Musi river of Hyderabad at different sites was contaminated with Cd, Ni, Pb, Co, Zn and Cu.

Other trace elemental content in soils irrigated with different lake water

Data pertaining to Fe, Mn, Cu, Zn and Co concentration in soils irrigated with Varthur lake water are presented in Table 1 and DTPA extractable elements in Table 2.

Total Fe, Mn, Cu and Zn concentration in soil samples irrigated with Varthur lake ranged from 20129.31-29908.94, 20.7-391.6, 12.3-44.5 and 72.19-213.45 mg kg^{-1}, respectively. DTPA extractable Fe, Mn, Cu and Zn, concentration in soil samples irrigated with Varthur lake ranged from 25.0-74.0, 0.8-28.2, 0.1-5.4 and 0.1-3.7 mg kg^{-1}, respectively.

Major portion of untreated city sewage is being let into the Bellandur lake thus hampering the ecological balance of the system as the quantity of the pollutant entering the lake is beyond the neutralizing ability of the lake. Since Bellandur and Varthur lakes are interconnected (Ramachandra *et al*., 2008), any mismanagement of solid wastes such as building demolition wastes, bulky wastes (carcasses), garbage *etc*. are being dumped in the shoreline are of greater concern which affect water quality and aesthetics. It was also observed that the average values of metal concentration of Fe, Zn, Cu, and Ni in Bellandur lake water was 1087, 132, 12, 3 mg L^{1}, respectively and were 2, 9, 4 and 6-fold higher than the natural elemental levels (Lokeshwari and Chandrappa, 2007).

Total heavy metal content in vegetables irrigated with Varthur lake water

Concentration of Cr, Cd, Pb and Ni in different vegetable ranged from 2.86-19.07, BDL-0.7, BDL and BDL-2.61 mg kg^{-1} (Table 3 and Fig. 3a, b, and c). The concentration of Cr was 14.69, 13.81, 12.67, 18.27, 9.06 and 12.18 mg kg^{-1} for spinach, radish tuber, radish leaves, coriander, knoll khol and amaranthus, respectively. The higher concentration of 19.07 mg kg^{-1} was observed in the amaranthus and the lower concentration of 2.86 mg kg^{-1} Cr was observed in knol khol. The mean values in different crops indicate that higher Cr content in coriander leaves followed by spinach, radish, amaranthus and knol khol. Among the leafy vegetables, coriander followed by spinach are known to be the accumulators of heavy metals but the reports for accumulation of heavy metals in knol khol were not found. Similar studies conducted by Varalakshmi and Ganeshmurthy (2010) reported that, spinach accumulated higher Cr, followed by amaranthus, radish and carrot.

EU standard for Cr permissible limits in vegetable crops is 0.3 mg kg^{-1} and the Indian standards for plant is 20.0 mg kg^{-1} (Table 4). All the plant samples recorded higher

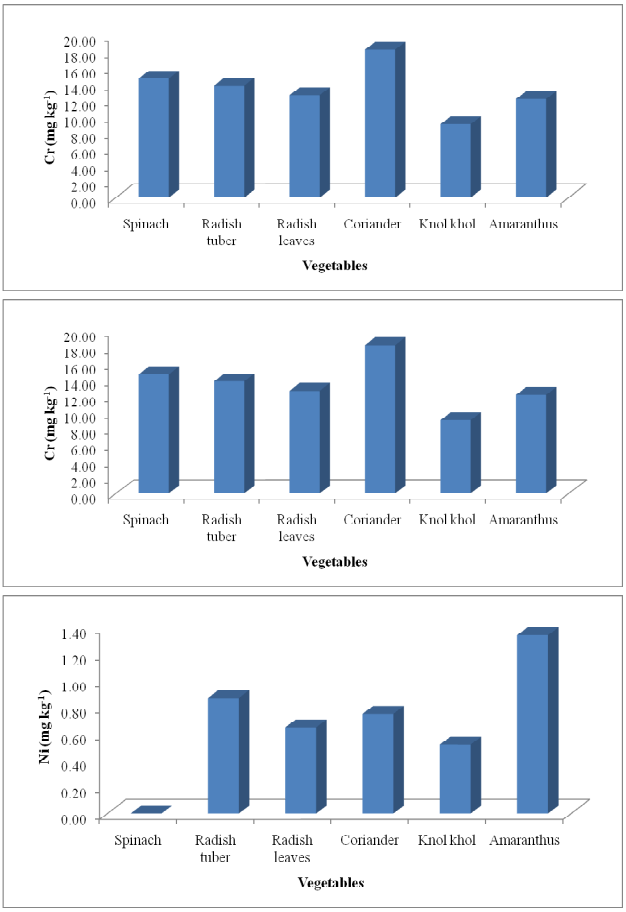

Fig. 3: Content of (a) Cr, (b) Cd and (c) Ni (mg kg^{-1}) in vegetables irrigated with lake water

concentration than EU permissible limits for Cr. Aboud and Nandini (2009) also reported lower concentration of Cr in plants grown under irrigation with Varthur lake which was found to be within the critical range. Heavy metals from contaminated lakes, enter the soils upon irrigation and ultimately leads to crop accumulation of heavy metals. Heavy metals are mainly taken up by crops from the soil through roots. Transportation of heavy metal from the soil to the roots largely depends on the type of soil, amount of organic matter, pH of the soil and other chemical and physical properties of the soil (Gupta *et al.,* 2012).

Other trace elements in crops irrigated with lake water

The concentration of Fe, Mn, Cu and Zn in different vegetable crops ranged from 52.1-1033.13, 16.01-45.77, 0.37-37.0, 2.07-31.5, 2.86-19.07, 3.55-48.14, BDL-0.7, BDL and BDL-2.61 mg kg^{-1}, respectively hence accumulated higher contents of iron in leafy vegetables. Leaves are considered as food making factories in plants and manganese content was higher in leafy vegetables compared to those in other vegetables as reported by Jayadev and Puttaih (2013) in soils irrigated with different lakes of Bangalore.

Present study showed that the soils irrigated with Varthur lake water were contaminated with chromium, cadmium and nickel at different concentration and most of them exceeded the permissible limits of European Union and Indian standards for soils. The concentration of Cr in vegetable crop samples exceeded the permissible limits of European Union (0.30 mg kg^{-1}) for vegetables. According to Ramesh and Yoganandamurthy (2012), the concentration of heavy metals was comparatively high in leafy vegetables, because of high translocation and transpiration rate of leafy vegetables.

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