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TRACE METAL CONTAMINATION IN SOILS AND PLANTS NEAR INDUSTRIAL AREAS IN JHARKHAND

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ABSTRACT
Soil contamination by trace elements is caused by several processes. Anthropogenic sources of trace elements are a consequence of industrial development and urbanization. To assess the extent of trace metal contamination, soil and plant samples were collected around industries of Patratu, Bokaro and Jamshedpur. Results revealed that DTPA extractable Zn, Cu, Mn, Fe, Cd, Pb, Ni and Co content in soil samples ranged from 0.09 to 5.25, 0.44 to 5.13, 2.23 to 24.94, 11.50 to 70.18, tr. to 0.20, tr. to 5.16, 0.04 to 6.54 and 0.79 to 3.59 mg kg^{-1}, respectively. Cadmium was detected in 47 per cent samples; however, none of the samples crossed the critical limit for toxicity (0.5 mg kg^{-1}). Zn content in plants varied from 2 to 141 mg kg^{-1}, Mn from 11 to 506 mg kg^{-1}, Cu from 3 to 50 mg kg^{-1}, Fe from 315 to 2145 mg kg^{-1}, Cd from tr. to 5.00 mg kg^{-1}, Pb from tr. to 19.60 mg kg^{-1}, Ni from 3.15 to 36.35 mg kg^{-1} and Co from tr. to 39.85 mg kg^{-1}. It was noticed that palash leaves collected around Patratu Thermal Power Station had high trace metal content, while jamun leaves collected around Central Coalfield Limited had relatively low trace metal content. Vegetable crops collected around industries contained toxic trace metals above maximum tolerable limit. Among vegetables 53, 63 and 95 per cent samples crossed maximum tolerable limit for Cd, Pb and Co, respectively. Maize and paddy also contained high amount of trace metal during present study. Lead was not detected in any paddy plants, while Cd was found above MTL.

KEY WORDS: trace metal contamination, soils, plants.

INTRODUCTION
Soil is the key component of natural ecosystems because environmental sustainability depends largely on a sustainable ecosystem. Unlike other environmental components, pollutants have long residence time in soil. Therefore, soil acts as a sink or a filter in which pollutants are accumulated rapidly but depleted slowly. Soil contamination by trace elements is caused by several processes. Natural inputs to trace elements to soil are weathering processes, volcanic activities and plant burning. Anthropogenic sources of trace elements are a consequence of industrial development and urbanization. These sources are related to human activities such as mining and smelter activities, fossil fuel combustion, waste incineration and disposal, agricultural practices like use of fertilizers and pesticides (Adriano *et al.*, 1995). In our country, disposal of industrial and urban effluents has become a serious problem due to rapid industrial development and urbanization during the last two decades. The application of city and industrial effluents to land has become popular during recent years as an alternative means of treatment and disposal. Besides being a useful source of plant nutrients in most cases, these effluents often contain high amounts of various organic and inorganic materials as well as heavy metals. Unscientific disposal of untreated and under-treated effluents result in accumulation of heavy metals in land and water bodies (Chhonkar, 2004). Though several regulatory steps have been implemented to reduce or restrict the release of pollutants in soil and water, they have proved to be in-sufficient. Jharkhand has several coal mines. The Damodar river basin is a repository of approximately 46 per cent of the Indian coal reserves. Due to extensive coal mining and rapid growth of industries, soil and water resources have been badly contaminated. Besides mining, coal based industries like coal washeries, coke oven plant, coal fired thermal power plant, steel plants and other related industries in the region are responsible for degradation of environmental quality. Therefore, soil and plant samples were collected around industries of Ramgarh, Bokaro and East Singhbhum districts of Jharkhand to evaluate the extent of trace metal contamination.

MATERIALS & METHODS
The soil and plant samples were collected around Patratu Thermal Power Station, Patratu (Ramgarh), Gobindpur and Kathara Project Central Coalfield Limited (Bokaro) and solid waste disposal site, Jamshedpur (East Singhbhum). Altogether 60 soil and 48 plant samples were collected following standard sampling methods. The description of soil samples are presented in table 1.

TABLE 1: Description of soil samples

Sl. No.	Location	Topography	Land Use
PTPS, Patratu (Ramgarh)			
1	0-1 km North to PTPS	Low land	Paddy-Fallow
2	0-1 km North to PTPS	Medium land	Paddy-Fallow
3	0-1 km North to PTPS	Medium land	Paddy-Fallow
4	0-1 km North to PTPS	Upland	Paddy-Fallow
5	0-1 km North to PTPS	Upland	Paddy-Fallow
6	1-2 km North to PTPS	Upland	Maize-Vegetables
7	1-2 km North to PTPS	Upland	Paddy-Fallow
8	1-2 km North to PTPS	Upland	Paddy-Fallow
9	1-2 km North to PTPS	Upland	Paddy-Fallow
10	1-2 km North to PTPS	Upland	Paddy-Fallow
11	4-5 km West to PTPS (Vill. – Labga)	Upland	Maize-Vegetables
12	4-5 km West to PTPS (Vill. – Labga)	Medium land	Maize-Mustard
13	4-5 km West to PTPS (Vill. – Labga)	Medium land	Maize-Mustard
14	4-5 km West to PTPS (Vill. – Labga)	Medium land	Maize-Mustard
15	4-5 km West to PTPS (Vill. – Labga)	Low land	Paddy-Paddy
16	2-3 km South to PTPS (Vill. –Rasada)	Upland	Maize-Mustard
17	2-3 km South to PTPS (Vill. –Rasada)	Medium land	Vegetables
18	2-3 km South to PTPS (Vill.–Rasada)	Medium land	Vegetables
19	2-3 km South to PTPS (Vill.–Rasada)	Low land	Paddy-Mustard
20	2-3 km South to PTPS (Vill.–Rasada)	Low land	Paddy-mustard
Gobindpur and Kathara Project CCL (Bokaro)			
21	0-1 km near Gobindpur Project	Low land	Paddy-Fallow
22	0-1 km near Gobindpur Project	Low land	Paddy-Fallow
23	0-1 km near Gobindpur Project	Medium land	Paddy-Fallow
24	0-1 km near Gobindpur Project	Medium land	Paddy-Fallow
25	0-1 km near Gobindpur Project	Medium land	Paddy-Fallow
26	1-2 km near Gobindpur Project	Upland	Maize-Vegetables
27	1-2 km near Gobindpur Project	Upland	Maize-Vegetables
28	2-3 km near Gobindpur Project	Upland	Vegetables
29	2-3 km near Gobindpur Project	Upland	Vegetables
30	2-3 km near Gobindpur Project	Upland	Vegetables
31	0-1 km near Kathara Project	Low land	Paddy-Fallow
32	1-2 km near Kathara Project	Medium land	Paddy-Fallow
33	0-1 km near Kathara Project	Low land	Paddy-Fallow
34	0-1 km near Kathara Project	Medium land	Paddy-Fallow
35	1-2 km near Kathara Project	Upland	Paddy-Fallow
36	1-2 km near Kathara Project	Medium land	Paddy-Fallow
37	1-2 km near Kathara Project	Medium land	Paddy-Fallow
38	0-1 km near Kathara Project	Upland	Paddy-Fallow
39	1-2 km near Kathara Project	Upland	Paddy-Fallow
40	1-2 km near Kathara Project	Upland	Paddy-Fallow
Waste disposal site, Jamshedpur (East Singhbhum)			
41	4-5 km from Dimna Nala	Low land	Paddy-Fallow
42	4-5 km from Dimna Nala	Low land	Paddy-Fallow
43	4-5 km from Dimna Nala	Low land	Paddy-Fallow
44	4-5 km from Dimna Nala	Low land	Paddy-Fallow
45	4-5 km from Dimna Nala	Upland	Paddy-Fallow
46	3-4 km from Dimna Nala	Medium land	Maize-Vegetables
47	3-4 km from Dimna Nala	Medium land	Paddy-Fallow
48	3-4 km from Dimna Nala	Medium land	Paddy-Fallow
49	3-4 km from Dimna Nala	Medium land	Paddy-Fallow
50	3-4 km from Dimna Nala	Medium land	Paddy-Fallow
51	2-3 km from Dimna Nala	Medium land	Maize-Vegetables
52	2-3 km from Dimna Nala	Low land	Maize-Mustard
53	2-3 km from Dimna Nala	Upland	Maize-Mustard
54	2-3 km from Dimna Nala	Medium land	Maize-Mustard
55	1-2 km from Dimna Nala	Low land	Maize-Vegetables
56	1-2 km from Dimna Nala	Upland	Maize-Vegetables
57	1-2 km from Dimna Nala	Medium land	Vegetables
58	1-2 km from Dimna Nala	Medium land	Vegetables
59	1-2 km from Dimna Nala	Low land	Paddy-Maize
60	1-2 km from Dimna Nala	Low land	Paddy-Maize

Trace metals concentration including Zn, Cu, Mn, Fe, Cd, Pb, Ni and Co in soil and plant samples were analysed. The available trace metal was determined by extracting soil with DTPA (0.005M DTPA, 0.01M $CaCl_2$, 0.1M TEA), pH adjusted to 7.3 with the help of dilute HCl, maintaining 1:2 soil to extractant ratio and shaking for 2 hrs at 120 rpm (Lindsay and Norvell, 1978). For estimation of total trace metal, soil sample was digested in perchloric-hydrofluoric mixture on platinum crucible near to dryness, residue was redissolved in hydrochloric acid (Hesse, 1994) and metal content was determined on Atomic Absorption Spectrophotometer (EICL AAS4139). Oven dried plant sample was digested in mixture of HNO_3:$HClO_4$ in the ratio of 9:4 at 80^0C until a transparent solution was obtained (Allen *et al.*, 1986). The transparent solution was diluted with double distilled water and filtered. The content of trace metal was determined on Atomic Absorption Spectrophotometer (EICL AAS4139) by employing the appropriate hollow cathode lamp.

RESULTS & DISCUSSION

DTPA extractable trace metal in soil

The DTPA extractable Zn, Cu, Mn, Fe, Cd, Pb, Ni and Co content in soil samples ranged from 0.09 to 5.25, 0.44 to 5.13, 2.23 to 24.94, 11.50 to 70.18, tr. to 0.20, tr. to 5.16, 0.04 to 6.54 and 0.79 to 3.59 mg kg^{-1}, respectively (Table 2).

TABLE 2: DTPA-extractable trace metal content (mg kg^{-1}) in soils

Sample No	Zn	Cu	Mn	Fe	Cd	Pb	Ni	Co
1	1.60	3.62	22.84	41.90	ND	2.10	1.38	2.06
2	0.43	1.63	24.94	19.94	ND	0.91	0.89	2.06
3	0.74	1.53	23.96	27.56	0.02	1.02	0.48	2.15
4	1.16	3.20	24.88	11.50	0.01	1.42	0.69	2.32
5	3.98	1.49	14.90	62.46	0.02	0.68	0.41	1.21
6	4.51	1.34	11.78	14.52	0.05	1.31	0.62	0.87
7	1.61	0.77	19.17	36.76	0.04	1.99	0.41	0.79
8	0.31	0.79	18.31	27.10	0.02	0.79	0.27	1.04
9	0.14	0.44	10.78	30.88	ND	0.63	0.28	0.87
10	0.90	1.78	18.60	36.10	ND	1.14	0.48	1.47
11	1.53	1.29	24.00	46.22	0.03	0.45	0.04	1.29
12	1.36	2.30	19.95	52.92	ND	0.85	0.07	1.64
13	1.85	1.15	21.78	20.58	ND	0.80	0.41	1.55
14	1.06	2.34	24.62	51.90	ND	1.40	0.89	2.23
15	1.11	2.47	23.80	41.26	ND	0.97	0.96	2.23
16	0.99	1.40	24.66	35.00	0.01	0.57	1.10	1.72
17	0.26	1.50	24.32	35.00	0.01	0.28	1.38	2.40
18	0.61	2.34	23.94	37.48	ND	1.20	0.90	1.98
19	1.16	1.98	18.78	46.86	0.01	2.52	1.17	1.64
20	0.83	2.74	21.48	40.14	ND	1.58	1.03	1.89
21	0.33	1.76	22.96	68.24	ND	ND	1.52	1.29
22	1.43	1.84	23.60	70.18	ND	ND	2.34	1.98
23	0.95	2.36	17.32	42.08	ND	ND	1.99	1.64
24	0.90	1.95	22.94	39.24	0.01	ND	1.58	1.30
25	1.79	2.47	16.03	31.42	ND	1.42	1.79	2.15
26	0.93	1.47	22.64	29.32	0.01	1.14	1.45	1.81
27	0.51	2.09	21.60	27.66	ND	0.85	1.44	1.98
28	1.08	3.37	19.80	29.50	0.03	0.80	1.31	1.47
29	5.25	1.76	19.79	27.94	0.01	0.45	1.30	1.46
30	2.81	1.38	19.57	25.36	ND	0.68	2.27	1.04
31	4.74	2.70	20.90	25.08	ND	0.28	6.54	2.83
32	5.13	3.08	22.64	31.34	ND	1.36	2.69	2.06
33	1.04	3.09	14.54	30.26	ND	1.08	1.86	2.66
34	1.16	2.76	12.64	28.76	0.01	5.16	1.65	1.89
35	0.52	2.03	20.30	26.52	ND	0.79	2.20	2.57
36	0.77	1.93	23.14	25.42	ND	ND	2.13	2.49
37	0.15	1.57	24.62	26.32	0.01	ND	2.27	3.59
38	2.95	5.13	20.94	44.34	0.04	ND	4.48	3.17
39	2.41	3.49	18.13	38.62	0.02	ND	2.75	3.17
40	0.78	3.52	19.33	30.40	0.01	ND	2.62	3.00
41	0.65	2.76	16.96	26.10	ND	ND	1.52	1.29
42	0.48	2.03	14.70	16.35	ND	ND	2.34	1.98
43	0.46	1.76	8.08	44.56	ND	ND	1.99	1.64
44	0.40	1.40	2.23	39.50	0.01	ND	1.58	1.30
45	1.97	2.26	20.30	41.52	ND	1.42	1.79	2.15
46	0.75	2.09	16.05	32.34	0.01	1.14	1.45	1.81
47	0.25	2.83	19.18	33.90	ND	0.85	1.44	1.98
48	1.16	2.36	10.32	52.08	0.03	0.80	1.31	1.47
49	0.48	2.41	22.92	25.72	0.01	0.45	1.30	1.46
50	0.57	2.47	23.86	48.04	ND	0.68	2.27	1.04
51	0.59	1.70	19.28	41.34	ND	0.28	6.54	2.83
52	0.49	2.66	21.14	38.86	ND	1.36	2.69	2.06
53	0.62	1.40	13.04	26.10	ND	1.08	1.86	2.66

54	0.54	2.39	19.80	36.72	0.01	5.16	1.65	1.89
55	1.60	0.98	7.08	26.64	ND	0.79	2.20	2.57
56	0.09	1.65	22.02	28.44	ND	ND	2.13	2.49
57	1.03	1.90	19.46	32.42	0.01	ND	2.27	3.59
58	1.40	1.55	16.63	30.30	0.04	ND	4.48	3.17
59	2.41	1.84	19.97	36.82	0.02	ND	2.75	3.17
60	1.95	0.84	21.02	24.78	0.01	ND	2.62	3.00
Range	0.09 – 5.25	0.44 – 5.13	2.23 – 24.94	11.50 – 70.18	ND – 0.20	ND – 5.16	0.04 – 6.54	0.79 – 3.59
Mean	1.33	2.09	19.25	34.94	0.01	0.84	1.77	2.01
SD ±	1.22	0.82	4.85	11.67	0.01	1.01	1.27	0.70

It was noticed that DTPA-Zn was above the critical value (0.6 mg kg^{-1}) in 70 per cent soil samples, however, all soils collected from these districts contained Cu (0.2 mg kg^{-1}), Mn (2.0 mg kg^{-1}) and Fe (4.5 mg kg^{-1}) above their respective critical values. Thus the soils may be regarded as sufficient in micronutrient content. Alarming presence of toxic trace metal was noticed. Cadmium was detected in 47 per cent samples, however, none of the samples crossed the critical limit for toxicity (0.5 mg kg^{-1}). One sample each collected from Bokaro and Jamshedpur had DTPA-Pb above maximum allowable limit (3.0 mg kg^{-1}), while Pb was detected in 70 per cent samples. DTPA extractable Ni and Co were found in all soil samples and it was observed that 33 per cent samples crossed the maximum allowable limit for Ni (2.0 mg kg^{-1}), while all samples for Co (0.5 mg kg^{-1}). Detection of toxic metals in many soils in considerable amount is a matter of concern as acidic condition favours their accumulation in growing plants and edible parts and there is chance to enter these metals in food chain. Similar results were reported by Kumar *et al.* (2010) in Jharkhand soils.

Total trace metal in soil

Data presented in table 3 indicate total trace metal content in soil samples collected around industries of Patratu, Bokaro and Jamshedpur. The range of Zn, Mn, Cu, Fe, Cd, Pb, Ni and Co was 2 – 126, 16 – 1900, 2 – 189, 9170 – 24640, 1 – 38, 22 – 1220, 26 – 495 and 5 – 450 mg kg^{-1}, respectively. Perusal of mean data indicated that soils collected from Patratu had highest Zn (43.6 mg kg^{-1}) and Mn (689.4 mg kg^{-1}), soils collected from Bokaro had highest Pb (159 mg kg^{-1}) and Ni (243 mg kg^{-1}), while highest mean value for Cu (112 mg kg^{-1}), Fe (18763 mg kg^{-1}), Cd (18 mg kg^{-1}) and Co (333 mg kg^{-1}) was observed in soils collected from Jamshedpur.

Trace metal content in plant

Zn content in plants varied from 2 (jamun) to 141 mg kg^{-1} (palash), Mn from 11 (jamun) to 506 mg kg^{-1} (palash), Cu from 3 (neem, jamun, bhindi, bitter gourd, poi sag) to 50 mg kg^{-1} (palash), Fe from 315 (jamun) to 2145 mg kg^{-1} (palash), Cd from tr. to 5.00 mg kg^{-1} (cucumber), Pb from tr. to 19.60 mg kg^{-1} (akwan), Ni from 3.15 (maize) to 36.35 mg kg^{-1} (bitter gourd) and Co from tr. to 39.85 mg kg^{-1} (palash). It was noticed that palash leaves collected around Patratu Thermal Power Station had high trace metal content, while jamun leaves collected around Central Coalfield Limited had relatively low trace metal content. Vegetable crops collected around industries contained toxic trace metals above maximum tolerable limit (Cd – 3, Pb – 10, Ni – 50 and Co – 5 mg kg^{-1}). Among vegetables 53, 63 and 95 per cent samples crossed maximum tolerable limit for Cd, Pb and Co, respectively. Maize and paddy also contained high amount of trace metal during present study. Lead was not detected in any paddy plants, while Cd was found above MTL. Accumulation of trace metal by plants in fly ash amended soil (Sharma and Kalra, 2006), in sewage water irrigated soil (Patel *et al.*, 2004) and effluent irrigated soil (Rattan *et al.*, 2005) were reported earlier.

TABLE 3: Total trace metal content (mg kg^{-1}) in soils

Sample No	Zn	Mn	Cu	Fe	Cd	Pb	Ni	Co
1	40	339	45	17660	1	57	201	79
2	126	698	74	19620	1	29	289	153
3	58	572	2	18220	1	29	260	190
4	24	931	59	18540	2	52	289	190
5	23	318	62	24640	1	45	407	153
6	31	536	74	12840	2	32	348	153
7	55	572	45	21820	3	29	465	190
8	28	482	45	16190	1	57	377	190
9	37	231	45	9939	4	84	174	153
10	43	231	117	14940	1	29	201	153
11	70	159	31	16890	2	24	231	5
12	39	716	59	15880	23	31	148	5
13	21	698	31	17490	16	33	55	5
14	46	752	31	19970	8	36	348	153
15	73	877	45	20880	12	57	84	5
16	83	1075	88	22520	12	57	172	42
17	24	1541	16	21610	4	29	231	116
18	39	1164	74	22660	19	29	172	42
19	21	1290	88	21790	12	32	84	79
20	3	1129	88	21510	1	32	201	42
21	24	339	74	15500	16	29	289	109

22	9	303	74	17660	4	32	495	153
23	24	52	88	16540	5	36	172	79
24	64	16	88	14660	4	1220	172	79
25	24	321	74	17210	6	182	377	190
26	37	285	59	17450	5	116	319	153
27	70	644	88	15430	4	154	231	190
28	24	375	59	9170	5	168	172	264
29	28	231	74	12140	8	181	114	116
30	3	375	102	15040	16	234	172	153
31	9	105	117	18330	5	36	143	190
32	49	249	88	16650	12	42	201	227
33	2	303	88	17030	8	29	201	301
34	61	141	74	19270	8	29	289	264
35	42	177	88	20770	5	171	231	264
36	24	70	102	19100	5	142	348	301
37	70	1164	102	17560	6	142	407	339
38	43	249	117	17380	8	114	348	264
39	2	339	131	15430	21	86	84	431
40	3	662	160	18260	23	29	84	301
41	67	446	160	19970	7	22	231	376
42	18	518	146	20770	38	57	348	301
43	3	357	88	18400	6	29	26	339
44	37	213	59	15740	12	142	26	264
45	55	375	174	19970	17	114	172	339
46	46	267	160	16300	34	142	201	376
47	3	249	131	18920	24	86	26	376
48	9	123	160	17380	14	86	26	376
49	46	446	117	18680	7	57	55	339
50	34	518	131	18820	4	57	143	301
51	34	285	88	18190	24	86	26	227
52	3	518	189	18570	31	171	26	376
53	9	572	160	18290	7	142	84	190
54	12	1021	160	23110	4	199	348	339
55	34	608	189	23570	24	199	143	376
56	52	859	4	15500	11	199	172	264
57	31	464	3	15710	31	227	144	450
58	37	195	31	14660	17	256	144	227
59	58	1541	45	22450	34	86	289	413
60	89	1900	45	20250	4	171	231	413
Range	2 – 126	16 – 1900	2 – 189	9170 – 24640	1 – 38	22 – 1220	26 – 495	5 – 450
Mean	36	536	87	18024	11	108	207	219
SD ±	25	403	47	3097	10	160	118	122

TABLE 4: Trace metal content (mg kg^{-1}) in different plant species

Plant Sp.	Pt Parts	Zn	Mn	Cu	Fe	Cd	Pb	Ni	Co
Jatropha	Leaves	28	82	16	877	0.35	3.25	17.30	11.95
Jatropha	Leaves	33	136	16	1075	4.05	0.59	18.95	11.95
Sagwan	Leaves	31	100	31	1353	1.90	ND	13.55	9.95
Sagwan	Leaves	27	42	25	1144	3.75	4.65	7.95	15.95
Palash	Leaves	141	506	50	2145	4.35	11.45	36.00	39.85
Palash	Leaves	17	35	24	786	ND	7.35	24.75	15.95
Akwan	Leaves	38	79	5	714	2.80	3.25	11.70	2.00
Banayan	Leaves	31	45	5	489	ND	ND	4.20	ND
Neem	Leaves	24	14	5	1396	0.05	4.60	8.05	6.00
Neem	Leaves	15	15	3	483	5.00	10.05	17.30	11.95
Mahua	Leaves	6	83	4	386	0.95	ND	13.55	4.00
Gular	Leaves	32	34	8	1107	3.15	16.95	11.70	7.95
Akwan	Leaves	57	84	31	1546	5.00	19.60	22.90	13.95
Jamun	Leaves	2	11	3	315	2.50	8.70	19.10	13.95
Guava	Leaves	22	21	7	533	0.34	0.50	6.05	ND
Guava	Leaves	16	29	4	441	2.50	12.80	6.05	15.95
Sahajan	Leaves	10	21	7	760	0.05	4.90	7.95	9.95
Sahajan	Leaves	12	41	9	908	3.15	15.45	15.25	17.95
Bhindi	Leaves	32	95	3	914	0.35	4.75	15.40	4.00
Bhindi	Leaves	37	97	13	739	2.20	16.90	19.35	19.90
Bhindi	Leaves	25	73	11	774	0.65	14.15	28.50	19.90
Cowpea	Leaves	47	39	9	1082	0.65	1.90	13.55	17.95
Cowpea	Leaves	26	186	11	1100	3.45	15.10	26.65	11.95
Cowpea	Plant	33	96	32	1491	3.45	8.90	19.40	23.90

Kachchu	Leaves	38	97	4	1286	3.45	5.95	17.30	7.95
Cucumber	Leaves	29	87	7	1130	5.00	11.90	6.90	11.95
Sponge gourd	Leaves	43	46	9	889	2.50	10.55	19.15	15.95
Sponge gourd	Plants	46	132	9	1695	2.80	15.55	30.35	15.95
Sponge gourd	Leaves	45	227	21	1916	1.60	14.15	21.30	33.85
Bitter gourd	Leaves	92	73	3	916	0.65	11.45	17.30	9.95
Bitter gourd	Leaves	30	73	9	522	4.35	18.25	36.35	25.90
Bitter gourd	Leaves	37	131	21	1842	4.05	15.75	32.25	31.85
Bottle gourd	Leaves	53	173	25	1328	4.35	8.95	24.75	23.90
Brinjal	Leaves	28	85	18	1247	2.20	19.45	21.15	33.85
Radish	Plants	87	275	13	1936	3.75	3.35	16.95	25.90
Spinach	Plants	50	77	12	1666	4.35	1.80	17.30	25.90
Poi sag	Plants	47	137	3	1318	4.05	10.00	21.05	7.95
Maize	Plants	6	13	5	544	ND	ND	7.95	4.00
Maize	Plants	68	136	11	1444	0.05	4.50	13.55	5.00
Maize	Leaves	32	74	13	886	ND	3.35	11.70	4.00
Maize	Leaves	21	56	11	1025	4.35	18.25	3.15	8.70
Maize	Leaves	26	103	22	1397	1.90	5.95	11.90	21.90
Paddy	Plants	44	308	10	1668	ND	ND	4.20	17.00
Paddy	Plant	45	460	12	1479	3.45	ND	6.45	21.90
Paddy	Plants	47	335	13	1649	3.45	ND	5.45	21.90
Paddy	Plants	41	322	11	1604	2.90	ND	6.20	19.90
Doob Grass	Plants	19	93	7	843	ND	8.70	21.40	13.95
Dudhi Grass	Plants	20	171	21	671	5.00	10.05	17.30	7.95

CONCLUSION

Results thus indicate that soils around industries contained higher amount of available and total trace metals particularly Cd, Pb, Ni and Co. It is a matter of concern as acidic soil condition favours their accumulation in growing plants and edible parts which may enter the food chain and create health hazards. Many of the plants collected around industrial area showed trace metal concentration above maximum tolerable limit. Vegetable crops studied had Cd, Pb, Ni and Co concentration 2-3 times more than maximum tolerable limit which calls for ameliorative measures.

REFERENCES

Adriano, D.C., Chlopecka, A., Kaplan, K.I., Clijsters, H. & Vangronsveld, J. (1995) Soil contamination and remediation: philosophy, science and technology. In: Contaminated Soils, R. Prost ed. INRA Les olloques, n^{0}85, Paris. pp. 465-504.

Allen, S.E., Grimshaw, H.M. and Rowland, A.P. (1986) Chemical analysis. pp. 285-344. In: *P.D. More and S.B. Chapman (eds.) Methods in Plant Ecology*. Blackwell Scientific Publication, Oxford, London.

Chhonkar, P.K. (2004) Phytoremediation: A ‘Green Cure’ for heavy metal contaminated soils. *Journal of the Indian Society of Soil Science,* **52**: 357-373.

Hesse, P.R. (1994) A Textbook of Soil Chemical Analysis. CBS Publishers and Distributors, New Delhi.

Kumar, R., Kumar, R., Karmakar, S. and Agrawal, B.K. (2010) Vertical and topographical distribution of cobalt, nickel and lead in relation to soil characteristics in different agro-climatic zones of Jharkhand. *Journal of the Indian Society of Soil Science.* **58**: 293-298.

Lindsay, W.L. & Norvell, W.A. (1978) Development of DTPA test for zinc, iron, copper and magenese. *Soil Science Society of America Journal.* **42**: 421-428.

Patel, K.P., Pandya, R.R., Maliwal, G.L., Patel, K.C., Ramani, V.P. and George, V. (2004) Heavy metal content of different effluents and their relative availability in soils irrigated with effluent waters around major industrial cities of Gujarat. *Journal of the Indian Society of Soil Science.* **52**: 89-94.

Rattan, R.K., Datta, S.P., Chhonkar, P.K. and Singh, A.K. (2005) Heavy metal contamination through sewage irrigation in peri-urban areas of National Capital Territory of Delhi. Technical Bulletein, Divison of Soil Science and Agricultural Chemistry, Indian Agricultural Research Institute, New Delhi, pp. 51.

Sharma, S.K. & Kalra, N. (2006) Effect of fly ash incorporation on soil properties and productivity of crops: A review. *Journal of Scientific and Industrial Research.* **65**: 383-390.