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Appraisal of Metal Contamination in Soil around Industrial Areas of Chennai, Tamil Nadu, India

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Abstract: The concentration of metals (Al, Fe, Mn, Ti, Cr, Co, Ni, Cu, Zn and Pb) was studied in urban topsoil to identify the metal contamination due to modern urbanization and industrial developments. The soil samples were collected from the top portion of the soil layer (0-25 cm). The accumulation of elements in the soil was analyzed using X-ray fluorescence spectrometer. Metal contamination was calculated using Index formulas such as enrichment factor (EF), Geo accumulation index (I_{geo}), contamination factor (CF) and pollution load index (PLI). The trace elements are derived from anthropogenic process. Maximum concentrations of Pb, Zn and Cu was noticed near by the road side soils and are specifically derived from the high road traffic volume and leaded fuel combustion in the urban environment. The other enriched metals (Cr and Mn) were derived from industrial wastes like chrome electroplating industries. The correlation results suggest that the strong correlation between Cr, Cu and Zn indicates their common origin, especially from urban development, such as electro chrome plating industries, sewage sludge and urban runoff.

Keywords: *Metals, Soils, Industrial areas, Contamination, Chennai city, India*

1. INTRODUCTION

The first step in the monitoring of the metal pollution of soil is to determine whether the total content of metals is within the range of background level or over the concentration limits according to World Health Organization (WHO) and ISI standards. Heavy metal contamination in soil is a global problem due to the wide range of metal application in all aspects of human life. In general, the distribution of these metals are influenced by the nature of parent material, climate and their relative mobility depending on soil parameters like mineralogy, textural characteristics and classification of soil [1].The heavy metals may enter the biological systems by inhalation or ingestion through the water supply and human causes such as mining, smelting, sewage sludge disposal, application of pesticides, inorganic fertilizers and atmospheric emissions [2].

In recent days, the main anthropogenic pollutant sources include power and heat generation in waste incineration and traffic emissions. Significant increasing trend of metal contamination may be several times higher than the average value of non-contaminated areas and this concentration migrated to distant areas by long-range atmospheric transport. The geochemical processes that control the metal mobility and its availability are dissolution, adsorption into mineral and organic particles complexation by biogenic or non-biogenic ligands and subsequent uptake by biota [3]. The presence of organic carbon and calcium carbonate is directly or indirectly contribute to the accumulation of heavy metals in soil. The concentration of heavy metals in soil by various processes like release of heavy metals from organic matter, extraction of metals by organic matter in the soil forming organic complexes etc. The solubility and migration of metal ions in soil was mainly controlled by various parameters such as pH, conductivity etc. Contaminated soil sites often share critical properties such as high acute and/or chronic toxicity, high environmental persistence, often high mobility leading to contamination of groundwater and high lipophilicity leading to bioaccumulation in food web [1]. Statistical analysis like multivariate analysis such as factor extractions has been widely used to distinguish between natural and anthropogenic source of metals in soil. The pollution index values are also calculated to provide information on the relative contribution of different pollutant sources. In general, the investigations on urban soil are performed on sites suspected to have been impacted by large industrial activities, urbanization and traffic emissions.

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Recently, [1, 4 – 8] have recorded the toxicity of the trace elements in soil around the industrial/mining areas and the nearby urban areas and emphasized that the evaluation of trace elements in soils is important as it serves as a transitional link between lithosphere and biosphere.

The soil sampling locations are shown in Fig. 1. The sampling points, including heavy industrial area, coal storage and shipping area, waste incineration plants and petroleum refineries of Chennai city. Manali is major industrial area in the selected sampling sites for this study. This industrial area is one of the polluted regions in Chennai identified by the Central Pollution Control Board (CPCB). This industrial town is situated in the north Chennai near Buckingham canal. It comprises an area, of over 800 ha, intersected by villages. This industrial town is consisting of known industries like Madras Fertilizers, Madras Petrochemicals limited and Madras Refineries Limited. Such high industrial activities pose a major threat to the entire ecosystem/environment. We suspect that there will be some sort of heavy metal pollution in the top soil of this region. Therefore, the aim of the present study was (1) to evaluate the degree of contamination of urban top soils in 9 elements (Fe, Mn, Ti, Cr, Co, Ni, Cu, Zn and Pb) around selected industrial areas of Chennai, (2) to compare the urban top soil contamination with crustal average values.

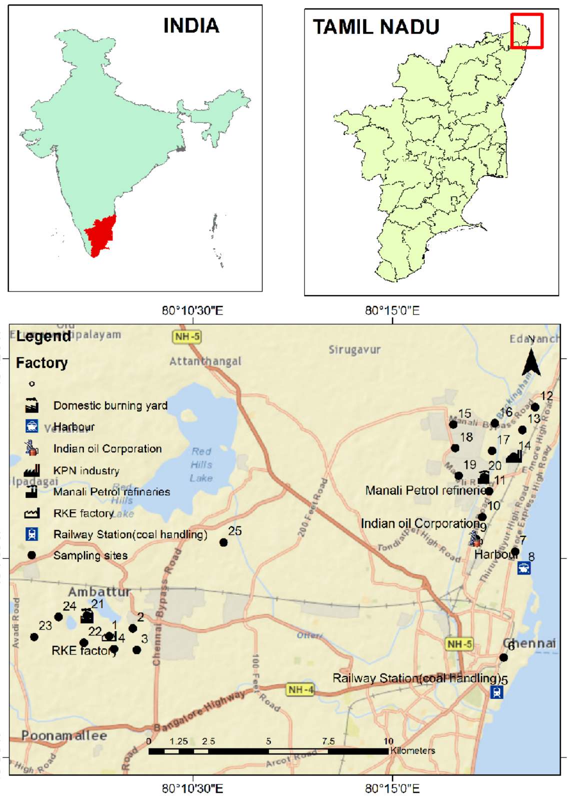

Fig. 1. Sampling points and location map of the industrial areas, Chennai City

2. MATERIALS AND METHODS

The soil samples were collected from the top portion of the soil layer (0-25 cm). The collected soil samples were air dried and then kept overnight in a hot air oven at 40° C. The dried samples were disintegrated, homogenized, pulverized with agate mortar and sieved using 2 mm mesh. Soil pH and EC were measured in solution using 1:2 and 1:5 soil to water ratios using a digital pH and EC meter as described by [9]. The total organic carbon content (TOC) in soil samples were analyzed after digestion of samples with $K_2Cr_2O_7$ – H_2SO_4 solution using $FeSO_4$ titration method [10]. The soil samples were filled in quartz crucible and kept in muffle furnace at 500° C for determination of Loss of Ignition Index (LOI). Further, the samples were adopted for major and trace elements using X-ray fluorescence spectrometer (XRF). The pellets were prepared using collapsible aluminum cups. These cups were filled with boric acid and soil samples and the pellets prepared under 20 tons hydraulic press for further analysis. XRF analysis was carried out in the soil pellets in Centre for Earth Science Studies, Tiruvananthapuram, India.

Geo-accumulation index (I_{geo}) was originally defined by Muller in order to determine the metal concentration of sediments by comparing current concentrations with preindustrial levels [11]. The Geo-accumulation index enables the assessment of contamination by comparing the current and crustal average value metal concentrations. It is computed using the following equation.

$$Igeo = Log_2 \frac{Cn}{1.5 \times Bn} \qquad (1)$$

Concentrations of geochemical background are multiplied each time by 1.5 in order to allow content fluctuations of a given substance in the environment as well as very small anthropogenic influences. Where C*n* is the measured concentration of the examined metal *n* in the sediments and B*n* is the geochemical background concentration of the metal *n* of crustal average [12]. The sediment quality is classified based on Igeo values and class ranging from <0 – Unpolluted, 0 to 1 – Unpolluted to moderately polluted, 1 to 2 – Moderately polluted, 2 to 3 – Moderately polluted to strongly polluted, 3 to 4 – Strongly Polluted, 4 to 5 – strongly polluted to extremely polluted, >5 – Extremely polluted.

The enrichment factor for each metal is calculated by dividing its ratio to the normalizing elements by the same ratio found in the chosen baseline.

$$\frac{(Metal/Fe)_{sample}}{(Metal/Fe)_{Background}} \qquad (2)$$

The values of the earth crustal average are from Taylor [13] and represent the average composition of the surficial rocks exposed to weathering. EFs are close to unity point to crustal origin, while those >1.0 indicate that the element is of anthropogenic origin. EFs greater than 10 are considered to be non-crustal source. The assessment of soil contamination was also carried out using the contamination factor and degree. The CF is the ratio obtained by dividing the concentration of each metal in the soil by the baseline or background value (average crustal value). The CF is the single element contamination index, the sum of contamination factors for all elements examined represents the contamination degree of the environment [14]. The concentration levels may be classified based on their intensities on a scale ranging from 1 to 6 ((0 = none, 1 = none to medium, 2 = moderate, 3 = moderately to strong, 4 = strongly polluted, 5 = strong to very strong, 6 = very strong) [15]. Where $C_{\text{heavy metal}}$ is the concentration of metals in soil and $C_{\text{Background}}$ is the average concentration of individual metal in the earth crust. The higher number indicates that the metal contamination is 100 times greater than what would be expected in the crust.

$$CF_{metal} = \frac{C_{heavy\ metal}}{C_{background}} \quad (3)$$

The Pollution load index (PLI) is proposed by Tomlinson for detecting pollution, which permits a comparison of pollution levels between the sites and at different times [16]. The PLI was calculated as a concentration factor of each metal with respect to the background level of the crust. According to Angulo, PLI can able to give an estimate of the metal contamination status and the necessary action that should be taken [17].

$$PLI = (CF_1 \times CF_2 \times CF_3 \times \ldots\ldots \times CF_n)1/_n \quad (4)$$

The statistical analysis was performed using SPSS software version 11 for windows. Principal component analysis (PCA) was useful for data reduction, to assess the continuity/overlap of clusters or clustering/similarities in the datasets and was used to determine the source of variation between the parameters [18]. In the multivariate statistical analysis, correlation matrix was applied in order to find the significant relationship between parameters. Kaiser normalization was employed to minimize the number of variables with a high loading on each component for possible interpretation of PCA results.

3. RESULTS AND DISCUSSION

The pH, EC, Total organic carbon (TOC), range and average metal concentrations (Fe, Mn, Ti, Cr, Co, Ni, Cu, Zn and Pb, Enrichment Factor (EF), Geo-accumulation Index (I_{geo}), Contamination Factor (CF), Pollution Load Index (PLI) are presented in Table 1. The texture of the collected soil samples are medium to fine grained in nature with 62 to 75% of sand, 12 to 22% of silt and 3 to 7% of clay. The pH values range from 6.3 to 7.8 with the mean of 6.92. The varying soil pH indicates the presence of various types of soil compositions in the study area. The values of the EC and TOC range from 470 to 8760 µS/cm and 1.3 to 21 mg/kg with a mean value of 1360.68 µS/cm and 8.30 mg/kg respectively. The low organic carbon content was observed in the low-lying areas of the study area. This was probably due to transportation of organic matter by rainfall runoff. The concentration of Fe in the investigated area ranges from 38461.54 to 197762.24 mg/kg with an average of 73488.11mg/kg. The Mn concentration in the study area ranged from 333.08 to 2246.32mg/kg with a mean value of 797.21 mg/kg. The Ti concentration ranges from 2997.60 to 5917.29 mg/kg with a mean concentration of 3920.14mg/kg. The concentration of Cr in the soil samples of study area ranges from 92 to 458 mg/kg with a mean of 173.16 mg/kg. The anthropogenic sources of Cr are mainly from the metallurgic and galvanic industry as it is employed as an alloy constituent to impart corrosion resistance. Dyes and paints, motor vehicle exhaust, waste incineration, and combustion of oil and coal are the chief sources of human induced Cr content. The natural source of Cr is from ultramafic rocks and especially from serpentinites [19]. The result of the metals reveals that the concentration of Co ranges from 11 to 42 mg/kg with the mean of 17.76 mg/kg. The Ni values in soil ranges from 10 to 91mg/kg, while all the average is 51.84 mg/kg. Ni metal is often found in mafic and ultramafic rocks in nature. The metal-processing industry, stainless steel making, coinage, special alloys, and the burning of fossil fuels have added to the total concentration of Ni in city soils [19]. In soils, Ni is usually present in the organically bound form, which under acidic and neutral conditions increases its mobility and bioavailability [20]. Disposal of fly ash on land is the single largest input to both Ni and Cr to soils [21]. The Cu distribution in the study area ranges from 16 to 710 mg/kg with an average of 150.72 mg/kg. The abundance of copper in igneous rocks is partly controlled by the process of differentiation during crystallization. The waste dumping places is implying great contamination risk for not only the soil but also groundwater [22]. Copper is widely used for manufacturing and electrical wiring. Electronic equipment is also emerging as a source of Cu [23].

Zinc level in the soil ranges from 54 to 4300 with an average of 566.04 mg/kg. The common range of Zn concentration in soils is from 10 to 300 mg/kg with an average of 50 mg/kg [30]. The metallurgic and galvanic industry, waste treatment and fuel burning are the common sources of Zn contamination in soil. Zinc is present in tires, batteries, electronic equipment and numerous alloy objects [24]. In addition to aerial sources of Zn and all sewage-derived materials, fertilizers and pesticides also increase Zn concentrations in soil [22, 25]. The lead concentration in the study area ranges from 8 to 106 mg/kg with a mean value of 65.04 mg/kg. Lead has been used as an antiknocking agent in gasoline and has been one of the major sources of pollution in cities. The other sources of Pb are car batteries, glass, radiation shields, and soldering. In recent years, electronic products, e-wastes, have grown as a considerable Pb source [23].

TABLE I
METAL CONCENTRATION, MEAN, METALS CRUSTAL AVERAGE, PH, EC, TOTAL ORGANIC CARBON (TOC), ENRICHMENT FACTOR (EF), GEO-ACCUMULATION INDICES (I_{GEO}), CONTAMINATION FACTOR (CF), POLLUTION LOAD INDEX (PLI) OF METALS IN SELECTED INDUSTRIAL AREAS OF CHENNAI CITY ALLOCATION FOR VARIOUS THEMATIC LAYERS

Sample	**pH**	**EC**	**TOC**	**Al**	**Fe**				**Mn**			
					Concentration	**EF**	**Igeo**	**CF**	**Concentration**	**EF**	**Igeo**	**CF**
1	6.5	660	16.1	69295.92	41188.81	1.09	-0.69	0.93	464.76	0.71	-1.32	0.60
2	7.5	850	2.1	80148.23	46083.92	1.06	-0.53	1.04	464.76	0.61	-1.32	0.60
3	6.5	550	12.4	76389.62	47412.59	1.14	-0.49	1.07	542.22	0.75	-1.10	0.70
4	6.4	470	9.9	84277.4	56293.71	1.23	-0.24	1.27	697.13	0.87	-0.74	0.90
5	7.5	560	21	78613.02	197762.24	4.63	1.57	4.46	2246.32	3.01	0.95	2.90
6	7.3	730	15.3	74695.61	59440.56	1.46	-0.16	1.34	542.22	0.76	-1.10	0.70
7	7.2	5170	10.3	79301.22	52377.62	1.21	-0.34	1.18	542.22	0.72	-1.10	0.70
8	7.3	660	6	64425.62	42097.90	1.20	-0.66	0.95	542.22	0.89	-1.10	0.70
9	7.8	1180	4.6	70301.75	44825.17	1.17	-0.57	1.01	619.67	0.93	-0.91	0.80
10	7.5	980	7.6	72578.08	183356.64	4.65	1.46	4.14	1471.73	2.13	0.34	1.90
11	7.5	1050	1.3	70884.07	153216.78	3.98	1.20	3.46	1316.81	1.96	0.18	1.70
12	6.5	1260	5.4	69084.17	114825.17	3.06	0.79	2.59	1316.81	2.01	0.18	1.70
13	7.1	680	14.2	68448.91	92377.62	2.48	0.47	2.08	929.51	1.43	-0.32	1.20
14	7.1	480	12.5	72578.08	183356.64	4.65	1.46	4.14	1471.73	2.13	0.34	1.90
15	7.6	780	1.5	84012.71	38461.54	0.84	-0.79	0.87	697.13	0.87	-0.74	0.90
16	6.5	780	4	83377.45	47342.66	1.04	-0.49	1.07	542.22	0.68	-1.10	0.70
17	6.5	690	15.2	78665.96	56853.15	1.33	-0.23	1.28	697.13	0.93	-0.74	0.90
18	6.5	750	5	75330.86	53916.08	1.32	-0.30	1.22	697.13	0.97	-0.74	0.90
19	7	710	7.6	85812.6	54125.87	1.16	-0.30	1.22	619.67	0.76	-0.91	0.80
20	6.5	760	7.5	80465.85	49510.49	1.13	-0.43	1.12	619.67	0.81	-0.91	0.80
21	7.1	687	2.6	106352.6	48041.96	0.83	-0.47	1.08	333.08	0.33	-1.80	0.43
22	6.3	1470	4.8	71307.57	46643.36	1.20	-0.51	1.05	619.67	0.91	-0.91	0.80
23	6.5	2320	1.5	84330.33	46013.99	1.00	-0.53	1.04	619.67	0.77	-0.91	0.80
24	6.3	8760	8.2	81524.62	42657.34	0.96	-0.64	0.96	697.13	0.90	-0.74	0.90
25	6.4	1030	11	79777.66	39020.98	0.90	-0.77	0.88	619.67	0.82	-0.91	0.80
Mean	6.92	1360.68	8.30	77169.44	73488.11				797.21			
Crustal average				81524.62	44323.48				774.59			

Cont…

TABLE I

Sample	Ti				Cr				Co			
	Concentration	**EF**	**Igeo**	**CF**	**Concentration**	**EF**	**Igeo**	**CF**	**Concentration**	**EF**	**Igeo**	**CF**
1	2997.60	0.84	-1.07	0.71	131	1.22	-0.53	1.04	11	0.54	-1.71	0.46
2	3836.93	0.93	-0.71	0.91	136	1.10	-0.47	1.08	12	0.51	-1.58	0.50
3	3836.93	0.98	-0.71	0.91	130	1.10	-0.54	1.03	12	0.53	-1.58	0.50
4	5035.97	1.16	-0.32	1.20	152	1.17	-0.31	1.21	13	0.52	-1.47	0.54
5	4136.69	1.02	-0.61	0.99	111	0.91	-0.77	0.88	42	1.81	0.22	1.75
6	4136.69	1.08	-0.61	0.99	112	0.97	-0.75	0.89	17	0.77	-1.08	0.71
7	3417.27	0.84	-0.88	0.81	111	0.91	-0.77	0.88	16	0.69	-1.17	0.67
8	3836.93	1.16	-0.71	0.91	246	2.47	0.38	1.95	13	0.69	-1.47	0.54
9	3237.41	0.89	-0.96	0.77	141	1.30	-0.42	1.12	14	0.68	-1.36	0.58
10	4136.69	1.11	-0.61	0.99	307	2.74	0.70	2.44	34	1.59	-0.08	1.42
11	3477.22	0.95	-0.86	0.83	224	2.04	0.25	1.78	28	1.34	-0.36	1.17
12	3776.98	1.06	-0.74	0.90	231	2.16	0.29	1.83	23	1.13	-0.65	0.96
13	3896.88	1.11	-0.69	0.93	458	4.33	1.28	3.63	19	0.94	-0.92	0.79
14	4136.69	1.11	-0.61	0.99	307	2.74	0.70	2.44	34	1.59	-0.08	1.42
15	3776.98	0.87	-0.74	0.90	92	0.71	-1.04	0.73	13	0.53	-1.47	0.54
16	3477.22	0.81	-0.86	0.83	114	0.88	-0.73	0.90	14	0.57	-1.36	0.58
17	3417.27	0.84	-0.88	0.81	149	1.23	-0.34	1.18	16	0.69	-1.17	0.67
18	3537.17	0.91	-0.83	0.84	144	1.24	-0.39	1.14	14	0.63	-1.36	0.58
19	3717.03	0.84	-0.76	0.89	127	0.96	-0.57	1.01	15	0.59	-1.26	0.63
20	3776.98	0.91	-0.74	0.90	128	1.03	-0.56	1.02	14	0.59	-1.36	0.58
21	5917.27	1.08	-0.09	1.41	121	0.74	-0.64	0.96	12	0.38	-1.58	0.50
22	3357.31	0.91	-0.91	0.80	179	1.62	-0.08	1.42	14	0.67	-1.36	0.58
23	4916.07	1.13	-0.36	1.17	185	1.42	-0.03	1.47	14	0.56	-1.36	0.58
24	4136.69	0.99	-0.61	0.99	142	1.13	-0.41	1.13	16	0.67	-1.17	0.67
25	4076.74	0.99	-0.63	0.97	151	1.22	-0.32	1.20	14	0.60	-1.36	0.58
Mean	3920.14				173.16				17.76			
Crustal average	4196.64				126				24			

Cont…

TABLE I

Sample	**Ni**				**Cu**			
	Concentration	**EF**	**Igeo**	**CF**	**Concentration**	**EF**	**Igeo**	**CF**
1	29	0.61	-1.53	0.52	98	4.61	1.39	3.92
2	88	1.60	0.07	1.57	107	4.35	1.51	4.28
3	42	0.80	-1.00	0.75	83	3.54	1.15	3.32
4	55	0.95	-0.61	0.98	106	4.10	1.50	4.24
5	10	0.19	-3.07	0.18	16	0.66	-1.23	0.64
6	25	0.49	-1.75	0.45	56	2.44	0.58	2.24
7	30	0.55	-1.49	0.54	47	1.93	0.33	1.88
8	17	0.38	-2.30	0.30	74	3.75	0.98	2.96
9	61	1.26	-0.46	1.09	303	14.05	3.01	12.12
10	91	1.83	0.12	1.63	249	11.19	2.73	9.96
11	60	1.23	-0.49	1.07	163	7.50	2.12	6.52
12	83	1.75	-0.02	1.48	710	33.51	4.24	28.40
13	42	0.89	-1.00	0.75	129	6.15	1.78	5.16
14	91	1.83	0.12	1.63	249	11.19	2.73	9.96
15	58	1.01	-0.53	1.04	208	8.07	2.47	8.32
16	41	0.72	-1.03	0.73	79	3.09	1.07	3.16
17	49	0.91	-0.78	0.88	118	4.89	1.65	4.72
18	32	0.62	-1.39	0.57	70	3.03	0.90	2.80
19	47	0.80	-0.84	0.84	87	3.31	1.21	3.48
20	47	0.85	-0.84	0.84	60	2.43	0.68	2.40
21	64	0.88	-0.39	1.14	64	1.96	0.77	2.56
22	60	1.22	-0.49	1.07	221	10.11	2.56	8.84
23	66	1.14	-0.35	1.18	150	5.80	2.00	6.00
24	55	0.98	-0.61	0.98	143	5.72	1.93	5.72
25	53	0.97	-0.66	0.95	178	7.28	2.25	7.12
Mean	51.84				150.72			
Crustal average	56				25			

Cont…

TABLE I

Sample	**Zn**				**Pb**				**PLI**
	Concentration	**EF**	**Igeo**	**CF**	**Concentration**	**EF**	**Igeo**	**CF**	
1	174	3.15	0.84	2.68	63	5.01	1.50	4.26	1.11
2	242	3.79	1.31	3.72	67	4.60	1.59	4.53	1.08
3	624	10.25	2.68	9.60	94	6.78	2.08	6.35	1.14
4	476	7.08	2.29	7.32	87	5.69	1.97	5.88	1.28
5	247	3.94	1.34	3.80	8	0.56	-1.47	0.54	1.12
6	191	3.21	0.97	2.94	68	5.01	1.61	4.59	1.19
7	173	2.74	0.83	2.66	71	4.93	1.68	4.80	1.13
8	247	4.81	1.34	3.80	63	5.39	1.50	4.26	1.21
9	464	8.28	2.25	7.14	96	7.52	2.11	6.49	1.04
10	317	5.48	1.70	4.88	17	1.29	-0.39	1.15	1.04
11	243	4.30	1.32	3.74	26	2.02	0.23	1.76	1.12
12	1600	29.05	4.04	24.62	106	8.45	2.26	7.16	1.13
13	94	1.72	-0.05	1.45	56	4.51	1.33	3.78	1.27
14	317	5.48	1.70	4.88	17	1.29	-0.39	1.15	1.04
15	157	2.34	0.69	2.42	84	5.51	1.92	5.68	1.08
16	168	2.53	0.78	2.58	73	4.82	1.72	4.93	1.21
17	487	7.76	2.32	7.49	66	4.62	1.57	4.46	1.22
18	223	3.71	1.19	3.43	65	4.75	1.55	4.39	1.27
19	241	3.52	1.31	3.71	68	4.37	1.61	4.59	1.05
20	161	2.51	0.72	2.48	70	4.79	1.66	4.73	1.23
21	54	0.64	-0.85	0.83	78	4.04	1.81	5.27	1.10
22	2300	40.45	4.56	35.38	69	5.33	1.64	4.66	1.20
23	4300	63.95	5.46	66.15	69	4.51	1.64	4.66	1.01
24	267	4.11	1.45	4.11	69	4.66	1.64	4.66	1.17
25	384	6.04	1.98	5.91	76	5.25	1.78	5.14	1.21
Mean	566.04				65.04				
Crustal average	65				14.8				

However, its long application and persistence in the environment has concentrated Pb in urban areas and numerous studies have been carried out in cities to investigate the possible toxicological consequences or to simply monitor the content of the soils. The comparative results of metal accumulation in soil and crustal average suggest that the majority of the metals are higher than the crustal average except few (Table 1). The high concentration of Cr, Cu, Pb and Zn are likely to be of concern to human health and the environment.

3.1. Enrichment Factors (EFs)

The analytical results of the present study show that significant accumulation of heavy metals in the soil. The enrichment factors (EFs) of metals are 0.83 to 4.65 for Fe, 0.33 to 3.01 for Mn, 0.81 to 1.16 for Ti, 0.70 to 4.32 for Cr, 0.38 to 1.81 for Co, 0.18 to 1.82 for Ni, 0.66 to 33.51 for Cu, 0.63 to 63.95 for Zn, 0.56 to 8.45 for Pb. The overall order of the EF value was found to be in the order of Zn (9.23) > Cu (6.59) > Pb (4.63) > Fe (1.79) > Cr (1.49), Mn (1.11) > Ti (0.98), Ni (0.977), Co (0.79). EFs greater than 1.0 indicate that the element is of anthropogenic impact. EF values lower than 0.5 can reflect mobilization and the loss of these elements relative to Al or indicative an over estimation of the reference metal content [18]. All the sampling sites are highly enriched with heavy metals such as Pb, Zn and Cu whereas other studied elements like Fe, Mn, Ti, Cr, Co and Ni is showing minimum to moderate enrichment in the soil. The risk from high concentrations of trace elements is usually related to their likelihood to leach to groundwater or to enter the food chain through plant uptake. In urban environments, the proximity of the soil to humans is mostly through dermal contact with the soil, direct ingestion, and inhalation of particles that trace elements exert their toxicity [26, 27].

The Cu, Pb and Zn are key elements contained in car parts and these components are a major source of metals in roadside soil. This was supported by the high concentration of Zn and Cu in soils of high road traffic areas. The elevated concentrations of Pb have originated from combustion of leaded fuels in the urban environment. Urban storm water runoff plays a key role in the transport of metal rich particles from their origin. The high concentration of some heavy metals (Cu, Zn) was recorded on the road side soil samples (S.No 12, 22 and 23).

3.2. Geo-accumulation Index (I_{geo})

The I_{geo} values for Fe range from -0.79 to 1.57, -1.80 to 0.95 for Mn, -1.07 to -0.09 for Ti, -1.04 to 1.27 for Cr, -0.71 to 0.22 for Co, -3.07 to 0.12 for Ni, -1.23 to 4.24 for Cu, -0.85 to 5.46 for Zn and -1.47 to 2.26 for Pb. The I_{geo} value of Ti is less than zero indicates that this metal does not pollute the area. The high I_{geo} values in sampling sites 5 to 10 showing considerable increasing of Cr, Fe and Mn metals, which is probably due to the effect of electro ferrochrome plating industries. The low I_{geo} values in few locations are may be due to removal of significant quantities of metals by erosion and leaching of soil and transported in particulate or dissolved phases in surface water runoff [28]. The geoaccumulation index supported the geogenic origin of total Fe and Mn in the soil and suggested moderate to heavy metal accumulation depending on the metals and sampling sites.

3.3. Contamination Factor (CF) and Pollution Load Index (PLI)

The average value of contamination factor (CF) is 1.66 for Fe, 1.03 for Mn, 0.93 for Ti, 1.37 for Cr, 0.74 for Co, 0.93 for Ni, 6.03 for Cu, 8.71 for Zn, 4.39 for Pb. According to Hakanson [14], Ti, Co and Ni are showing low contamination factor while Fe, Mn and Cr indicate moderate contamination and Cu, Zn and Pb are showing moderate to high contamination factors in the soil. The pollution load index (PLI) of the studied metals indicates that the area is low to moderately polluted (1.01 to 1.28).

3.4. Statistical analysis

Twelve variables such as pH, EC, TOC, Fe, Mn, Ti, Cr, Co, NI, Cu, Zn and Pb were used in factor analysis. The coefficient correlation matrix with the principal component analysis method was used to extract the factor values (Table 2). Factor 1 (F1) has high loading of pH, TOC, Fe, Mn, Cr, Co and account of 33.33% of the total variance. Factor 1 is strongly loaded by Fe, Mn and Co and moderately loaded by pH, TOC and Cr, whereas factor 2 (F2) have high factor loadings on EC, Cu, Zn. Moreover, Ti, Ni, Cu and Zn have high positive factor loading in factor 3 (Table 3). The strong correlation between Cr, Cu and Zn indicates their common origin, especially from urban development, such as electro chrome plating industries, sewage sludge and urban runoff. The strong correlation between Fe and Mn clearly indicates the high affinity nature of Fe-Mn oxy-hydroxides with other elements [29]. The correlation and geochemical results reveal that the contaminant is probably derived from common sources like urban and industrial effluents.

4. CONCLUSIONS

The potential accumulation of metals in the soils was evaluated in an industrial and urban development area of Chennai city, Tamil Nadu, India. Totally 25 samples were collected from the study area to analyze its physico-chemical characteristics and metal accumulation in soil samples. Metal accumulation, especially Pb, Zn and Cu were noticed near by the roadside soils and are derived from the high road traffic volume and the elevated concentrations of Pb have originated due to leaded fuel combustion in the urban environment. Cr and Mn were derived from chrome electro plating industrial wastes. Low metal accumulation index in few locations are probably due to removal of significant quantities of metals by

TABLE 2

CORRELATION COEFFICIENT MATRIX OF PHYSICAL PARAMETERS, TOTAL ORGANIC CARBON (TOC) AND METALS IN STUDIED URBAN SOILS

Component	**pH**	**EC**	**TOC**	**Fe**	**Mn**	**Ti**	**Cr**	**Co**	**Ni**	**Cu**	**Zn**	**Pb**
pH	1.000											
EC	-0.203	1.000										
TOC	-0.092	-0.072	1.000									
Fe	0.385	-0.180	0.292	1.000								
Mn	0.308	-0.117	0.345	0.940	1.000							
Ti	-0.031	-0.006	-0.125	0.056	-0.003	1.000						
Cr	0.129	-0.133	0.082	0.478	0.362	0.027	1.000					
Co	0.385	-0.084	0.354	0.978	0.964	0.035	0.384	1.000				
Ni	0.060	-0.004	-0.485	0.244	0.108	0.226	0.306	0.148	1.000			
Cu	-0.040	-0.007	-0.258	0.244	0.281	-0.119	0.311	0.196	0.601	1.000		
Zn	-0.350	0.087	-0.297	-0.099	-0.033	0.181	0.062	-0.089	0.260	0.314	1.000	
Pb	-0.369	0.089	-0.317	-0.795	-0.703	0.003	-0.375	-0.806	-0.002	0.264	0.173	1.000

TABLE 3
FACTOR ANALYSIS OF PARAMETERS, TOTAL ORGANIC CARBON (TOC) AND METALS IN STUDIED URBAN SOILS

Components	**1**	**2**	**3**
pH	**0.511**	-0.305	0.024
EC	-0.178	**0.331**	-0.18
TOC	**0.399**	-0.083	-0.631
Fe	**0.953**	0.128	0.132
Mn	**0.904**	0.188	0.022
Ti	0.079	-0.414	**0.570**
Cr	**0.450**	0.293	0.229
Co	**0.954**	0.159	0.015
Ni	0.157	0.292	**0.797**
Cu	0.138	**0.642**	**0.431**
Zn	-0.243	**0.568**	**0.433**
Pb	-0.814	0.046	0.121

erosion and leaching of soil and transported through particulate or dissolved phases in surface runoff. The strong correlation between Cr, Cu and Zn indicates their common origin, especially from urban development such as electro chrome plating industries, sewage sludge and urban runoff. Similarly, Fe and Mn clearly indicate the high affinity nature of Fe-Mn oxy-hydroxides with other elements. The metal accumulation with soil clearly suggests that strict measures should be implemented to further reduce heavy metal emissions in the urban area.

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