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Distribution of Heavy Metals in Soil

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ABSTRACT

As a result of anthropogenic activities in different parts of the world, the soils are seen to be contaminated by heavy metals. The acceleration of urbanization has created wealth and opportunity as well as intensified ecological and environmental problems, especially soil pollution. In view of this, accumulation of heavy metals such as Fe, Mn, Zn, Cu, Ni, Cd, Pb and Cr in the surface soils 0-20cm and 20-40cm of Madurai traffic area has been investigated. Total 6 top soil samples with triplicates 0-20cm and 20-40cm were collected from different sites namely S1(Kalavasal), S2(Palaganantham), S3(Periyar), S4(Simmakal), S5(Goripalayam) and S6(Mattuthavani) for a period of July 2012-January 2013 and the heavy metal contents were analyzed by Atomic Absorption Spectroscopy. The mean metal concentration of chromium was found to be maximum in soil at depth 0-20cm and 20-40cm in all the sampling sites. The studies with enrichment factor indicates that lead has been enriched to quite great extent in all sampling sites in soil at depth 0-20cm and 20-40cm followed by chromium. The Normalized Scatter Coefficient value implies faster enrichment of chromium. The Heavy Metal Index study implies that in soil at depth 0-20cm and 20-40cm, all the sampling sites are highly polluted with heavy metals. The roadside soil have significantly high contents of heavy metals and their levels increased with increasing traffic densities and furthermore, they revealed elevated levels in urban areas.

Keywords: Heavy metals, Atomic Absorption Spectroscopy, Enrichment Factor, Normalized Scatter Coefficient, Heavy Metal Index, enriched

INTRODUCTION

The knowledge of environmental conditions, including soils, within the urban environment is of increasing importance in terms of human health [1,2].Heavy metals are some of the most common pollutants in urban areas due to the vehicles, industry, waste disposal and other human activities. Heavy metal pollution, especially Pb of urban soils have been widely reported in the last 20 years[3]. Urban areas are exposed to numerous airborne contaminants emitted from anthropogenic sources in the form of solid particles or gases. The main sources of these pollutants are industrial plants, power stations, domestic heating systems and motor vehicles, the last two usually being prominent in urban areas [4].Traffic pollution, contamination due to high levels of traffic, caused mainly by the burning of fossil fuels, primarily oil in the form of petrol and diesel. Metal contamination of natural environment is a global phenomenon [5].Public motor roads influence natural environment to a very high degree [6], because automobile traffic act as line sources of heavy metal pollutants. Heavy metals affect the immune systems of human and animals [7].Various researchers have found that the concentrations of the metals Pb, Cu, Zn, Cd and Ni decrease rapidly within 10-50m from the roadsides [8,9]. Pollution of roadside soils and plants by combustion of leaded petrol products is localized[10] and usually limited to a belt of several meters wide on either side of the road and that for similar topography and vegetation, the level of pollution decreases with the distance from the road. The objective of this study is to determine the concentrations of the elements such as Fe, Mn, Zn, Cu, Ni, Cd, Pb and Cr in Madurai urban soils to relate these locations within the urban environment.

MATERIALS AND METHODS

Field Methodology: To understand the state of environment of the Madurai area a detailed field survey was carried out and after having identified possible sources of pollution a part of Madurai area was selected. This area is under intense human interference in terms of growing urbanization (municipal sewage sludge, traffic pollution in particular) and industrialization.

Selection of Sampling Sites : In the present study stratified regular sampling method was adopted for soil sample collection as in geo-assessment of the variables estimated, the stratified regular sampling is more suitable because this kind of sampling draws homogenous error .Different traffic areas namely Site 1(Kalavasal), Site 2(Palaganantham), Site 3 (Periyar), Site 4 (Simmakal), Site 5 (Goripalayam) and Site 6 (Mattuthavani) were selected and samples collected from the top layer of the soil at a depth (0-20cm) and (20-40cm) using plastic spatula after removing the debris, rock pieces and physical contaminants. In order to have the background concentration values of the heavy metal elements, three soil samples were collected, each from 100cm below ground level, which are least affected by anthropogenic activities(table1). The samples were placed in the clean polythene bags, which were brought to the laboratory.

Table 1. Natural Local background concentration values (mg kg^{-1}) of the heavy elements of soil

Sampling stations	Fe	Mn	Zn	Cu	Ni	Cd	Pb	Cr
Traffic Area	2.74	2.32	11.76	9.58	11.29	0.30	5.22	10.09

Laboratory Methodology: The samples were brought to the laboratory where they are dried and mixed thoroughly to obtain the representative samples. Soon after drying the debris and other objects were hand picked up and the sample were ground in a mortar to break up the aggregates or lumps, taking care not to break actual soil particles. Soil samples were then passed through a 2mm sieve in order to collect granulometric fraction. The sample fraction were digested with 2.5ml HCl and 2.5ml HNO_3 in order to completely digest the soil. This jar was shaken on an orbital shaker for 16 hours at 200-220 rpm before being filtered through Whatman filter paper (No.42) into acid washed bottles. The solution was stored and heavy metals such as Fe, Mn, Zn, Cu, Ni, Cd, Pb and Cr were analyzed by Atomic Absorption Spectrophotometer as per the method recommended by committee of soil standard methods for analyses and measurement (1986). The raw data obtained during the course of laboratory analyses were stored in Microsoft Excel software and further processed to obtain various parameters required for interpretation.

Accumulative Signature of Heavy Metals: An increasing trend has been found for the heavy metal elements lead, copper, chromium, zinc nickel and cadmium whereas the lead and cadmium are getting accumulated with very rapid rate mainly due to anthropogenic activities [11].In order to assess the variations in the heavy metal accumulations in the soils, the calculated measures that is Enrichment Factor and Normalized Scatter Coefficient were used. The Enrichment Factor (EF) is a ratio of the concentrations of the heavy metals in the soil samples to the corresponding concentration of natural background concentration. EF is calculated with the help of the formula given by Subramanian et al. [12] and presented in Table 2.

$$EF = \frac{\text{Value of a given metal concentration found on soil (mg kg}^{-1})}{\text{Natural local background concentration of the metal (mg kg}^{-1})}$$

Normalized Scatter Coefficient (NSC) has been calculated to accesses the temporal variability of the heavy metals in the soils. It helps to understand the increasing or decreasing concentration of heavy metals in the soils with the passage of time which is independent of the past focusing only at the period of study. The NSC for any element is calculated (Table 3) with the following formula [13].

$$NSC = \frac{\text{Concentration in the last sampling} - \text{concentration in first sampling}}{\text{concentration in the last sampling} + \text{concentration in first sampling}} \times 100$$

The NSC values + 100% indicates absolute increase while – 100% means absolute decrease. The value of 0% can be regarded for no change in the parameters under consideration.

Statistical Analysis: For the surface soil, Heavy Metal Index (HMI) was determined, which is the mathematical function for indicating total heavy metal pollution of each site, according to the summation equation [14]

$$\text{Heavy Metal Index} = \sum_{i=1}^{n} LC_i$$

Where LC_i represents load class that is the load category, value of the i^{th} heavy metal and 'n' is the number of heavy metals used for computing HMI. The numerical load class is hard to pick up at a glance and hence converted into dots representing proportionally increasing load representative supply (LRS). The LRS values for each metal were obtained by dividing their range values into six equidistant categories. This graphic conversion of heavy metal pollution into a pictograph enables a quick overview and allows simple direct comparisons of elements amongst the study sites. Similarly, a six-level verbal evaluation called the "predicate" of the load representative supply is used to facilitate the verbal evaluation. Furthermore, HMI is divided into six equidistant load categories and provided with pictographs and predicates which assist in the characterization of study sites from least to the heaviest pollution level (Table2)

Table 2. Heavy Metal Index (HMI) Categories, Pictographs and Predicates

HMI Load Categories	Pictographs	Predicates
< 7.0	•	Very low
7.01-14.00	•	Low
14.01-21.00	•	Medium
21.01-28	•	High
28.01-35.00	•	Very high
>35.00	•	Critically high

Iron: Iron was found to be the dominant metals detected compared with others in the roadside dust. The concentration of Fe in soil depth 0-20cm at different sampling sites S1, S2, S3, S4, S5 and S6 are 2.79µg m^{-3}, 4. 84 µg m^{-3}, 4.84 µg m^{-3}, 4.71 µg m^{-3}, 5.79 µg m^{-3} and 2.723 µg m^{-3} respectively. The results revealed that the concentration of Fe in soil at depth 20-40cm at different sampling sites S1, S2, S3, S4, S5 and S6 are 2.45 µg m^{-3}, 3.91 µg m^{-3}, 3.12 µg m^{-3}, 3.90 µg m^{-3}, 3.45 µg $m^{-3}$and 1.99 µg m^{-3}respectively.

Manganese: The deficiency of Mn in the human body can produce severe skeletal and reproductive abnormalities in mammals. High doses of Mn produce adverse effects primarily on the lungs and brain. The concentration of Mn in soil at depth 0-20cm at different sampling sites S1, S2, S3, S4, S5 and S6 are 4.13 μg m^{-3}, 3.91 μg m^{-3}, 2.30 μg m^{-3}, 2.51 μg m^{-3}, 2.51 μg $m^{-3}$and 3.94 μg m^{-3}respectively. It has been found that the concentration Mn in soil depth 20-40cm at different sampling sites S1, S2, S3, S4, S5 and S6 are 1.76 μg m^{-3}, 1.07 μg m^{-3}, 0.72 μg m^{-3}, 0.65 μg m^{-3}, 1.33 μg $m^{-3}$and 0.82 μg m^{-3}respectively.

Zinc: The traffic situation in the study area is regarded as a source of zinc in the roadside dust. Wear and corrosion of vehicle parts (brakes, tyres, radiators, body and engine parts) might also be one of the potential sources of Zn in roadside dust. The results revealed that the concentration of Zn in soil depth 0-20cm at different sampling sites S1, S2, S3, S4, S5 and S6 are 2.09 μg m^{-3}, 2.05 μg m^{-3}, 1.93 μg m^{-3}, 4.90 μg m^{-3}, 3.55 μg $m^{-3}$and 2.63 μg m^{-3}respectively. It has been found that the concentration of Zn at depth 20-40cm at different sampling sites S1, S2, S3, S4, S5 and S6 are 1.93 μg m^{-3}, 1.97 μg m^{-3}, 1.65 μg m^{-3}, 2.98 μg m^{-3}, 2.45 μg $m^{-3}$and 1.59 μg m^{-3}respectively.

Copper: Copper may be toxic to both humans and animals when its concentration exceed safe limits [15]. The mean concentrations of Cu in the soil depth 0-20cm at sampling site S1(0.7μg m^{-3}), S2(1.03μg m^{-3}), S3(1.15μg m^{-3}), S4(1.09μg m^{-3}), S5(0.83μg m^{-3}) and S6(0.57μg m^{-3}). The mean concentration of Cu at soil depth 20-40cm at sampling site S1, S2, S3, S4, S5 and S6 are 1.63μg m^{-3}, 1.01μg m^{-3}, 1.02μg m^{-3}, 0.60μg m^{-3}, 0.52 μg $m^{-3}$and 0.52 μg m^{-3}respectively.

Nickel : Nickel pollution on a local scale is caused by emissions from vehicle engines that use gasoline which contains Ni and by the abrasion and corrosion of Ni from vehicle parts [16].The burning of fossil fuels as well as the refining of metals such as Cu introduces considerable amounts of Ni into the atmosphere .The mean concentration of Ni in soil at depth 0-20cm at sampling site S1, S2, S3, S4, S5 and S6 are 37.0μg m^{-3}, 27.25μg m^{-3}, 30.72μg m^{-3}, 25.25μg m^{-3}, 15.93μg m^{-3}, 28.16 μg m^{-3}respectively. At depth 20-40cm the mean concentration of Ni in soil at different sampling sites was observed to be S1 (36.4μg m^{-3}), S2 (20.38μg m^{-3}), S3 (10.65μg m^{-3}), S4 (7.60μg m^{-3}), S5 (14.8μg m^{-3}) and S6 (16.71μg m^{-3}).

Cadmium: It was reported that cadmium is accumulated mainly in kidneys, spleen, liver and its blood serum level increases considerably following mushroom consumption[17].Cadmium is now most commonly encountered in Cd-Ni battery production, although it continues to be used in paints as well as in plastic production where it is an effective stabilizing agent. It was observed from the results that the concentration of Cd in soil at depth 0-20cm at different sampling sites S1, S2, S3, S4, S5 and S6 are 0.28μg m^{-3}, 1.6μg m^{-3}, 1.14μg m^{-3}, 1.13μg m^{-3}, 1.22 μg $m^{-3}$and 1.30 μg m^{-3}respectively. The results revealed that the concentration of Cd in soil at depth 20-40cm at different sampling sites S1, S2, S3, S4, S5 and S6 are 0.16μg m^{-3}, 0.73μg m^{-3}, 0.84μg m^{-3}, 0.96μg m^{-3}, 1.07μg m^{-3} and 1.20μg m^{-3} respectively.

Lead: Lead is one of the major heavy metal considered as an environmental pollutant [18].Besides natural weathering processes the main source of lead pollution are exhaust fumes of automobiles, chimneys of factories using lead, effluents from the storage battery, industry, mining and smelting of lead ores and roadsides vehicles pollution [19].The results of our analysis showed that the mean concentration of Pb in soil at depth 0-20cm at different sampling sites S1(15.79μg m^{-3}), S2(32.27μg m^{-3}), S3(54.16μg m^{-3}), S4(45.31μg m^{-3}), S5(63.56μg m^{-3}) and S6(55.54μg m^{-3}). At soil depth 20-40cm the mean concentration of Pb at different sampling sites S1, S2, S3, S4, S5 and S6 are 14.28μg m^{-3}, 30.37μg m^{-3}, 45.41μg m^{-3}, 28.90μg m^{-3}, 59.42 μg $m^{-3}$and 32.57 μg m^{-3}respectively.

Chromium: Chromium is considered as a serious environmental pollutant, due to wide industrial use [20]. Leather industry is the major cause for the high influx of chromium to the biosphere [21]. The results revealed that the concentration of Cr in soil depth 0-20cm at different sampling sites S1, S2, S3, S4, S5 and S6 are 52.25μg m^{-3}, 50.02μg m^{-3}, 50.58μg m^{-3}, 48.43μg m^{-3}, 61.09μg $m^{-3}$and 57.43 μg m^{-3}respectively.

It has been found that the concentration of Cd at depth 20-40cm at different sampling sites S1, S2, S3, S4, S5 and S6 are 47.58µg m^{-3},42.35µg m^{-3},45.13µg m^{-3}, 35.61µg m^{-3},54.13µg $m^{-3}$and 52.01µgm^{-3}respectively.

RESULTS AND DISCUSSION

The mean concentration of heavy metals such as Fe, Mn, Zn, Cu, Ni, Cd, Pb and Cr in soil at different sampling station at depth 0-20cm is given in figs.1,2,3,4,5,6 and 20-40cm in figs. 7,8,9,10,11 and 12.

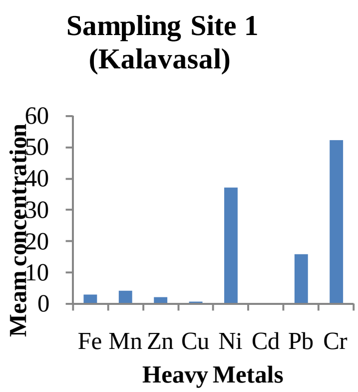


Fig: 1

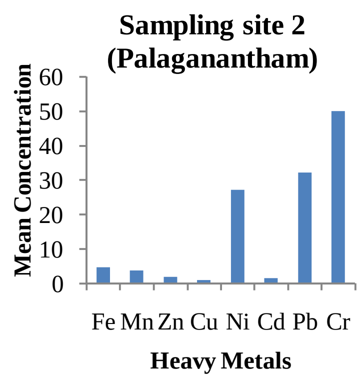


Fig:2

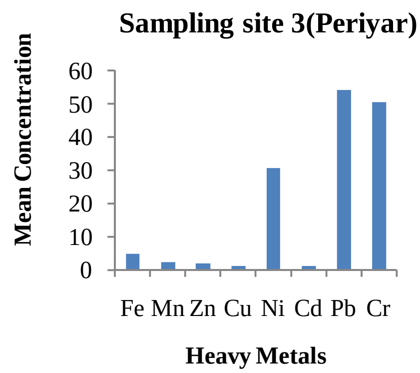
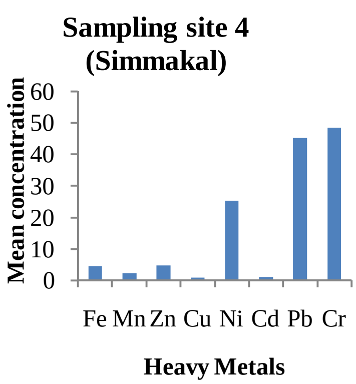


Fig:3



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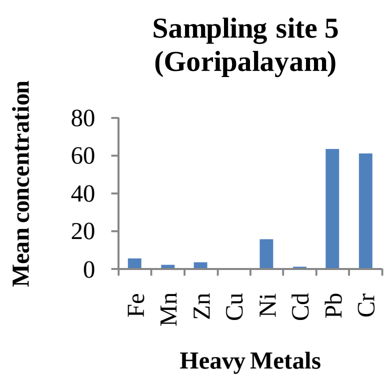

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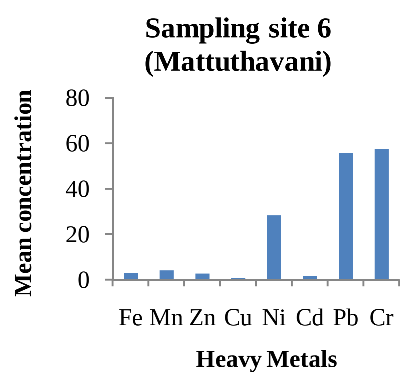

Fig:6

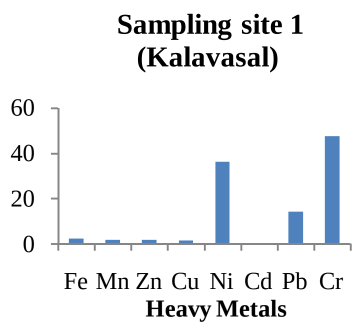

Fig: 7

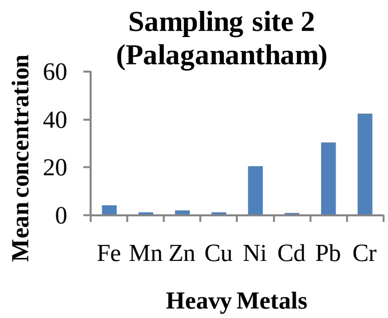

Fig:8

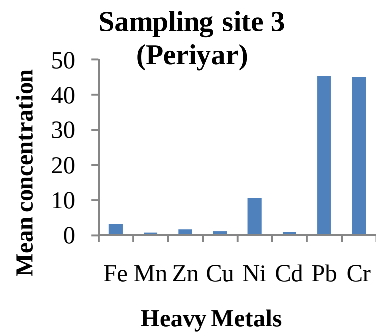

Fig:9

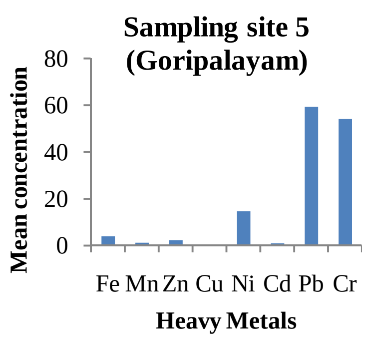

Fig: 10

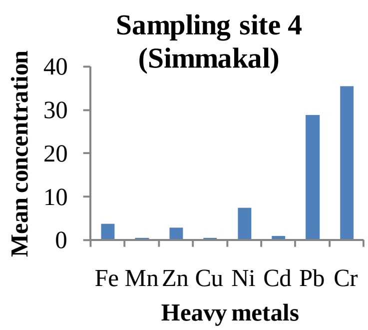

Fig:11

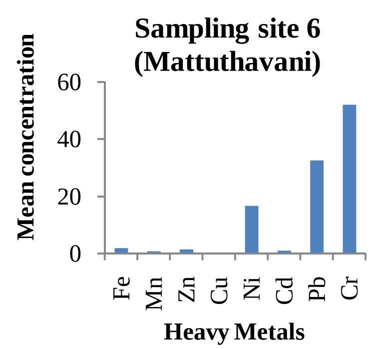

Fig:12

Enrichment Factor(EF) : In order to evaluate the rate of accumulation of heavy metals in the soils the mean values for heavy metals such as Fe, Mn, Zn, Cu, Ni, Cd, Pb and Cr in the soil at depth 0-20cm and 20-40cm were considered along with Enrichment factor values (table 3 and 4).

Table 3. Enrichment Factor for heavy metals in the soil depth (0-20cm)

Sampling Sites	Heavy Metals							
	Fe	**Mn**	**Zn**	**Cu**	**Ni**	**Cd**	**Pb**	**Cr**
S1	1.02	1.78	0.18	0.07	3.28	0.93	3.02	5.18
S2	1.77	1.69	0.17	0.11	2.41	5.33	6.18	4.96
S3	1.77	0.99	0.16	0.12	2.72	3. 80	10.38	5.01
S4	1.72	1.08	0.42	0.11	2.24	3.77	8.68	4.79
S5	2.11	1.08	0.30	0.09	1.41	4.07	12.17	6.05
S6	0.99	1.69	0.22	0.08	2.49	4.33	10.64	5.69

The results clearly indicate that the highest enrichment was found to be Pb in sampling sites S2, S3, S4, S5 and S6 in soil at depth 0-20cm, while the sampling site S1 is highly enriched with Cr. It is observed from the results that in all sampling sites, lead and chromium shows maximum concentration in soil at depth 0-20cm and also have high enrichment factor. Cadmium shows lowest concentration in soil but it has quite high enrichment factor, while Fe, Mn, Zn and Cu shows higher concentration in all sampling sites, but rather low enrichment factor when compared to lead.

Table 4. Enrichment Factor for heavy metals in the soil depth (20-40cm)

Sampling Sites	Heavy Metals							
	Fe	**Mn**	**Zn**	**Cu**	**Ni**	**Cd**	**Pb**	**Cr**
S1	0. 89	0.76	0.16	0.17	3.22	0.53	2.74	4.72
S2	1.43	0.46	0.17	0.11	1.81	2.43	5.82	4.19
S3	1.14	0.30	0.14	0.11	0.94	2.80	8.60	4.47
S4	1.42	0.28	0.25	0.06	0.67	3.20	7.45	3.53
S5	1.49	0.57	0.21	0.05	1.31	3.56	4.38	5.36
S6	0.73	0.35	0.13	0.05	1.48	4.00	6.23	5.15

It has been found that the that the highest enrichment was found to be Pb in sampling sites S2, S3, S4, and S6 in soil at depth 20-40cm, while the sampling site S1 and S5 are highly enriched with Cr. It is observed from the results that in all sampling sites, lead and chromium shows maximum mean concentration in soil at depth 20-40cm and also have high enrichment factor. Cadmium shows lowest concentration in soil but it has quite high enrichment factor, while Fe, Mn, Zn and Cu shows higher concentration in all sampling sites, but rather low enrichment factor when compared to lead.

Normalized Scatter Coefficient(%) : The Normalized Scatter Coefficient(%) of the heavy metals such as Fe, Mn, Zn, Cu, Ni, Cd, Pb and Cr in soil at depth 0-20cm and 20-40cm is given in the Table 5 and Table 6. The Normalized Scatter Coefficient(%) value of heavy metals such as Fe, Mn, Zn, Cu, Ni, Cd, Pb and Cr in soil depth 0-20cm at sampling site 1(Kalvasal), Cadmium has got enriched in faster rate followed by Cu, Zn, Mn, Ni, Pb, Fe and Cr. At sampling site S2(Palaganantham), S3(Periyar), S4(Simmakal) ,S5(Goripalayam) and S6(Mattuthavani) the soil depth 0-20cm, Copper is getting enriched in the faster rate. Similarly the NSC of heavy metals such as Fe, Mn, Zn, Cu, Ni, Cd, Pb and Cr in soil depth 20-40cm value showed that at sampling site S1(Kalavasal), S3(Periyar) and S5(Goripalayam) are greatly enriched with cadmium. But the sampling site S2(Palagananatham) and S4(Simmakal) are found to be enriched with manganese and the sampling site 6(Mattuthavani) is getting enriched with zinc.

Table 5. Normalized Scatter Coefficient(%) of the heavy metals in the soil at depth 0-20cm

Sampling Sites	Heavy Metals							
	Fe	**Mn**	**Zn**	**Cu**	**Ni**	**Cd**	**Pb**	**Cr**
S1	221.70	46.02	48.07	48.93	43.30	53.77	34.36	2.25
S2	44. 87	45.74	46. 81	49.96	22. 83	47.75	17.69	0.04
S3	44.94	47.14	47.54	49.54	19.22	49.53	4.12	0.54
S4	45.15	47.06	44.92	49. 86	24.76	49.29	4.61	1.55
S5	44.48	47.39	46. 84	50.98	34.13	48.56	13.49	11.08
S6	47.17	46.21	47.49	50.37	21. 85	48.29	105.53	7.40

Table 6. Normalized Scatter Coefficient(%) of the heavy metals in the soil depth 20-40cm

Sampling Sites	Heavy Metals							
	Fe	**Mn**	**Zn**	**Cu**	**Ni**	**Cd**	**Pb**	**Cr**
S1	47.88	49.31	48.49	48.23	14.28	56.54	35.81	2.49
S2	45.85	50.39	47.89	49.23	29.69	49.62	19.66	7.74
S3	47.21	47.89	48.84	47.74	39.48	50.98	4.62	4.85
S4	46.27	51.32	47.16	47.75	42.53	50.12	21.08	14.37
S5	46.12	49.03	47.77	48.53	35.28	49.44	9.38	4.17
S6	47.89	47.65	48.61	48.53	33.31	47.52	17.54	2.05

The NSC of heavy metals such as Fe, Mn, Zn, Cu, Ni, Cd, Pb and Cr in soil depth 20-40cm value showed that, at sampling site S1(Kalavasal), S3(Periyar) and S5(Goripalayam) are greatly enriched with cadmium. But the sampling site S2(Palagananatham) and S4(Simmakal) are found to be enriched with Manganese and the sampling site 6(Mattuthavani) is getting enriched with zinc.

Heavy Metal Index: The heavy metal load patterns between different sampling sites are highly comparable because they portray low to very high HMI categories(table 7). At soil depth 0-20cm with a total of 24.0 LRS is categorized as high at sampling site 1 (Kalavasal). Heavy metal index strongly indicating that it is polluted. LRS for sampling site 2 (Palaganantham) was calculated as 30.1, it is categorized as very high. HMI strongly indicating its polluted nature. HMI in soil at depth 0-20cm is categorized as very high 30.1, at sampling site 3 (Periyar). It is strongly indicating its polluted nature. At sampling site 4 (Simmakal), the total LRS is 31.2, which is categorized as very high in soil depth 0-20cm. HMI strongly indicating that it is polluted. The LRS is 29.2 at sampling site 5 (Goripalayam) in soil at depth 0-20cm. LRS is categorized as very high. HMI indicates that the sampling site 5 is polluted. At sampling site 6 (Mattuthavani) in soil depth 0-20cm, the LRS 29.2 is categorized as very high. HMI inferred that the sampling site 6 is strongly polluted. At soil depth 20-40cm with a total of 27.4 LRS is categorized as high at sampling site 1 (Kalavasal). Heavy metal index strongly indicating that it is polluted. LRS for sampling site 2 (Palaganantham) was calculated as 26.6, it is categorized as high. HMI indicating its polluted nature. HMI in soil at depth 20-40cm is categorized as high 24.7, at sampling site 3 (Periyar). It is strongly indicating its polluted nature. At sampling site 4 (Simmakal), the total LRS is 24.1, which is categorized as high in soil depth 0-20cm. Heavy Metal Index strongly indicating that it is polluted. The LRS is 31.0 at sampling site 5 (Goripalayam) in soil at depth 0-20cm. LRS is categorized as very high. HMI indicates that the sampling site 5 is strongly polluted. At sampling site 6 (Mattuthavani) in soil depth 0-20cm, the LRS 23.8 is categorized as high. HMI inferred that the sampling site 6 is strongly polluted.

Table 7. Mean Heavy Metal concentrations in soil at depth 0-20cm, 20-40cm and heavy metal index of the study sites

Sampling sites	Depth	Metals	Mean	SD	N	LRS	Pictograph	LRSP	Sum	HMI
S1	0-20cm	Fe	2.79	0.026	6	2.4	•	Low		
		Mn	4.13	0.017	6	5.0	●	Very high		
		Zn	2.09	0.018	6	2.1	•	Low		
		Cu	0.70	0.026	6	3.0	•	Medium		
		Ni	37.0	0.147	6	5.0	●	Very high		
		Cd	0.28	0.016	6	0.9	•	Very low		
		Pb	15.79	0.026	6	1.2	•	Very low		
		Cr	52.25	0.019	6	4.3	●	High	24	High
	20-40cm	Fe	2.45	0.026	6	3.0	●	High		
		Mn	1.76	0.028	6	5.0	●	High		
		Zn	1.93	0.019	6	3.2	•	Low		
		Cu	1.63	0.019	6	5.0	●	High		

		Ni	36.4	0.306	6	0.6	•	Medium		
		Cd	0.16	0.022	6	1.2	•	Very high		
		Pb	14.28	0.026	6	4.4	•	Low		
		Cr	47.58	0.017	6	4.8	•	High	27.4	High
S2	0-20cm	Fe	4.18	0.024	6	4.2	•	High		
		Mn	4.7	0.019	6	4.7	•	High		
		Zn	2.0	0.041	6	2.0	•	Low		
		Cu	4.5	0.091	6	4.5	•	High		
		Ni	3.7	0.091	6	3.7	•	Medium		
		Cd	5.0	0.023	6	5.0	•	Very high		
		Pb	2.5	0.019	6	2.5	•	Low		
		Cr	4.0	0.037	6	4.0	•	High	30.1	Very high
	20-40cm	Fe	3.91	0.023	6	4.8	•	High		
		Mn	1.07	0.024	6	3.0	•	Medium		
		Zn	1.97	0.019	6	3.3	•	Medium		
		Cu	1.01	0.019	6	3.2	•	Medium		
		Ni	20.38	0.024	6	2.8	•	Low		
		Cd	0.73	0.019	6	3.0	•	Medium		
		Pb	30.37	0.028	6	2.6	•	Low		
		Cr	42.35	0.026	6	3.9	•	Medium	26.6	High
S3	0-20cm	Fe	4.84	0.026	6	4.2	•	High		
		Mn	2.30	0.029	6	2.8	•	Low		
		Zn	1.93	0.019	6	1.9	•	Very low		
		Cu	1.15	0.019	6	5.0	•	Very high		
		Ni	30.72	0.019	6	4.2	•	High		
		Cd	1.14	0.022	6	3.6	•	Medium		
		Pb	54.16	1.480	6	4.3	•	High		

		Cr	50.58	0.187	6	4.1	●	High	30.1	Very high
	20-40cm	Fe	3.12	0.019	6	3.8	●	Medium		
		Mn	0.72	0.019	6	2.0	•	Low		
		Zn	1.65	0.017	6	2.8	•	Low		
		Cu	1.02	0.026	6	3.1	●	Medium		
		Ni	10.65	0.022	6	1.5	●	Very Low		
		Cd	0.84	0.025	6	3.5	●	Medium		
		Pb	45.41	0.022	6	3.8	●	Medium		
		Cr	45.13	0.024	6	4.2	●	High	24.7	High
S4	0-20cm	Fe	4.71	0.018	6	4.1	●	High		
		Mn	2.51	0.023	6	3.0	●	Medium		
		Zn	4.90	0.023	6	5.0	●	Very high		
		Cu	1.09	0.015	6	4.7	●	High		
		Ni	25.25	0.030	6	3.4	●	Medium		
\		Cd	1.13	0.019	6	3.5	●	Medium		
		Pb	45.3	0.028	6	3.6	●	Medium		
		Cr	48.43	0.024	6	3.9	●	Medium	27.1	High
	20-40cm	Fe	3.90	0.019	6	4.8	●	High		
		Mn	0.65	0.023	6	1.8	•	Very low		
		Zn	2.98	0.024	6	5.0	•	Very low		
		Cu	0.60	0.023	6	1.8	•	Very low		
		Ni	7.60	0.052	6	1.0	•	Very low		
		Cd	0.96	0.022	6	4.0	●	High		
		Pb	28.90	0.016	6	2.4	•	Low		
		Cr	35.61	0.022	6	3.3	●	Medium	24.1	High
S5	0-20cm	Fe	5.79	0.019	6	5.0	●	Very high		
		Mn	2.51	0.023	6	3.0	●	Medium		

		Zn	3.55	0.022	6	3.6	•	Medium		
		Cu	0.83	0.021	6	3.6	•	Medium		
		Ni	15.93	0.019	6	2.2	•	Low		
		Cd	1.22	0.022	6	3.8	•	Medium		
		Pb	63.56	0.027	6	5.0	•	Very high		
		Cr	61.09	0.023	6	5.0	•	Very high	31.2	Very high
	20-40cm	Fe	4.09	0.019	6	5.0	•	Very high		
		Mn	1.33	0.022	6	3.8	•	Medium		
		Zn	2.45	0.014	6	4.1	•	High		
		Cu	0.52	0.019	6	1.6	•	Very low		
		Ni	14.84	0.023	6	2.0	•	Low		
		Cd	1.07	0.019	6	4.5	•	High		
		Pb	59.42	0.022	6	5.0	•	High		
		Cr	54.13	0.022	6	5.0	•	Very high	31.0	Very high
S6	0-20cm	Fe	2.72	0.023	6	2.4	•	Low		
		Mn	3.94	0.019	6	4.8	•	High		
		Zn	2.63	0.019	6	2.7	•	Low		
		Cu	0.57	0.023	6	2.4	•	Low		
		Ni	28.16	0.023	6	3.8	•	Medium		
		Cd	1.30	0.022	6	4.0	•	High		
		Pb	55.54	0.022	6	4.4	•	High		
		Cr	57.43	0.019	6	4.7	•	High	29.2	Very high
	20-40cm	Fe	1.99	0.019	6	2.4	•	Low		
		Mn	0.82	0.028	6	2.3	•	Low		
		Zn	1.59	0.022	6	2.7	•	Low		
		Cu	0.52	0.019	6	1.6	•	Very low		
		Ni	16.71	0.019	6	2.3	•	Low		

		Cd	1.20	0.022	6	5.0	●	Very high		
		Pb	32.57	0.026	6	2.7	•	Low		
		Cr	52.01	0.019	6	4.8	●	High	23.8	High

Correlation Coefficient between Heavy metals in soil at depth 0-20cm and 20-40cm: The Pearson correlation coefficient between elemental pairs in soil depth 0-20cm at different sampling sites were studied. It has been found that in all sampling sites at depth 0-20cm, the correlation between elemental pair showed strong relation to each other. At sampling site 1(Kalavasal), Fe-Mn (+0.742), Fe-Cd(+0.566), Fe-Pb(+0.595), Mn-Pb(+0.696) and Zn-Cd(+0.657) showed positive and significant, but the elemental pair such as Fe-Cu(-0.544), Fe-Cr(-0.775), Mn-Cu(-0.775), Mn-Cr(-0.775) and Cu-Pb(-0.707) showed negative but significant correlation. It has been observed that at sampling site 2 (Palaganantham), Fe-Mn(+0.550), Fe-Cd(+0.764), Mn-Zn(+0.621) and Zn-Cd(+0.634) have positive and significant correlation with each other , but elemental pair such as Mn-Ni(-0.8 29), Mn-Pb(-0.829), Zn-Cu(-0.932), Zn-Ni (-0.595), Zn-Pb (-0.595) and Cu-Cd(-0.854) showed negative correlated with each other but significantly. At sampling site 3 (Periyar), the results revealed that the elemental pair such as Mn-Zn(+0.798) and Cr-Cr(+0.829) showed positive and significant correlation but the elemental pair such as Fe-Cd(-0.970), Cu-Ni(-0.599), Ni-Pb(-0.891) and Ni-Cr(-0.543) showed negative but significant correlation. The results inferred that at sampling site 4 (Simmakal), the elemental pair such as Fe-Pb(+0.534), Mn-Zn(+0.814) and Mn-Pb(+0.790) are positively and significantly correlated. But elemental pair such as Mn-Cd(-0.761), Zn-Cd(-0.623), Ni-Pb(-0.548) and Cd-Pb(-0.877) showed negative but significant correlation. It has been observed that at sampling site 5 (Goripalayam), the elemental pair such as Fe-Zn(+0.940),Fe-Cu(+0.940),Fe-Ni(+0.771),Fe-Pb(+0.722),Zn-Cu(+0.843),Zn-Ni(+0.891),Zn-Pb(+0.575),Cu-Ni(+0.544),Cu-b(+0.811)and Pb-Cr(+0.552) are positively and significantly correlated. At sampling site 6 (Mattuthavani), the heavy metal such as Mn-Zn(+0.808), Mn-Cu(+0.992), Mn-Ni(+0.841), Mn-Pb(+0.771), Mn-Cr(+0.943), Zn-Cu(+0.826),Zn-Ni(+0.893),Zn-Cr(+0.715),Cu-Ni(+0.866),Cu-Pb(+0.715),Cu-Cr(+0.899),Ni-r(+0.792)and Pb-Cr(+0.829) have positive significant correlation with each other.

At all sampling sites at depth 20-40cm, the correlation between elemental pair showed strong relation to each other. At sampling site 1 (Simmakal),Fe-Zn(+0.902), Fe-Cd(+0.923), Fe-Pb(+0.559), Mn-Ni(+0.855), Mn-Pb(+0.569), n-Cd(+0.792), Zn-Cr(+0.531), Cu-Ni(+0.761), Cu-Pb(+0.861), Ni-Pb(+0.827) and Cd-Cr(+0.613) showed positive significant. It has been found that at sampling site 2 (Palaganantham), the elemental pair such as Mn-Cu(+0.904), Mn-Pb(+0.587), Mn-Cr(+0.833), Cu-Cr(+0.789), Ni-Cd(+0.638), Ni-Pb(+0.814), Ni-Cr(+0.764) and Pb-Cr(+.709) showed positive correlation but significantly. But the elemental pair Fe-Pb(-0.536) is negatively significantly correlated with each other. At sampling site 3 (Periyar), the elemental pair such as Fe-Zn(+0.838), Mn-Cr(+0.628), Zn-Ni(+0.502), Zn-Cd(+0.522) and Ni-Cd(+0.919) are positively and significantly correlated. The elemental pair such as Mn-Zn(-0.528), Zn-Pb (-0.643), Cu-Ni(-0.678), Ni-Cd (-0.615) and Pb-Cr(-0.508) showed negative and significant correlation. The results revealed that at sampling site 4(Simmakal), the elemental pair such as Fe-Mn(+0.621), Mn-Cd(+0.626) and Zn-Ni(+0.816) showed positive correlation but significantly while the elemental pair such as Fe-Pb (-0.589), Mn-Cu(-0.627), Mn-Cr(-0.533) and Cu-Cd(-0.946) are significantly negatively correlated with each other. At sampling site 5 (Goripalayam), the heavy metal pair such as Fe-Ni(+0.854), Fe-Pb(+0.841), Mn-Cu(+0.742), Zn-Ni(+0.854), Zn-Cd(+0.907), Zn-Pb(+0.589), Zn-Cr(+0.589), Ni-Cd(+0.669), Ni-Pb(+0.573) and Cd-Pb(+0.742) are positively and significantly correlated . But the elemental pair Ni-Cr(-0.773) showed negative correlation but significantly. At sampling site 6 (Mattuthavani) the heavy metal pair such as Fe-Zn(+.792), Fe-Cu(+0.886), Mn-Ce(+0.649), Zn-Cu(+0.544), Zn-Ni(+0.594), Zn-Pb(+0.759) and Ni-Pb(+0.668) are significantly positively correlated with each other. The heavy metal pair such as Mn-Zn(-0.836), Mn-Ni (-0.762), Mn-Pb(-0.964), Zn-Cd(-0.735), Cd-Pb(-0.818) and Cd-Cr(-0.742) showed negative but significant correlation .

APPLICATIONS

The Normalized Scatter Coefficient value indicates faster enrichment of metals. The Heavy Metal Index study indicates that in soil at depth 0-20cm and 20-40cm, all the sampling sites are highly polluted with heavy metals. The roadside soil have significantly high contents of heavy metals and their levels increased with increasing traffic densities and furthermore, they revealed that elevated levels in urban areas.

CONCLUSIONS

The analysis of the research work revealed that the soil collected at depth 0-20cm of the mean metal concentration of chromium was found to be maximum at sampling sites S1(Kalavasal), S2(Palaganantham), S3(Periyar), S4(Simmakal), S6(Mattuthavani) except sampling site S5(Goripalayam) where Lead is found to be maximum. The minimum concentration of heavy metal at depth 0-20cm in soil was found to be copper at sampling sites S1(Kalavasal), S2(Palaganantham), S4(Simmakal), S6(Mattuthavani), except sampling site S3(Periyar) where Lead is found to be minimum. From the observation it indicates that in soil at depth 20-40cm, the mean metal concentration of chromium was highest at sampling sites S1(Kalavasal), S2(Palaganantham), S4(Simmakal), S5(Goripalayam), S6(Mattuthavani) . But in the sampling site S3(Periyar), lead is maximum. The minimum concentration of heavy metal was found to be cadmium at sampling sites S1(Kalavasal), S2(Palaganantham), S3(Periyar) whereas in sampling site S5(Goripalayam) and S6(Mattuthavani) copper is minimum, while at sampling site S4, manganese was found to be minimum. The Enrichment Factor for heavy metals in soil depth 0-20cm revealed that the concentration of Lead is highly enriched at sampling sites S2(Palaganantham), S3(Periyar), S4(Simmakal), S5(Goripalayam) and S6(Mattuthavani) while the Sampling site S1(Kalavasal) is highly enriched with chromium. The result implies that in soil at depth 20-40cm, Lead is found to be enriched to a greater extent at sampling sites S2(Palaganantham), S3(Periyar), S4(Simmakal) and S6(Mattuthavani) but the sampling site S1(Kalavasal) and S5(Goripalayam) were found to be highly enriched with chromium. The NSC revealed that in soil depth 0-20cm, the metal concentration of copper was found to be maximum at sampling sites S2(Palaganantham), S3(Periyar), S4(Simmakal) and S6(Mattuthavani), and it is highly enriched in soil. But in soil at depth 20-40cm, sampling sites S1(Kalavasal) and S6(Mattuthavani) are enriched with cadmium and lead. Among the six different sampling sites studied, the extent of metal pollution in soil was influenced more by heavy traffic density. The present study emphasizes the need to continue to monitor concentration of toxic metals such as Pb, Zn, Fe and Cd in roadside soil in order to detect their toxicity on time.

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