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SPATIAL ANALYSIS OF HEAVY METALS IN ROADSIDE DUST AND SOIL

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Abstract : *Road surfaces receive varying amount of heavy metals by the process of atmospheric deposition, sedimentation, impaction and interception. Particularly in urban areas, the top soils and roadside dusts are indicators of heavy metal contamination from atmospheric deposition. Industries, traffic, and construction are some of the main anthropogenic sources of heavy metal pollution. Urban dust is contaminated by pollutants from various diffused sources and is often difficult to be controlled. Road dust has often been used as an indicator of heavy metal pollution in our environment. Nowadays it becomes mandatory to observe the concentration to know the level of contamination.In recent decades, considerable attention has been paid to the problem of urban soil contamination with heavy metals to prevent further environmental deterioration. In the study, roadside dust particles as well as the top surface of the soil in the roadside of different land use pattern (Commercial, Industrial and Residential area) are determined for possible heavy metals to find the distribution pattern of such metals on the roadside. Based on the study, the heavy metals such as Pb, Ni, As, Cd, Cr, Cu, Hg are present below the permissible level in soil as prescribed by WHO.*

IndexTerms **- Pollution, Dust, Soil, Heavy metals Distribution, Pollution Index**

I. INTRODUCTION

Due to the continuous urbanization and industrialization in many countries of the world, heavy metals are continuously emitted into the terrestrial environment and pose a great threat on human health. Of the three materials, soil, sediment and dust, which originate primarily from the earth's crust, dust is the most pervasive and important factor affecting human health and well-being (1). Road dust receives a large number of heavy metals inputs from a variety of mobile or stationary sources. Road dust is viewed as one of the major contributors for metal pollution in urban environment. Long-term exposure to the polluted dust environment would cause chronic damage through ways of inhalation, ingestion, and dermal contact (2).

Heavy metals are dangerous because they tend to be bioaccumulated, meaning that over a long time the concentrations of heavy metal within a biological organism can be higher than that in the environment. Therefore, the study of road dust is an important way of determining the origin, distribution and level of heavy metals. In fact, chronic problems associated with long-term heavy metal exposures are metal lapse caused by Pb exposure; Cd has effects on the kidney, liver and gastrointestinal tract (3).

According to numerous studies, the pollution sources of heavy metals in environment are mainly derived from anthropogenic sources. For urban soils and dusts, the anthropogenic sources of heavy metals include traffic emission (vehicle exhaust particles, tire wear particles, weathered street surface particles, brake lining wear particles), industrial emission (power plants, coal combustion, metallurgical industry, auto repair shop, chemical plant, etc.), domestic emission, weathering of building and pavement surface, atmospheric deposited and so on(4). For example, Pb, Zn, and Cu largely come from traffic pollution, Cd originates from industrial contaminants, and Cr is associated with atmospheric deposition (5).

Trace metals in roadside soils may come from various human activities, such as industrial and energy production, construction, vehicle exhaust, waste disposal, as well as coal and fuel combustion [6]. The contamination of the environment by heavy metals is a phenomenon of global importance today. This is because the accumulation of heavy metals in roadside dust is one major way through which heavy metals may find their way into soils and subsequently living tissues of plants, animals and human beings [7,8]. In monitoring urban pollution, chemical and biological indicators are of interest since they provide information on the concentration and accumulation of heavy metals in the ecosystem [9].

Pollutants can attack specific sites or organs of the body and disease can develop as a consequence to such exposure [10]. Although there have been considerable number of studies on the concentration of heavy metals in roadside dust, the vast majority have been carried out in developed countries with long histories of industrialization [11]. A very few studies have been carried out in developing countries especially in northeast Nigeria. Little interest has been focused on the contamination of roadside dust by heavy metals in Nigeria and Africa in particular[12,18]. A range of metals and chemical compounds such as lead dioxide and lead sulfate found in the roadside dust environment are harmful[19].

Abbreviations and Acronyms

HNO_3- Nitric acid
HCl- HydroChloric acid
WHO-World Health Organisation

ICP- OES-Inductively Coupled Plasma Optical Emission Spectroscopy
CF- Contamination Factor
CD- Degree of Contamination
Igeo- Index of geo-accumulation
Cb- Geochemical Background Concentration
Cs- Concentration of the examined metal in the road dust

II.RESEARCH METHODOLOGY

The sampling site is selected based on the land use pattern and then the collection of dust and soil samples were collected and analyzed for the possible heavy metals to found out the distribution pattern and to determine the pollution status of the selected sampling site. The distribution pattern is determined and represented in a graphical manner. In the graph, the X axis is the sampling location and Y axis is the concentration of the respective metal in that location. After that, the pollution status is determined using pollution indices such as contamination factor, degree of contamination and to determine the soil health, the geo accumulation index is used.

2.1 Sample collection

Collection of Dust Samples

. A collector consists of a plastic jar of about 20-35 cm height and 10-15 cm diameter at the base with slight inward tapering of the walls from top to bottom. The sample is deposited over a period of 30 days and the sample is dried and then followed by analysis (Air Pollution by M N Rao).

Collection of Soil Samples

The soil samples are collected from the top surface of the soils present in the road surface and then the sample is dried and followed by analysis(6,20).

2.2 Sample preparation

All the collected samples were passed through a 2 mm sieve, and five gram of sample were dissolved in aqua regia of 3:1 ratio of Hydrochloric acid (HCl) : Nitric acid (HNO_3).

- Heated it using hot plate at 600^0c, until the acid gets evaporated and it finally becomes residue.
- After completely turned to ash, add 10ml distilled water, filter the supernatant with whatman filter paper.
- The procedure is repeated till getting a volume of 100 ml.
- The metal concentrations were determined by ICP- OES. (Ref: US EPA 1999)

2.3 Pollution Index

In this study, heavy metal contamination of roadside soil were analyzed using single (contamination factor and index of geoaccumulation) and integrated (degree of contamination) indices (8). The contamination factor (CF) and degree of contamination (CD) were suggested by Håkanson (1980) and defined as follows:

$$CF=Cs/Cb$$
$$CD=\Sigma CF$$

Where, Cs is the measured concentration of the examined metal in the road dust and Cb is the geochemical background concentration or reference value of the metal or the background value (control) of heavy metals in the uncontaminated soil. The contamination was classified into four groups as follows: low ($CF < 1$), moderate ($1 \leqslant CF < 3$), considerable ($3 \leqslant CF < 6$) and very high ($6 \leqslant CF$)13.

In this study, four categories of CD will be used to evaluate metal contamination levels as follows: low ($CD < 5$), moderate ($5 \leqslant CD < 10$), considerable ($10 \leqslant CD < 20$), and very high ($20 \leqslant CD$) degree of contamination. If the CD values exceeded 20, then it is necessary to take immediate counter measures to reduce heavy metal contamination in the road dust.

An index of geo-accumulation (Igeo) was originally defined by Müller (1969), and can be calculated by the following equation (8,17):

$$Igeo=\log_2[Cs/(1.5Cb)]$$

Factor 1.5 is used because of possible variations in background values for a given metal in the environment as well as very small anthropogenic influences. Müller classified Igeo for each metal to 5 grade-categories as follows:

- $Igeo \leqslant 0$ = practically unpolluted
- $0 < Igeo \leqslant 1$ = unpolluted to moderately polluted
- $1 < Igeo \leqslant 2$ = moderately polluted
- $2 < Igeo \leqslant 3$ = moderately to strongly polluted
- $3 < Igeo \leqslant 4$ = strongly polluted
- $4 < Igeo \leqslant 5$ = strongly to extremely polluted
- $Igeo \geqslant 5$ = extremely polluted

III. RESULTS AND DISCUSSION

3.1 Analysis of Soil Samples

The soil samples were collected from the three study location. The collected samples were analyzed for some heavy metals such as Pb, Ni, As, Cr, Cu, Zn, Hg, Cd. The analyzed values are given in the following table I, II, III in mg/kg.

3.2 Analysis of Dust Samples

The dust samples were collected from nine locations and analysed for the metals such as nickel, lead and chromium. The analyzed values are given in the following table IV, V, VI in mg/kg.

TABLE I. HEAVY METAL ANALYSIS IN SOIL SAMPLE - AMBATTUR ESTATE ROAD

S.no	Metals							
	Pb	*Ni*	*As*	*Cr*	*Cu*	*Zn*	*Hg*	*Cd*
1	14.24	25.56	-	0.16	0.56	5.34	2.7	-
2	13.44	22.64	-	0.24	1.3	3.54	1.58	-
3	14	20.66	-	0.34	0.62	6.22	2.34	-
4	10.3	22.44	-	0.1	1.02	3.04	1.7	-
5	12.74	19.74	-	0.5	1.26	2.62	2.51	-

TABLE II. HEAVY METAL ANALYSIS IN SOIL SAMPLE - MOGAPPAIR ROAD

S.no	Metals							
	Pb	*Ni*	*As*	*Cr*	*Cu*	*Zn*	*Hg*	*Cd*
1	4.82	8.96	-	0.22	1.16	9.3	-	-
2	4.72	7.44	-	0.16	2.46	6.74	-	-
3	2.98	7.9	-	0.12	1.5	7.38	-	-
4	4.26	8.5	-	0.26	1.78	10.4	-	-
5	3.84	11.44	-	0.24	1.32	9.84	-	-
6	3.76	8.82	-	0.18	1.24	7.58	-	-
7	4.24	7.46	-	0.38	2.5	8.44	-	-

TABLE III. HEAVY METAL ANALYSIS IN SOIL SAMPLE - ANNA NAGAR ROAD

S.no	Metals							
	Pb	*Ni*	*As*	*Cr*	*Cu*	*Zn*	*Hg*	*Cd*
1	11.3	13.56	-	2.24	-	-	-	-
2	9.82	11.82	-	1.86	-	-	-	-
3	10.24	12.66	-	1.62	-	-	-	-
4	13.24	14.44	-	2.64	-	-	-	-
5	10.26	13.98	-	2.3	-	-	-	-
6	8.2	12.3	-	4.34	-	-	-	-
7	10.46	10.86	-	1.82	-	-	-	-
8	8.26	16.2	-	1.9	-	-		

The range of heavy metals present in soil sample for Ambattur Estate location is Pb (10.3 – 14.24 mg/kg), Ni (19.74 – 25.56 mg/kg), Cr (0.1 - 0.5 mg/kg), Cu (0.56 – 1.26 mg/kg), Zn (2.62 – 6.22 mg/kg), Hg (1.58 – 2.7 mg/kg). In Mogappair Road Pb(2.98 – 4.82 mg/kg), Ni (7.44 – 11.44 mg/kg), Cr (0.12 – 0.38 mg/kg), Cu (1.24 – 2.5 mg/kg), Zn (6.74 – 10.4 mg/kg). In Anna Nagar Road Pb (8.2 – 13.24 mg/kg), Ni (10.86 – 16.2 mg/kg), Cr (1.62 – 4.34 mg/kg). The figure shows analyzed values of soil samples from Ambattur Estate Road, Mogappair Road, Anna Nagar Road are as follows

AMBATTUR ESTATE ROAD

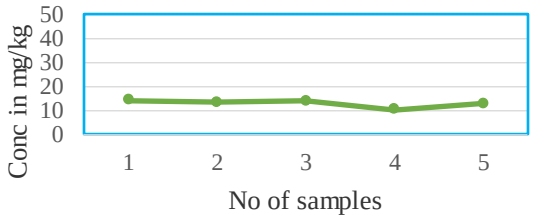

Fig 1. Pb concentration

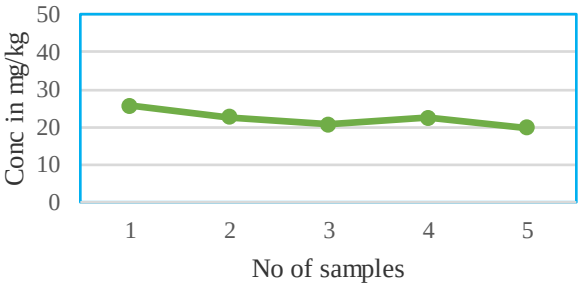

Fig 2. Ni concentration

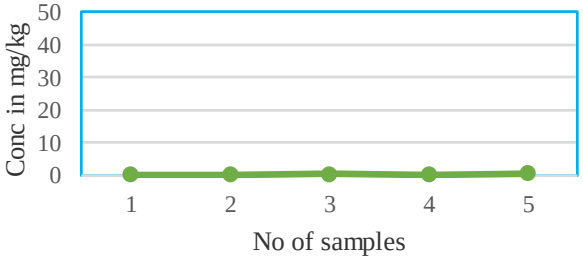

Fig 3. Cr concentration

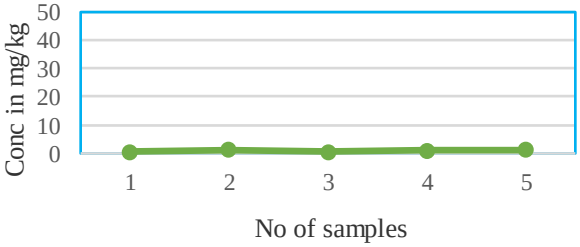

Fig 4. Cu concentration

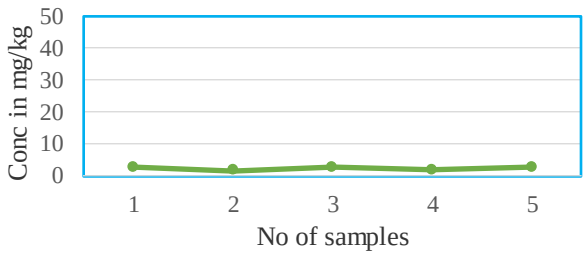

Fig 5. Hg concentration

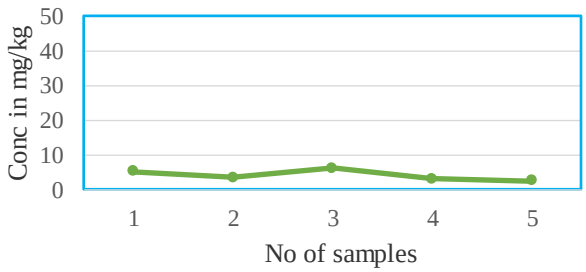

Fig 6. Zn concentration

MOGAPPAIR ROAD

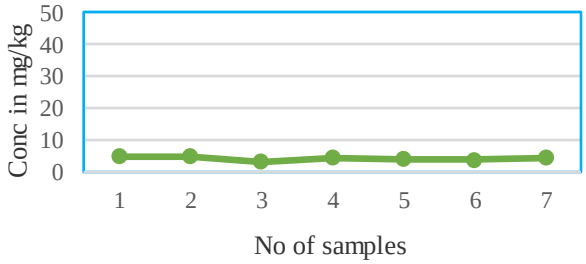

Fig 7. Pb concentration

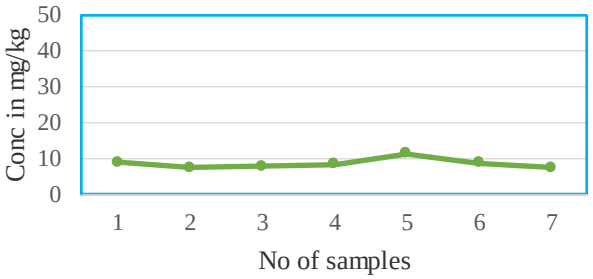

Fig 8. Ni concentration

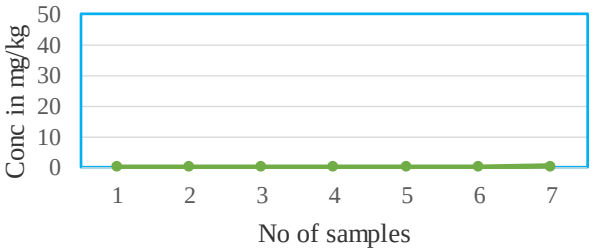

Fig 9. Cr concentration

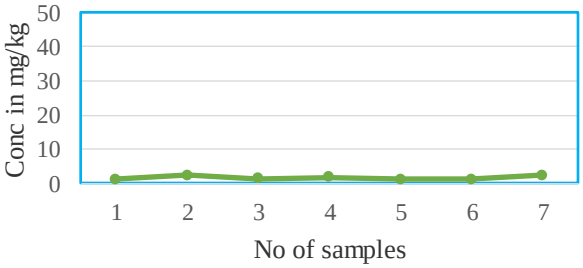

Fig 10. Cu concentration

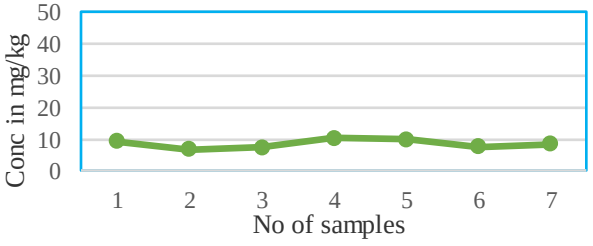

Fig 11. Zn concentration

ANNA NAGAR ROAD

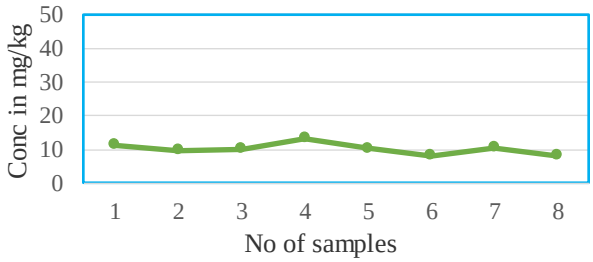

Fig 12. Pb concentration

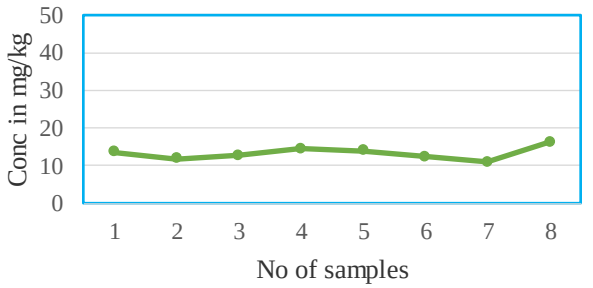

Fig 13. Ni concentration

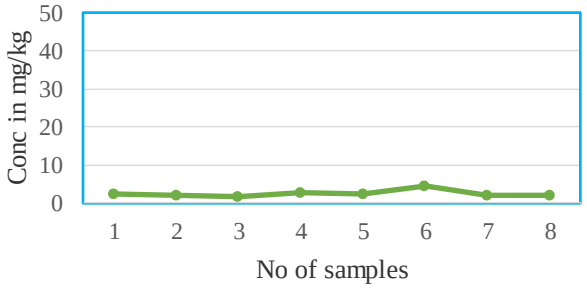

Fig 14. Cr concentration

TABLE IV. HEAVY METAL PRESENT IN DUST SAMPLE - AMBATTUR ESTATE ROAD

S.no	Metals		
	Pb	***Ni***	***Cr***
1	2.26	2.38	0.06
2	1.8	2.5	0.024
3	1.62	1.86	0.068

TABLE V. HEAVY METAL PRESENT IN DUST SAMPLE - MOGAPPAIR ROAD

S.no	Metals		
	Pb	***Ni***	***Cr***
1	0.42	2.04	0.04
2	0.5	1.9	0.026
3	0.62	2.14	0.038

TABLE VI. HEAVY METAL PRESENT IN DUST SAMPLE - ANNA NAGAR ROAD

S.no	Metals		
	Pb	***Ni***	***Cr***
1	0.16	0.24	0.08
2	0.24	0.38	0.064

S.no	Metals		
	Pb	*Ni*	*Cr*
3	0.184	0.48	0.042

The range of heavy metals present in dust sample of Ambattur estate road is Pb (1.62-2.26 mg/kg), Ni (1.86-2.5 mg/kg) and Cr (0.024-0.068 mg/kg). In Mogappair Road Pb (0.42-0.62 mg/kg), Ni (1.9-2.14 mg/kg) and Cr (0.026-0.04 mg/kg). In Anna Nagar Road Pb (0.16-0.24 mg/kg), Ni (0.24-0.48 mg/kg) and Cr (0.042-0.08 mg/kg). The figure shows the analyzed values of dust samples are as follows:

AMBATTUR ESTATE ROAD

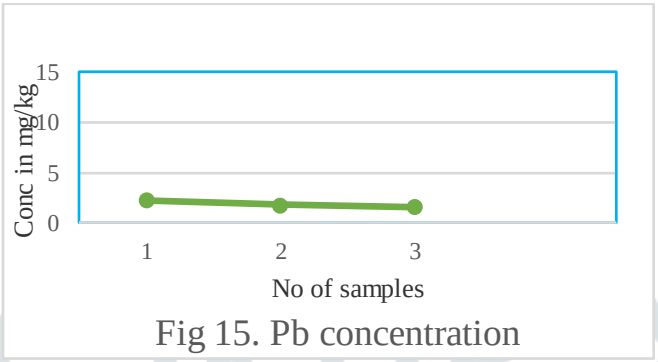

Fig 15. Pb concentration

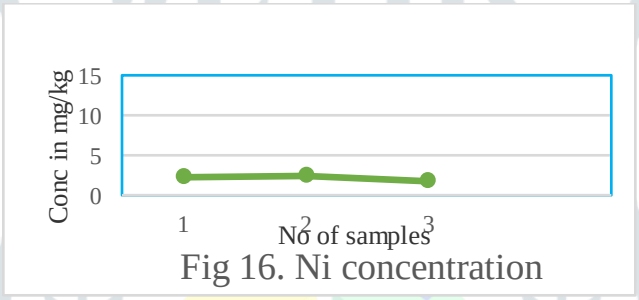

Fig 16. Ni concentration

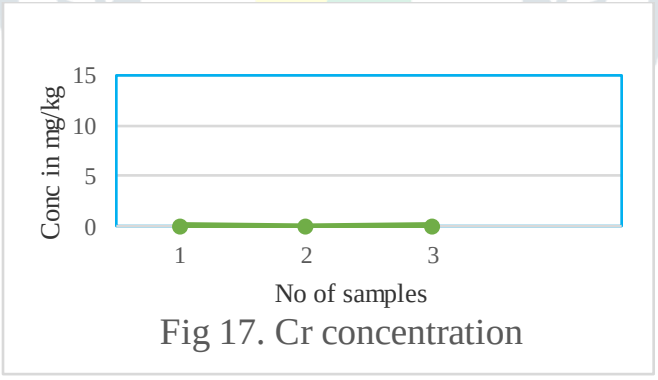

Fig 17. Cr concentration

MOGAPPAIR ROAD

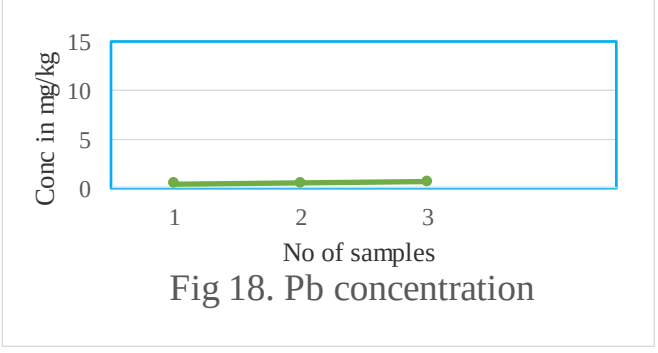

Fig 18. Pb concentration

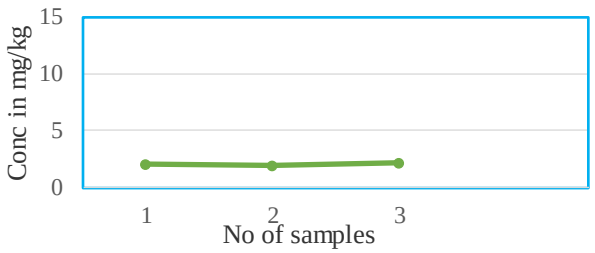

Fig 19. Ni concentration

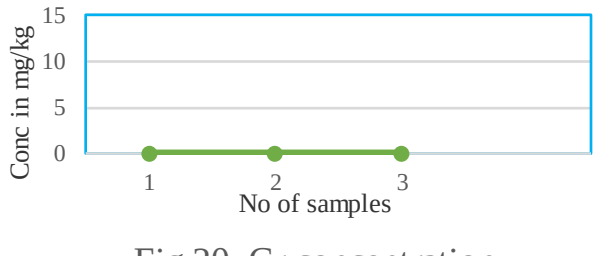

Fig 20. Cr concentration

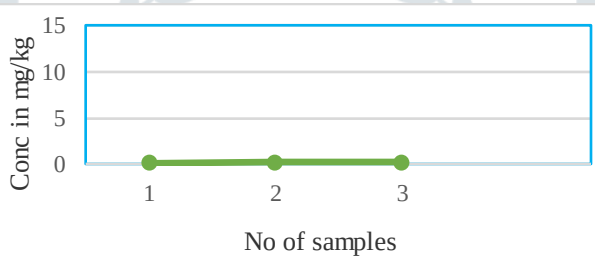

Fig 21. Pb concentration

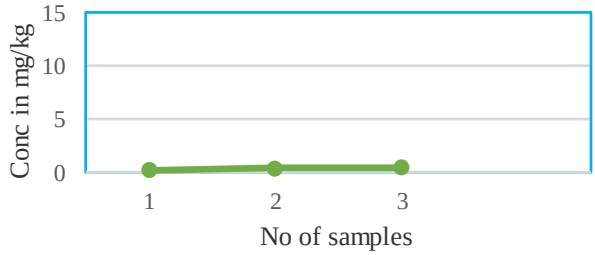

Fig 22. Ni concentration

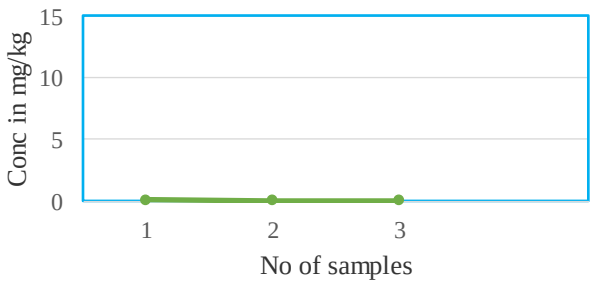

Fig 23. Cr concentration

3.3 Pollution index calculation

Heavy metal concentration and their level of contamination in the soil samples were identified using CF and to determine the soil health, Index of geo accumulation were used. The reference value taken from WHO 1996 (9,13,14,15).

TABLE VII. CONTAMINATION FACTOR FOR AMBATTUR ESTATE ROAD SOIL SAMPLES

S.no	Metals				
	Pb	*Ni*	*Cr*	*Cu*	*Zn*
1	0.167	0.730	0.0016	0.015	0.106
2	0.158	0.646	0.0024	0.036	0.070
3	0.164	0.590	0.0034	0.017	0.124
4	0.121	0.641	0.0010	0.028	0.060
5	0.149	0.564	0.0050	0.035	0.052

TABLE VIII. CONTAMINATION FACTOR FOR MOGAPPAIR ROAD SOIL SAMPLES

S.no	Metals				
	Pb	*Ni*	*Cr*	*Cu*	*Zn*
1	0.056	0.256	0.0022	0.032	0.186
2	0.055	0.212	0.0016	0.068	0.134
3	0.035	0.225	0.0012	0.041	0.147
4	0.050	0.242	0.0026	0.049	0.208
5	0.045	0.326	0.0024	0.036	0.196
6	0.044	0.252	0.0018	0.034	0.151
7	0.049	0.213	0.0038	0.069	0.168

TABLE IX. CONTAMINATION FACTOR FOR ANNA NAGAR ROAD SOIL SAMPLES

S.no	Metals		
	Pb	*Ni*	*Cr*
1	0.387	0.132	0.0224
2	0.337	0.115	0.0186
3	0.361	0.120	0.0162
4	0.412	0.155	0.0264
5	0.399	0.120	0.0223
6	0.351	0.096	0.0434
7	0.310	0.123	0.0182
8	0.462	0.097	0.0190

TABLE X. GEO ACCUMULATION INDEX FOR AMBATTUR ESTATE ROAD SOIL SAMPLES

S.no	Metals				
	Pb	*Ni*	*Cr*	*Cu*	*Zn*
1	-0.952	-0.312	-2.97	-1.98	-1.14
2	-0.977	-0.365	-2.79	-1.61	-1.32
3	-0.959	-0.400	-2.64	-1.94	-1.08
4	-1.090	-0.369	-3.17	-1.72	-1.39
5	-1.000	-0.424	-2.47	-1.63	-1.45

TABLE XI. GEO ACCUMULATION INDEX FOR MOGAPPAIR ROAD SOIL SAMPLES

S.no	Metals				
	Pb	*Ni*	*Cr*	*Cu*	*Zn*
1	-1.42	-0.767	-2.83	-1.66	-0.90
2	-1.43	-0.848	-2.97	-1.34	-1.04
3	-1.63	-0.822	-3.09	-1.55	-1.00

S.no	Metals				
	Pb	*Ni*	*Cr*	*Cu*	*Zn*
4	-1.48	-0.790	-2.76	-1.48	-0.85
5	-1.52	-0.661	-2.79	-1.61	-0.88
6	-1.53	-0.770	-2.92	-1.63	-0.99
7	-1.47	-0.847	-2.59	-1.33	-0.94

TABLE XII. GEO ACCUMULATION INDEX FOR MOGAPPAIR ROAD SOIL SAMPLES

S.no	Metals		
	Pb	*Ni*	*Cr*
1	-1.05	-0.58	-1.82
2	-1.11	-0.64	-1.90
3	-1.09	-0.61	-1.96
4	-0.98	-0.56	-1.75
5	-1.09	-0.57	-1.81
6	-1.19	-0.63	-1.53
7	-1.08	-0.68	-1.91
8	-1.18	-0.51	-1.89

Therefore, Contamination Factor calculation clearly indicates that the soil samples from the study area is having low contamination of metals because the index values are less than 1. Similarly, the Index of Geo Accumulation clearly indicates that the soil samples from the study area is practically unpolluted because the index values are less than 0.

3.4 Conclusion

The present study focusing on the concentration of heavy metals such as Ni, Pb, Cr, Cu, Zn, Hg, As, Cd in roadside dust fall and soil of the Ambattur Estate Road, Mogappair Road and Anna Nagar Road. The heavy metal concentration in soil samples of Ambattur Estate Road are Ni>Pb>Zn>Hg>Cu>Cr. The heavy metal concentration in soil samples of Mogappair Road are Ni>Zn>Pb>Cu>Cr. The heavy metal concentration in soil samples of Anna Nagar Road are Ni>Pb>Cr.

The heavy metal concentrations in dust samples are in the order of Ni>Pb>Cr for Ambattur Estate Road, Mogappair Road, Anna Nagar Road.

For soil samples in Ambattur Estate Road, the metals having less concentrations on comparing with the permissible values. In Mogappair Road, the metals are present in less concentrations than the permissible values. Also in Anna Nagar Road, the metals are present in lesser concentrations than the permissible values.

Contamination Factor calculation clearly indicates that the soil samples from the study area is having low contamination of metals because the index values are less than 1. Similarly, the Index of Geo Accumulation clearly indicates that the soil samples from the study area is practically unpolluted because the index values are less than 0.

The findings of the study are based on the limited number of samples; however, a further comprehensive study is needed in order to better understanding of metal contamination of road dust and soil in study location and to develop environmental policies and strategies to minimize the contamination.

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