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Assessing heavy metal contamination of road side soil in urban area

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ABSTRACT:

Environmental pollution of heavy metals from automobiles has attained much attention in the recent past. The pollution of soil by heavy metals is a serious environmental issue. Heavy metals are released during different operations of the road transport such as combustion, component wear, fluid leakage and corrosion of metals lead, cadmium, copper and zinc which are the major metal pollutants of the road side environment. The present research is conducted to study heavy metal contamination in road side and industrial soil of Madurai city. The soil samples are collected from three sites and analyzed for six heavy metals (Pb, Cu, Cr, Zn, Ni and Cd). Their concentration and distribution in different depths (0 cm, 5 cm and 10 cm) were determined. Heavy metal contents were analyzed by Atomic Absorption Spectroscopy (AAS). The studies with Enrichment Factor (EF) indicate that lead has been enriched to quite great extent while the Normalized Scatter Coefficient values (NSC) indicate faster enrichment of cadmium. The level of heavy metals in road side soils were higher as compared to their natural background levels. The results revealed that the heavy metals are harmful to the road side vegetation, wild life and the neighbouring human settlements.

Keywords:
Pollution, combustion, heavy metal enrichment, road side soils, enrichment factor, Normalized scatter coefficient value, environmental pollution.

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INTRODUCTION

Pollution in recent years has increased considerably as a result of increasing human activities such as burning of fossil fuels, industrial and automobile exhaust emissions. The pollution of soils by heavy metals from automobile sources is a serious environmental issue. The majority of the heavy metals are toxic to the living organisms and even those considered as essential can be toxic if present in excess. The heavy metals can impair important biochemical processes posing a threat to human health, plant growth and animal life (Jarup 2003; Michalke 2003; Silva *et al.,* 2005).

The waste products from vehicles that ply highways contain some heavy metals inform of smokes. Emissions from exhaust pipes of automobile engine and contacts between different metallic objects in machines contain such heavy metals as Lead (Pb), Zinc(Zn), Iron (Fe), Copper (Cu), Chromium (Cr) and Cadmium (Cd) and are major sources of pollution among soils (Turer and Maynard, 2003).

Soils are usually regarded as an ultimate sink. For heavy metals discharged into the environment (Banat *et al.,* 2005) and sediments can be sensitive indicators for monitoring contaminants in aquatic environment (Pekey *et al.,* 2004). Therefore the environmental problem of soil and sediment pollution by heavy metals has received increasing attention in the last few decades in both developing and developed countries throughout the world (Zhang *et al.,* 2007). Hence, inorder to monitor heavy metal pollution in an area, due to the anthropogenic activity (Sarala Thambavani and Vathana, 2011), the soil samples represent an excellent media because heavy metals are usually deposited in the top soil (Govil *et al.,* 2001; Romic and Romic, 2003) and help in knowing the sources of heavy metals and also controlling and optimizing their effects on the human health.

It is needless to say that the industrial activities in the metropolitan cities of the world are responsible for the addition of pollutants through chemical factories, residential activities (Point sources) and vehicular traffic (non-point sources) which are the primary sources of soil pollution. The objective of this study, is to investigate the effect of heavy metal pollution of soil along road sides.

The present study reports the role of industrial and urban activities in the heavy metal contamination of the soils in the Madurai industrial area with the objectives:

- To assess the extent of heavy metal pollution influenced by urban and industrial activities.
- To predict the rate of heavy metals pollution in the future if the activities are allowed with the same pace.
- To understand the variations in the behavior of different heavy metal.

METHODS

Field Methodolgy

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 site

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 (Burgess *et al.,* 1981). Different sampling stations were selected and samples are collected from the top layer of the soil 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 100 cm 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.

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 grounds 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 2 mm sieve in order to collect granulometric fraction. Since trace metals are often found mainly in clay and silt fractions of soil and hence the size fraction <63 µm sieve (wet sieving) and was used to measure the concentration of the heavy metals Lead, Copper, Chromium, Zinc, Nickel and Cadmium from all the samples collected.

For this purpose the clay and silt fraction were digested by acids to get the solution by taking 5 g of sample into a 300 ml polypropylene wide-mouthed jar and distilled water was added to make a total 200 ml. Then it was acidified with 10 ml HF, 5 ml $HClO_4$, 2.5 ml HCl and 2.5 ml HNO_3 in order to completely digest the soil. This jar was shaken on an orbital shaker for 16 h at 200-220 rpm before being filtered through whatman filter paper (No.42) into acid washed bottles. The solution was stored and heavy metal contents 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.

RESULTS

The concentration of heavy metals Lead, Copper, Chromium, Nickel and Cadmium in the soils of Madurai industrial, traffic and residential area were analyzed, collected at six sampling stations during May 2011- Oct 2011. The range of the concentrations found in different sampling stations are (i) Pb industrial (24.81-42.37 mg/kg), traffic (26.80-5.32 mg/kg) and residential (20.42-2.66 mg/kg) (ii) Cu industrial (10.40-16.24 mg/kg), traffic (10.69-18.20 mg/kg) and residential (10.5 -18.16 mg/kg) (iii) Cr industrial (17.0-34.50 mg/kg), traffic (14.56-21.60 mg/kg) and residential (25.12 mg/kg) (13.60-18.52 mg/kg) (iv) Zn industrial (22.5-45.6 mg/kg), traffic (22.32-25.46 mg/kg) and residential (22.24- 25.12 mg/kg) (v) Ni industrial (11.85-14.0 mg/kg), traffic (11.52 -14.80 mg/kg) and residential (11.70-13.9 mg/kg) (vi) Cd industrial (1.24-4.32 mg/kg), traffic (1.60-3.62 mg/kg) and residential (1.70-2.25 mg/kg).

The mean concentration for these heavy metals from the surface soil have been calculated to be (i) Pb industrial (33.23), traffic (41.50) and residential (24.31). (ii) Cu industrial (12.97), traffic (15.03) and residential (14.98). (iii) Cr industrial (24.33), traffic (17.53) and residential (15.51). (iv) Zn industrial (29.78), traffic (24.23) and residential (23.74). (v) Ni industrial (12.77), traffic (13.72) and residential (12.99). (vi) Cd industrial (2.94), traffic (2.59) and residential (1.92) respectively at the confidence limits of 95%.

The concentration of heavy metals in all the sampling stations exhibit an increasing trend over a very short period of monitoring from May 2011-Oct 2011 (Figure 1). It was observed that the mean concentration of Lead has been increased in all the three sampling

Table 1 Natural Local background concentration values (mg/kg) of the heavy elements of soils

Sampling stations	Pb	Cu	Cr	Zn	Ni	Cd
Industrial Area	5.14	9.44	9.89	11.32	11.28	0.32
Traffic Area	5.22	9.58	10.09	11.76	11.29	0.30
Residential Area	5.26	9.63	11.10	11.87	11.31	0.35

stations followed by Zinc, Chromium, Copper, Nickel and Cadmium.

Accumulative Signature of Heavy Metals

An increasing trend has been found for the heavy metal elements Lead, Copper, Chromium, Zinc Nickel and Cadmium wherein the Lead and Cadmium are getting accumulated with very rapid rate mainly due to anthropogenic activities (Sayadi, 2009). 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 and Datta dilip (1998) and presented in Table 2.

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

Normalized Scatter Coefficient (NSC) has been calculated to asses 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 (Sayadi and Sayyed, 2010).

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

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.

DISCUSSION

In order to evaluate the rate of accumulation of heavy metals in the soils the mean values for all heavy metals studied were considered along with Enrichment factor values of all six metals (Table 2), which clearly indicate the highest enrichment of Cadmium followed by Lead, Zinc, Chromium, Copper and Nickel in all the three sampling stations of industrial, traffic and residential area. The values of NSC for all six heavy metal showed that Cadmium is increasing in soil environment of industrial area followed by Zinc, Chromium, Lead, Copper and Nickel. In traffic area Lead is increasing in soil environment followed by Cadmium, Chromium, Copper, Nickel and Zinc and in residential area Copper is increasing in soil environment followed by Chromium, Cadmium, Lead, Nickel and Zinc.

It is observed that in all the sampling sites, Lead shows highest concentration in soil and also have high

Table 2 Enrichment Factor for heavy metals in the soils

Industrial Area

Pb	Cu	Cr	Zn	Ni	Cd
4.6	1.1	1.7	1.9	1.1	3.8
5.3	1.1	1.8	2.1	1.1	4.1
5.7	1.4	2.2	2.3	1.0	8.8
6.9	1.5	2.7	2.5	1.1	11.8
7.7	1.5	2.9	2.9	1.2	13.1
8.3	1.7	3.5	4.0	1.2	13.5

Traffic Area

Pb	Cu	Cr	Zn	Ni	Cd
5.1	1.1	1.4	1.9	1.0	5.3
5.6	1.4	1.6	1.9	1.2	6.6
6.9	1.5	1.6	2.1	1.2	8.3
8.7	1.7	1.8	2.1	1.3	9.5
10.1	1.8	1.8	2.1	1.3	9.9
11.2	1.9	2.1	2.2	1.3	12.1

Residential Area

Pb	Cu	Cr	Zn	Ni	Cd
3.9	1.1	1.2	1.9	1.0	4.9
4.2	1.3	1.3	1.9	1.1	4.9
4.7	1.3	1.3	2.0	1.2	5.3
4.8	1.8	1.4	2.0	1.2	5.7
5.0	1.9	1.5	2.1	1.2	5.7
5.1	1.9	1.7	2.1	1.2	6.4

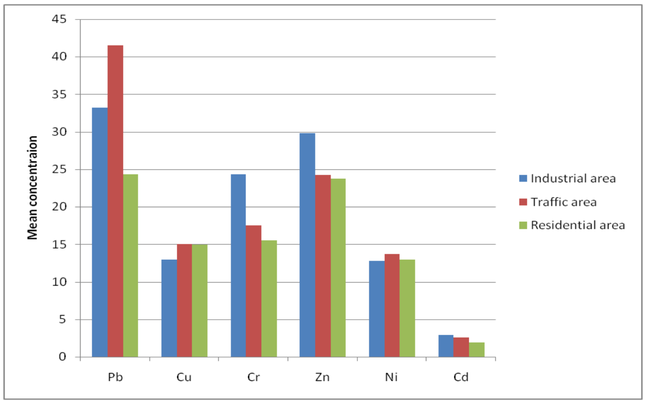

Figure 1. Mean Concentrations of the heavy metals on different sampling stations

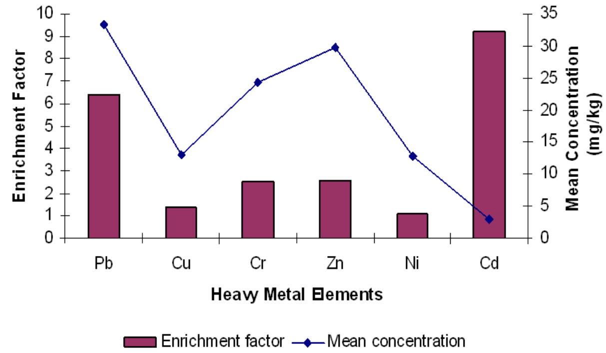

Figure 2. Industrial Area

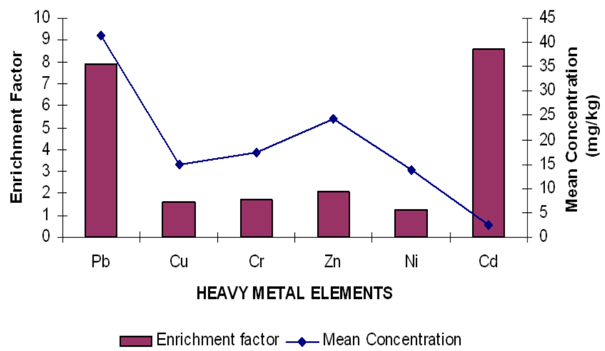

Figure 3. Traffic Area

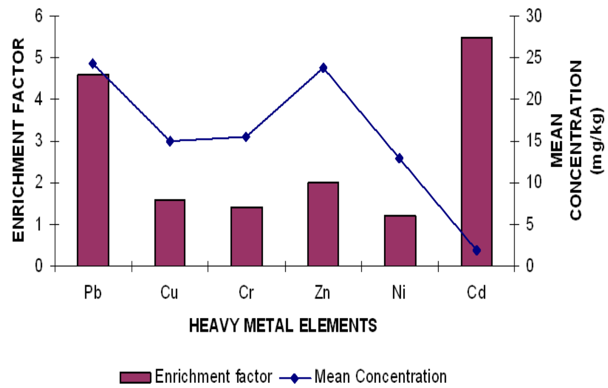

Figure 4. Residential Area

enrichment factor. Cadmium shows lowest concentration in soil but is has quite high enrichment factor, while Copper, Chromium, Zinc and Nickel shows higher metal concentration but rather low EF when compared to lead.

The scatter plot of the mean concentration of heavy metals was plotted against the EF for all the three sampling sites (Figures 5,6,7). Per usual of the result showed that Zinc is having high mean concentration but it is not getting enriched in proportion to its mean concentration. On the other hand Cadmium though having lowest mean concentration has higher rate of enrichment. Lead shows the highest mean concentration and also corresponding highest enrichment factor.

The behavior of Zinc may be attributed to its source mainly from weathering of the parent rock while that of Cadmium and Lead mainly due to anthropogenic activities. EF normally reveals the addition and or removal of metal under consideration which is a result of cumulative activity in the region. Hence the Enrichment factor should denote the total enrichment and or depletion of an element and cannot evaluate the trend for the short term accumulation.

When the mean values of EF and NSC for all the six heavy metals are studied at all the sampling stations (Figures 8, 9,10) it can be stated that Cadmium has been enriched to a quite greater extent followed by Lead, Zinc, Chromium, Copper and Nickel at all the sampling sites. On the other hand the Normalized Scatter Coefficient value indicates that Cadmium has got enriched in faster rate at industrial area followed by Zinc, Chromium, Lead, Copper and Nickel. In traffic area Lead is getting enriched in the faster rate followed by Cadmium, Chromium, Copper, Zinc and Nickel. But in residential area, the NSC value indicate that Cu is quite enriched with the faster rate followed by Chromium, Cadmium, Lead and Zinc.

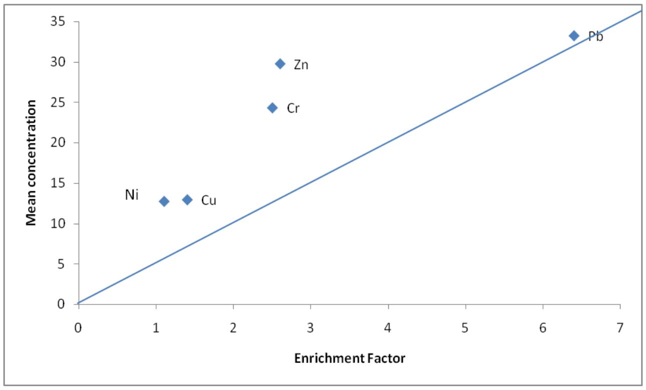

Figure 5. Industrial Area

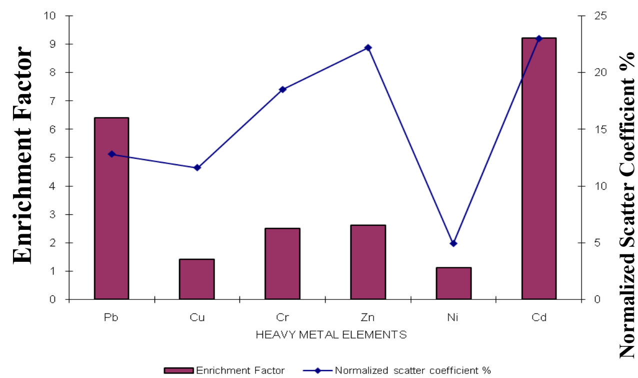

Figure 8 INDUSTRIAL AREA

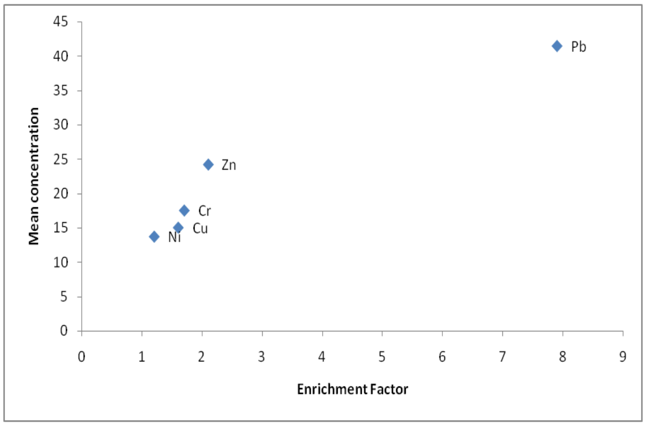

Figure 6. Traffic Area

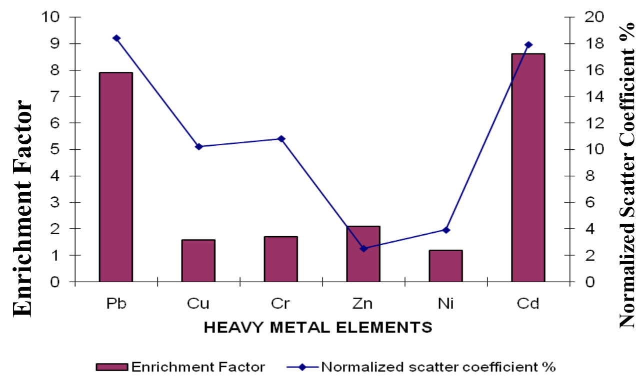

Figure 9 TRAFFIC AREA

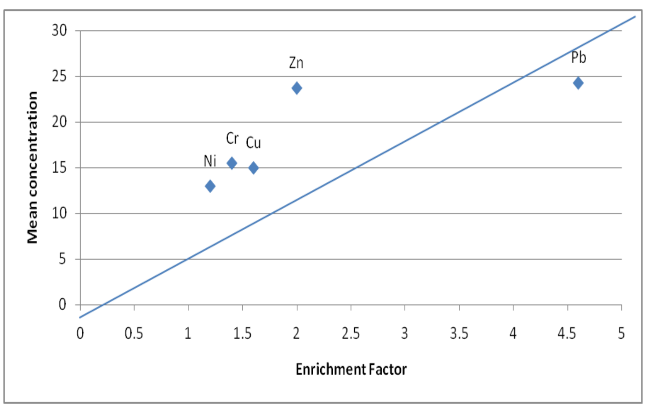

Figure 7. Residential Area

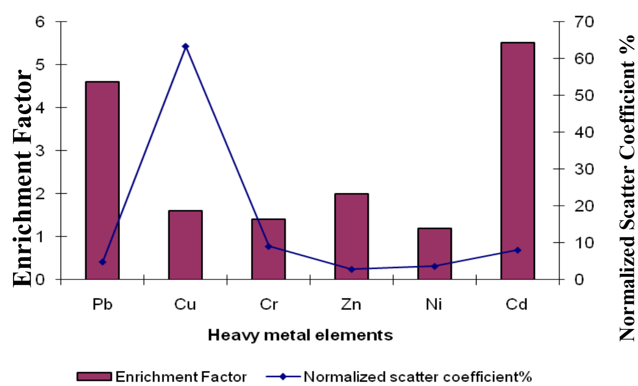

Figure 10. RESIDENTIAL AREA

CONCLUSION

The variation assessment of heavy metal pollution by using Enrichment Factor and Normalized Scatter Coefficient in the soil sample collected from the study area between May 2011-Oct 2011 has revealed significant increase in the six heavy metals (viz Pb, Cu, Cr, Zn, Ni and Cd). Enrichment Factor values shows that Cadmium has enriched to a greater extent followed by Lead, Zinc, Chromium, Copper and Nickel. Normalized Scatter Coefficient value indicate that Lead is getting accumulated in a faster rate followed by Cadmium, Chromium, Copper, Zinc and Nickel. In summary the soils in the Madurai industrial, traffic and residential area are significantly contaminated by heavy metals and hence more attention to be paid to heavy metal pollution particularly for Lead and Cadmium. In

Table 3 Normalized Scatter Coefficient (%)of the heavy metals in the soils of the study area

Industrial Area

Pb	Cu	Cr	Zn	Ni	Cd
26.1	21.9	33.8	33.8	8.6	55.4
21.1	21.1	30.9	31.7	8.1	53.2
17.8	12.0	23.6	26.7	6.6	21.3
8.9	7.8	13.0	24.3	4.7	6.7
3.4	7.6	9.8	16.8	1.9	1.4
0	0	0	0	0	0

Traffic Area

Pb	Cu	Cr	Zn	Ni	Cd
37.0	25.9	19.5	6.6	12.5	38.7
32.9	14.6	15.8	4.9	5.7	29.1
23.0	10.9	14.0	1.9	2.7	18.3
12.5	5.5	8.0	0.9	2.0	12.1
5.2	4.1	7.3	7.3	0.8	9.5
0	0	0	0	0	0

Residential Area

Pb	Cu	Cr	Zn	Ni	Cd
13.2	26.4	15.3	6.1	8.9	13.9
8.8	17.9	13.1	4.7	7.2	13.4
3.9	16.8	11.9	3.4	3.2	9.8
2.5	1.6	8.7	2.6	2.5	6.1
0.8	0.6	5.4	0.4	0.6	5.6
0	0	0	0	0	0

order to prevent heavy metal contamination in the soils from the Madurai city and to maintain the ecological balance some immediate measures as per environmental quality criteria, a need to be taken.

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