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Heavy Metal Concentrations in Road Deposited Dust at Ketu-South District, Ghana

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ABSTRACT

Increasing air pollution levels due to rapid urbanization and growth in vehicular emission have become a major source of concern. As a result, research on air pollution in urban environments has largely focused on road deposited dust. In the present study, road deposited dust samples collected from the Ketu-South District, Volta Region in Ghana were analyzed for heavy metals (As, Cr, Cu, Mn, Ni, Pb and Zn) using energy dispersive XRF. The ranges of metal concentration were: 0.4-18.2 µg/g for As; 284-9106 µg/g for Cr; 18.4-144.1 µg/g for Cu; 233-1240 µg/g for Mn; 12.3-493.2 for Ni; 3.1-67.8 µg/g for Pb; and 18.2-406.5 µg/g for Zn. The highest level of metal contamination was found in the only roadway of an industrial area (cement factory). The lowest contaminated site was noted in a roadway which runs through a host of rural communities. Inter-cities comparison with previous data established that Cr levels in the present study was very high while Pb was very low compared to other cities. Metal contamination assessment status of the metals was made using mathematical models in terms of enrichment factor, geoaccumulation index and contamination factor. All the models agreed that contamination levels is in increasing order of Mn>Ni>Cu>Pb>Zn>As>Cr.

Key words: *Roadside soil; Enrichment factor; Heavy metals; Chromium, Contamination factor; Ketu-South District.*

1. INTRODUCTION

Air pollution today is a major problem for modern societies. It has long been recognized as a potentially lethal form of pollution. Increasing pollution levels due to rapid urbanization and growth in emission related to vehicular transportation are now a cause of major concern. The mobilization of heavy metals into the biosphere by human activities has become an important process in the geochemical recycling of these metals. Pollution of the natural environment by heavy metals is a worldwide problem because these metals are indestructible and most of them have toxic effects on living organisms. While some of these elements are essential for humans, at high levels they can also mean toxicological risks [1,2].

In recent times, studies of air pollution especially in the urban environment have focused largely on road deposited dust [3,4,5,6,7,8,9,10]. The particles of dust that deposit from the atmosphere and accumulate along roadside are called road dust or road deposit dust [11]. Road dust represents complex chemical composition and originates from the interaction of solid, liquid and gaseous materials produced from different sources and activities [12,13]. It is a complex mixture of particulates and contaminants derived from an extensive range of urban and industrial sources and processes [14]. Road dust have been implicated to have the potential to carry a high loading of contaminant species such as heavy metals and organic pollutants [9; 10,15]. Road dusts are useful indicators of the level and distribution of heavy metal contamination in the surface environment. The relative ease of sampling road deposited dust has led to their increasing utilization in research in urban environmental quality in the past two decades [16,17,18].

Road deposited dust does not remain deposited for long [10]. It is easily re-suspended back into the atmosphere, where they contribute a significant amount of trace elements [11]. Dust borne heavy metals accumulate in topsoil due to atmospheric deposition by sedimentation, impaction and interception [10,19,20]. In general, influences between air and soil pollution are mutual. Just as the atmosphere can transfer a large amount of heavy metals into urban soils through precipitation [21,22], soil dust can also contribute to the concentration of heavy metals in the air [23]. Sakagami *et al* [24] in a study has confirmed the mutuality of the close relationship between heavy metal concentration in topsoils and in the dust falls. Therefore, heavy metals in street dust can generate airborne particles and dust which may affect air environmental quality.

Road dust pollution which gives rise to airborne trace metal is derived through industrial, vehicular and urban activities. Increasingly, airborne particles emitted from geologic media pose threat to human health and environment [25]. Interest on the effects of atmospheric particulates on health and environment has increased many folds over the last one decade on the basis of evidence that this type of pollution proved strong links with respiratory diseases [26]. It has also been reported that metal absorbed on ambient air suspended particulate produces tissue damage of the lungs [27]. The health effects of toxic metals in air and dust from road deposited dust on humans is better appreciated if one consider the fact that an active person typically inhales 10,000L to 20,000 L of air daily [28]. Derek [29] has emphasized that this intake increases with vigorous exercise. During inhalation and exhalation, these pollutants can inflame, sensitize and even scar the lungs and tissue. The pollutants may enter the numerous tiny air sacs deep inside the lungs and also blood stream thereby affecting several other organs than lungs [28].

Apart from direct health problem on man, adverse effect of airborne dust from road soil pollutants is the capability to contaminate foodstuffs sold in road side shops and markets hence may also carry viral diseases. In particular, the ingestion of dust and soil have been widely regarded as one of the pathways by which children are exposed to heavy metals and metalloids from leaded gasoline, vehicles and local industry [30,31]. Furthermore, in some instance road dust may act as pollution source especially when storm water run-off remove large part of the road soil and its associated metals causing a pollution threat to the surface water resources [32].

In view of the increasing evidence of the adverse effects of road deposited dust on the human health and environment, not much data on road dust, one of the major pre-requisite for health studies, is available for major cities and districts in Ghana, although a large population live in those places. Information regarding road dust quality of the Ketu South District of the Volta Region of Ghana, which is currently experiencing massive road construction infrastructure, is not available. In the present study, an attempt has been made to generate and evaluate levels of trace heavy metals, As, Cu, Cr, Pb, Mn, Ni and Zn in road deposited dust in the Ketu South District. The study would form the basis of establishing baseline data regarding heavy metals in road dust of the district. The study is also important in that it can be used as basis for planning management strategy to achieve better environmental quality and substantial development of the district.

2. EXPERIMENTAL

2.1 The Study Area

The study area, Ketu South District, is located at the south eastern corner of Ghana in the Volta Region (Fig. 1). The district averagely situated 41m above sea level has a total land size of about 400 km^2. The district experiences the dry equatorial type of climate in which the average monthly temperature vary between 24°C to 30°C. The rainfall is double maxima type occurring from April to July and September to October. The mean annual rainfall for the district is 850mm at the coast increasing to 1000mm inland. The dry season which is dominated by the dry harmattan winds, extends from December to February.

The original vegetation of the district is coastal savanna woodland made-up of short grassland with small clumps of bush and trees found mainly in the northern part of the district. To the south are coastal shrub, grassland and mangrove forest in the marshland. The investigated area is underlain by three main formations mainly of the Dahomayan formation of the Precambrian age to the north made-up of soils such as tropical grey and black earth, the regosolic groundwater literates, the recent deposits of the littoral consisting of marine sands and the tertiary formation comprising savannah ochrosols for its soil types.

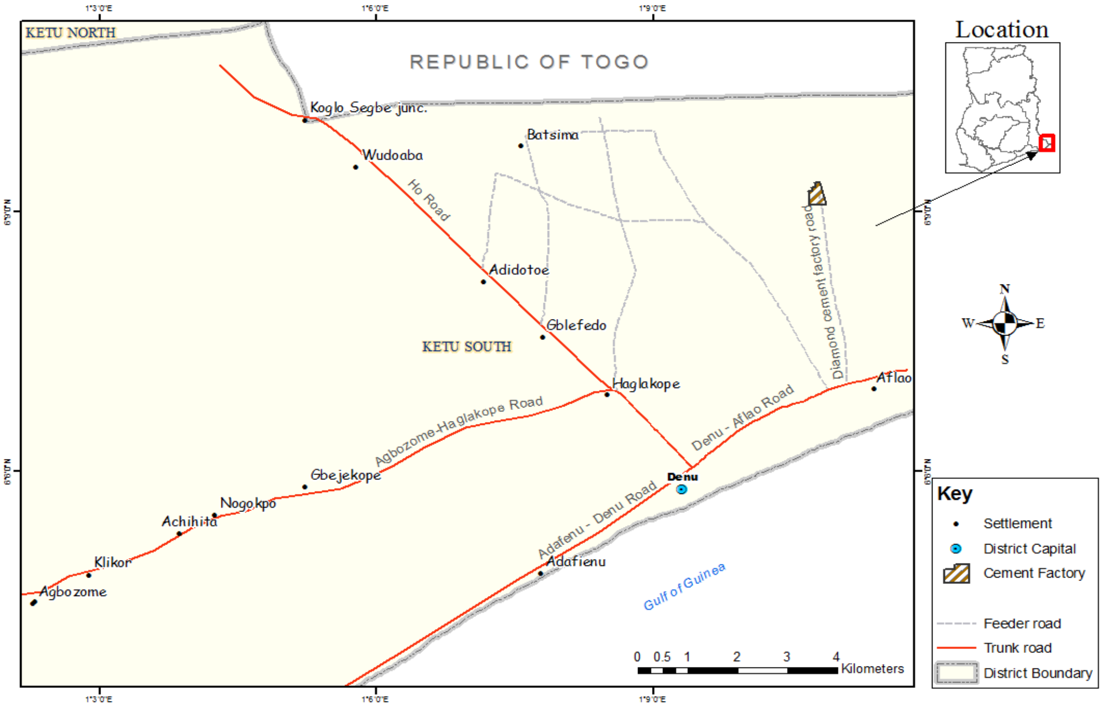

Figure 1. Map showing the important roads of the investigated area.

The investigated area is an important district as it shares a boundary with the republic of Togo. The Aflao boarder (a town which links Ghana into Togo) is a place of high commercial activities. This make the district experienced high traffic density comparatively. The West African truck highway from Cote I'voire through Ghana, Togo, and Benin ending up in Nigeria passes through the district. Six important roadways in the Ketu-South District were selected for road soil collection. The roadways were selected on the basis of traffic load, population density and anthropogenic activities.

2.2 Sample Collection and Analysis

Fifty sampling sites were selected in the Ketu South District of the Volta Region for road dust sample collection. The samples were collected from popular roads that experiences intense traffic conditions within the district. At every sampling location, dust composite sample was collected by sweeping using polyethylene brush and tray from four to six points of road edges during the dry season in March, 2011. Along the roadways, sites with obvious pollution sources such as a factory, filling stations, car parking points, fitting shops, soiled or oil stained samples were avoided. The samples were also collected within two consecutive days such as to minimize temporal changes. At the sampling sites, a Geographical Positioning System was employed to record the geographical position. The entire collected road deposited dust samples were stored in labeled plastic containers and then transported into the laboratory of the Ghana Research Reactor-1 Center (GHARR-1), Ghana Atomic Energy Commission (GAEC).

The samples were air-dried in the laboratory for 10 days and then screened through a 250 µm mesh nylon sieve by the aid of a sieve shaker for two minutes to remove small stones and oversized residue which were not needed for the analysis. The sieve and container were cleaned thoroughly to prevent contamination of the subsequent sample to be sieved; the process underwent repetitions until all the samples were sieved. The samples were further screened in 125 µm mesh sieve after grinding in pulverizer to obtain smaller grain-sized sand particles before they were subjected to X-ray Fluorescence (XRF) analysis.

Before the XRF analysis, 4g of the milled dust samples were made into pellets after which 0.9g of Hoechst wax was added and grinded in a sample cup and fitted into a manual press to obtain a homogeneous mixture. Consequently, the concentration of As, Cr, Cu, Mn, Ni, Pb, Fe and Zn in the road dust samples were directly measured by XRF. Meanwhile, a series of soil and sediment Standard Reference Materials (SRM) were used to calibrate the XRF system. The standards used were: Soil 7 SRM and Soil 3 SRM, all of the International Atomic Energy Commission (IAEA), and Estuarine Sediment SRM of the National Institute of Standards and Technology (NIST). To validate the instrumentation, the mean concentration of the elements obtained from the standard used was compared with the certified values by calculating the ratio of experimental values to certified reference values. The results gave ratios between 6 and 8% indicating that the results of the XRF work were in good agreement with the certified values.

2.3 Contamination Assessment Methods of the Roadside Dust

The assessment of soil or sediment enrichment can be carried out in many ways. The most common ones are the index of geoaccumulation and enrichment factors [10]. In this work, the index of geoaccumulation (I_{geo}), Enrichment Factor (EF), Contamination Factor (CF) and Pollution Load Index (PLI) have been applied to assess heavy metals (As, Cr, Cu, Mn, Ni, Pb and Zn) distribution and contamination in the road dust samples of the various categories of roads in the Ketu-South District.

The index of geoaccumulation index (I_{geo}) was originally used with bottom sediment by Muller [33]. It is computed by the following equation:

$$I_{geo}=\log_2\left[\frac{C_n}{1.5B_n}\right]$$

Where, C_n is the measured concentration of the element in the tested sediment (road dust) and B_n is the geochemical background value of the element in fossil argillaceous sediment (continental crusted average or average shale). The constant 1.5 is introduced to minimize the effect of possible variations in the background values which may be attributed to lithologic variations in the sediments [10]. Lu *et al* [10] gave the following interpretation for the geoaccumulation index: $I_{geo} < 0$ = practically unpolluted; $0 < I_{geo} < 1$ = unpolluted to moderated polluted; $1 < I_{geo} < 2$ = moderately polluted, $2 < I_{geo} < 3$ = moderately to strongly polluted;$3 < I_{geo} < 4$=strongly polluted;$4 < I_{geo} < 5$= strongly to extremely polluted; and $I_{geo} > 5$ = extremely polluted.

2.4 Enrichment Factor

Enrichment factor (EF) has been employed for the assessment of contamination in various environmental media by several researchers [10,34,35,36]. Its version adapted to assess the contamination of various environmental media is as follows:

$$EF=\frac{[C_x/C_{ref}]_{Sample}}{[B_x/B_{ref}]_{Background}}$$

Where:

C_x = content of the examined element in the examined environment;

C_{ref} = content of the examined element in the reference environment;
B_x = content of the reference element in the examined environment; and
B_{ref}= content of the reference element in the reference environment;

An element is regarded as a reference element if it is of low occurrence variability and is present in the element in trace amounts. It is also possible to apply an element of geochemical nature whose substantial amounts occur in the environment but has no characteristic effects i.e. synergism or antagonism towards an examined element.

Five contamination categories are recognized on the basis of the enrichment factor: EF < 2 states deficiency to minimal enrichment; EF = 2-5 moderate enrichment; EF = 5-20 severe enrichment; EF = 20-40 very high enrichment; and EF > 40 extremely high enrichment [34]. Despite certain short comings [37], the enrichment factor, due to its universal formula, is relatively simple and easy tool for assessing enrichment degree and comparing the contamination of different environment.

2.5 Contamination Factor and Pollution Load Index

To assess the extent of contamination of heavy metals in road dust and also provide a measure of the degree of overall contamination along a particular road, contamination factor and pollution load index has been applied [38]. The contamination Factor (CF) parameter is expressed as:

$$CF = C_{metal} / C_{background}$$

Where CF is the contamination factor, C_{metal} is the concentration of pollutant in sediment $C_{background}$ is the background value for the metal and n is the number of metals. The CF reflects the metal enrichment in the sediment. The geochemical background values in continental crust averages of the trace metals under consideration reported by Taylor and McLennan [39] was used as background values for the metal. The CF was classified into four groups [40.41]. Where the contamination factor CF < 1 refers to low contamination; 1 ≤ CF < 3 means moderate contamination; 3 ≤ CF ≤ 6 indicates considerable contamination and CF > 6 indicates very high contamination.

Each roadway site was evaluated for the extent of metal pollution by employing the method based on the pollution load index (PLI) developed by Thomilson *et al.* [42], as follows:

$$PLI = {}^{n}\sqrt{} (CF_1 \times CF_2 \times CF_3 \times .... CF_n)$$

where *n* is the number of metals studied (seven in this study) and *CF* is the contamination factor calculated as described in an earlier equation. The PLI provides simple but comparative means for assessing a site quality, where a value of PLI < 1 denote perfection; PLI = 1 present that only baseline levels of pollutants are present and PLI >1 would indicate deterioration of site quality [42].

3. RESULTS AND DISCUSSION

3.1 Heavy Metals in the Roadside Dust

Table 1 summarizes the minimum, maximum, mean and median concentrations of a number of metals (As, Cr, Cu, Mn, Ni, Pb and Zn) in fifty road dust samples collected along the important streets of the Ketu-South District of the Volta Region of Ghana. All the metals under the current study were found present in all the samples collected for analysis. A close look at Table 1 shows that the variability in the range of all the metal distributions as compared with their means respectively is an indication of pollution of the sample with that metal ion. The decreasing trend of averages of metal levels was as follows: Cr > Mn > Zn > Ni > Cu > Pb > As.

Table 1. Basic statistical parameters for the distribution of selected heavy metals (µg/g) in road soils from the study area.

Heavy Metal	Minimum	Maximum	Mean	Medium	Std. Dev.
As	0.40	18.20	8.06	7.20	3.94
Cr	284.0	9106.0	744.02	480.50	1244.7
Cu	18.40	144.10	60.53	58.90	21.16
Fe (%)	0.54	19.92	10.57	8.99	4.86
Mn	233.0	1240.0	564.42	54.30	190.51
Ni	12.30	492.30	73.45	58.30	71.04
Pb	3.10	67.80	22.89	21.00	11.21
Zn	18.20	406.50	133.52	116.60	75.62

For the purpose of discussing the metal distribution, the road distribution within the district was categorized as follows: Diamond Cement road (DC); Denu-Aflao road (DA); Market-District Hospital road (MH); Adafienu-Denu road (AD); Agbozome-Heglakope road (AH); and Heglakope-Ho road (HH). Table 2 summarizes the distribution of heavy metals among individual roadways of the study area. It is of interest to note that, minimum concentration values of all the metals have been found along the A-H road which experience the less traffic density. Apart from the less soil pollution from vehicular emissions, the H-H roadways run through a host of rural communities and therefore roadside dust contamination from other anthropogenic inputs could be minimal. The maximum concentration of Cr (9106.0 µg/g), Mn (1240.0 µg/g), and Pb (67.80 µg/g) were found in road soil samples collected from the D-C roadway normally patronized by heavy trucks used in conveying cement products and raw materials to and from the cement factory. Therefore, much cement dusts are spread along the road as loaded cement trucks made use of the road. These metals have been implicated as important pollutants in cement dust [43,44,45].

Table 2. Heavy metal concentration (µg/g) in the road soils of various road soils in the ketu-South district of the Volta Region.

Roadways	Statistical parameters	Concentration of heavy metals (µg/g)							
		As	Cr	Cu	Fe (%)	Mn	Ni	Pb	Zn
(DC)	Min	5.2	359.0	53.4	8.02	465.0	32.2	16.20	103.5
	Max	16.7	9106.0	92.2	17.71	1240.0	161.8	69.80	182.2
	Mean	9.67	1486.72	72.08	12.62	732.56	69.56	25.06	142.23
	Median	9.70	564.0	75.80	12.64	620.0	59.0	20.30	139.30
(DA)	Min	2.1	287.0	42.80	2.59	388.0	30.1	14.3	62.2
	Max	**18.2**	1934.0	98.90	19.37	698.0	492.3	57.00	272.5
	Mean	9.62	586.62	62.40	9.95	530.77	95.15	27.46	154.41
	Median	7.7	476.0	61.10	8.44	465.0	63.7	23.10	141.4
(MH)	Min	3.5	286.0	33.60	4.65	388.0	39.9	10.3	97.70
	Max	12.6	1172.0	69.20	14.77	620.0	257.7	33.6	216.5
	Mean	7.16	571.8	50.86	9.05	527.2	103.52	21.82	132.38
	Median	6.4	338.0	45.90	9.52	534.0	72.30	22.6	108.20
(AD)	Min	5.80	288.0	42.3	6.54	388.0	43.2	13.3	18.2
	Max	16.30	1229.0	144.10	19.38	698.0	104.60	38.60	262.20
	Mean	8.77	598.11	70.37	9.27	551.33	67.49	23.17	148.51
	Median	7,80	436.0	54.50	8.44	620.0	69.1	20.10	126.90
(AH)	Min	0.40	284.0	18.40	0.54	233.0	12.30	3.10	48.90
	Max	10.20	1016.0	78.70	19.92	1008.0	58.60	24.30	93.00
	Mean	5.62	555.67	46.69	11.56	517.0	47.06	15.97	65.10
	Median	5.10	485.0	49.00	13.73	388.0	49.10	14.30	58.60
(HH)	Min	3.50	431.0	33.10	5.38	465.0	37.90	13.60	45.10
	Max	7.20	881.0	71.10	17.53	620.0	61.60	32.00	406.50
	Mean	5.10	591.20	51.72	10.54	511.60	52.26	20.14	160.86
	Median	4.80	518.0	48.90	7.78	465.0	54.30	19.80	59.70

Lu *et al* [10] has also indicated in a study that the source of these metals in road soil may originate from industrial activities and automotive emissions. The maximum of As and Ni which were 18.2 and 492 µg/g respectively was recorded for Denu-Adafienu road soil samples which also experiences considerable traffic load. The source of Cu and Zn in the samples was indicated by research as tyre abrasion, the corrosion of metallic parts of cars, lubricant and industrial [46,47]. The maximum of these two metals at concentrations levels of 144.1 µg/g for Cu and 406.5 µg/g for Zn were analyzed for Adafienu-Denu and Heglakope-Ho roads respectively.

There is no information available on typical background values for Ghanaian soils for heavy metal concentrations in urban soils; therefore these data were compared with available background values of world's surface rock averages reported by Chakravarty and Patgiri [48] for Cr, Cu, Mn, Ni, Pb and Zn; and previous study reported by Loska *et al* [34] for As. The mean concentrations of Cr, Cu and Ni of the present study are higher than background values of 97, 32 and 49 µg/g respectively, while Mn is the only metal lower than background value of 720 µg/g. However, the concentration levels of As, Pb and Zn in the road soil samples are comparable to their background.

Most research reports on roadside soil in urban environments usually compare mean concentrations of heavy metals in street dust samples with different urban environments [10,49,50]. There are no universally accepted sampling and analytical procedures for these geochemical studies of these urban deposits regarding those comparisons [10]. Table 3 depicts concentrations of heavy metals measured in roadside dust of ketu-South District compared with available data reported for some cities. A close observation at Table 3 specified that metals like Cu, Ni, Pb and Zn have gained more prominence in roadside dust studies as against others like As, Cr and Mn. For instance, As has been completely absent in the reported data available for the comparison.

Table 3. Comparison of heavy metal concentration in street dust from some popular cities of the world with data from the Ketu-South District.

City	As	Cr	Cu	Mn	Ni	Pb	Zn	Reference
Calcutta	-	54.0	44.0	-	42.0	536.0	159.0	Chatterjjee and Banerjee [51]
Islamabad	-	-	52.0	-	23.0	104.0	116.0	Faiz *et al* [11]
N. Zealand	-	103.0	90.8	-	-	1223.0	716.0	Fergusson *et al* [52]
Amman	-	-	177.0	-	88.0	236.0	358.0	Al-Khashman [15]
Dhaka	-	-	304.0	-	54.0	205.0	169.0	Ahmed and Ishiga [8]
Oslo	-	-	123	830	41.0	180	412.0	De Miguel *et al* [3]
Ottawa	-	-	65.8	431.5	15.2	39.1	112.5	Rasmussen *et al* [53]
Hong Kong	-	-	110.0	594.0	28.6	120.0	3840.0	Yeung *et al* [54]
Shanghai	-	159.3	196.8	-	83.9	294.9	733.8	Shi *et al* [55]
Luanda	-	26.0	42.0	-	10.0	315.0	317.0	Ordóñez *et al.*, [56]
Ketu-south District	8.06	744.02	60.53	564.42	73.45	22.89	133.52	This work

Chromium concentration in the roadside dust samples in the present study ranged from 284 to 9106 µg/g with a mean of 744.02 µg/g was higher than other levels report in Table 3. On the other hand, the mean concentration of Pb for the street dust samples was lower than those reported from other literature such as: 236 µg/g for Amman; 294.9 µg/g for Shanghai; and 315 µg/g for Luanda. The Manganese levels found in the present study is similar to Hong Kong, while higher than Ottawa and lower that the reported value for Oslo.

The mean level of Ni in the street dust sampled from the Ketu-South District (this work) is similar to those sampled in Amman and Shanghai, higher than those in Calcutta, Islamabad, Dhada, Oslo, Ottawa and Luanda. Nickel pollution in street dust is caused by emission from vehicle engines that used nickel gasoline and by abrasion and corrosion from vehicle parts [57]. Zinc concentration ranged from 18.2 to 406.5 µg/g with a mean of 133.52 µg/g was much lower compared with previous studies in several cities except for Islamabad and Ottawa. The maximum acceptable limit for Zn in normal soil is 300 µg/g. With the exception of the Diamond Cement Factory, no industries of potential industrial significance exist in the study area. The major industrial source for Zn is smelting, therefore zinc used as a vulcanization agent in tires was most likely source [58], resulting from attrition of motor vehicle tire rubber exacerbated by poor road surfaces.

The source of Cu in street dust was indicated by research as being due to corrosion of metallic parts of cars derived from engine wear, thrust bearing, brushing and bearing metals [59]. The levels of Cu in the samples were generally lower than most of worldwide values as reported for Amman, Dhaka, Oslo, Hong Kong and Shanghai.

However, the study indicated that the present level was similar to Ottawa and higher than previous values obtained for Calcutta, Islamabad and Luanda. From the inter-worldwide city comparisons of street dust studies, it can be inferred that each urban environment has its own characteristics combination of heavy metal levels and that has resulted in some similarities as well as in variations. Duzgoren *et al* [18] have observed that these discrepancies of heavy metal levels among different urban environments may not reflect actual natural and anthropogenic diversities among the different urban settings. Therefore, Duzgoren *et al* [18] suggested an immediate need to established standard procedures to represent and analyzed urban samples.

Inter-elemental association by Pearson Correlation Co-efficient, r, and the results for the study area are presented in Table 4. The correlation measures the strength of a linear relationship between any two variables on the scale of -1 (perfect inverse relation) through zero (0) to +1 (perfect sympathetic relation). The inter-elemental relationship showed positive correlation between the given studied metals with the exception of Ni with Cr and Mn.

Table 4. The correlation constant, r, between concentrations of the heavy metal in Kuala road side dust of the study area.

	As	Cr	Cu	Mn	Ni	Pb	Zn
As	1						
Cr	0.51	1					
Cu	0.88*	0.58	1				
Mn	0.60	0.99**	0.67	1			
Ni	0.53	-0.06	0.45	-0.07	1		
Pb	0.88*	0.37	0.78	0.42	0.65	1	
Zn	0.41	0.15	0.56	0.16	0.38	0.74	1

* Correlation is significant at the 0.05 level (2-tailed)
**Correlation is significant at the 0.05 level (2-tailed)

Table 4 indicated that some elemental pairs for example, As/Cu (r=0.88), Cr/Mn (r=0.99), Pb/Cu (r=0.78), Zn/Pb (r=0.74) etc., have strong correlation with each other. On the other hand, pairs such as Ni/Cu (r=0.45), Mn/Pb (0.42) and Zn/Ni (r=0.38) have moderate relationships. Table 4 indicates that the elemental pair Mn/Cr significantly shows strong correlation (r=0.99, P<0.01). On the other hand the pairs of As/Pb and As/Cu are significant at 95% confidence level whereas the other elemental pairs shows no significant correlation with each other. The results indicated that road side dust contamination by the metals originated from a common anthropogenic source. The study area with the exception of the Diamond Cement factory has no heavy or major industrial development, it can be assumed that the heavy metals analyzed in the street dust was derived almost exclusively from automobiles and local industries.

3.2 Contamination assessment Results of Roadside Dust Samples

The contamination levels of heavy metals in the street dust samples of the Ketu-South district are assessed by using enrichment factor, geoaccumulation index, contamination factor and pollution load index. These methods have been widely employed in trace metal studies over the past decades [33,42,46,52].

The enrichment factor (EF) of heavy metals under the current study was computed for each element for each roadway soil samples relative to the background value of the element in continental crust average value of the element. The enrichment factor of As, Cr, Cu, Mn, Ni, Pb and Zn is in the range of 1.51-3.01, 2.71-6.63, 0.41-0.78, 0.27-0.35, 0.31-0.86, 0.62-1.25 and 0.45-1.25 with the average of 2.31, 3.84, 0.58, 0.32, 0.54, 0.98 and 1.05 respectively (Table 4). Table 4 illustrated the mean EFs increase in the order Mn>Ni>Cu>Pb>Zn>As>Cr. Basically, as the EF values increase the contribution of anthropogenic origins also increase [60]. According to Zhang and Liu [61], the EF value between 0.5-1.5 indicate the metal is entirely from crusted material or natural processes, whereas EF greater than 1.5 suggest the source is more likely to be anthropogenic.

Table 5. Enrichment Factor of heavy metals in roadside soils in the Ketu-South District

Roadway/ Metal	As	Cr	Cu	Mn	Ni	Pb	Zn
DC	2.4	6.63	0.59	0.34	0.42	0.89	0.91
DA	3.01	3.32	0.64	0.31	0.72	1.25	1.25
MH	2.48	3.56	0.58	0.35	0.86	1.09	1.18
AD	2.96	3.63	0.78	0.35	0.55	1.13	1.29
AH	1.52	2.71	0.41	0.27	0.31	0.62	0.45
HH	1.51	3.16	0.5	0.29	0.37	0.86	1.23
Mean	**2.31**	**3.84**	**0.58**	**0.32**	**0.54**	**0.97**	**1.05**

The mean EF calculation results indicated that As (EF=2.31) and Cr (EF=3.84) were in the category of

moderate enrichment. Thus, from the calculations, it showed that As and Cr were moderately enriched, which is providing additional support to the As and Cr level in the roadway soils of the Ketu-South District due to human related activities. However, Mn, Cu, Mn, Ni, Pb and Zn EF values were in deficient to minimal enrichment. It is therefore important to highlight a fact that all the roadway sample soils exhibited minimal enrichment which can be ascribed to natural processes.

Table 6. Contamination Factor of heavy metals in roadside soils in the Ketu-South District

Roadway	As	Cr	Cu	Mn	Ni	Pb	Zn
DC	5.37	14.87	1.31	0.77	0.93	2.01	2.03
DA	5.34	5.87	1.14	0.56	1.27	2.20	2.21
MH	3.98	5.72	0.92	0.56	1.38	0.94	0.89
AD	4.87	5.98	1.28	0.58	0.90	1.85	2.12
AH	3.12	5.56	0.85	0.54	0.63	1.28	0.93
HH	2.83	5.91	0.94	0.54	0.7	1.61	2.30
Mean	4.25	7.31	1.07	0.59	0.96	1.65	1.75

The contamination Factor (CF) for each heavy metal at each roadway was calculated according to the equation previously described and presented in Table 6. The first glance of the means of the elements in Table 6 indicated that Mn and Ni were in the low contamination category and these low contamination status of the soil samples occurred throughout the study area with the exception of the DA and MH roadways where Ni was moderately contaminated. Using the CF categories previously described, all the roadways suffered considerable enrichment for Cr with the exception DC roadway in which the contamination earned a very high contamination status. Generally, all the roadways suffered considerable contamination with As with the exception of the HH roadway where the contamination was of a moderate status. Meanwhile, Cu, Pb and Zn exhibited moderate status at the study area with few exceptions where the contaminations were of low categories for Cu at (MH, AH and HH), Pb at (MH) and Zn at (MH and AH).

To effectively compare whether the six roadways suffer contamination or not, the Pollution Load Index (PLI) described earlier was applied. The PLI is aimed at providing a measure of the degree of the overall contamination at the sampling sites along the various roadways. Figure 2 shows results of the PLI for the seven metals studied at the various roadways.

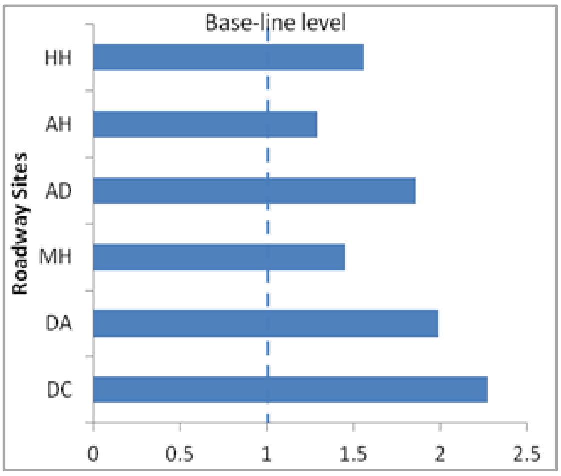

Figure 2. Pollution load index for the various roadways

Based on the results presented in Figure 2, the overall degree of contamination is of the order DC>DA>AD>HH>MH>AH. DC and DA show strong signs of pollution or deterioration of site quality, whereas AH exhibited signs of less pollution comparatively. Relatively, high PLI values at DC and DA and to some extent AD suggest input from anthropogenic sources attributed to human activities and/or vehicular emissions. Roadways AD and DA runs through a number of commercial centers and townships having high population. On the otherhand, DC roadway is strictly patronized by heavy trucks which convey cement materials and products to and from the Diamond Cement factory. Cement material and products are associated with heavy metals [44,62,63] and hence may increase roadside soils with metal pollutants. AH is less polluted for reasons which may be attributed to the relatively less traffic load and also portions of the road is untarred and therefore pollutant contributions coming from the tarred materials to pollute the side soil samples would be minimal.

Meanwhile, it is important to note that in similar studies regarding road side dust or urban surface soils where enrichment indexes have been used for heavy metal contamination assessment, Pb has been mostly rated as a very high contaminant compared to other metals [10,4164,65,66]. Chen *et al* [23] attributed this high Pb contamination to the emission of Pb from automobile exhaust and its deposition near highways and roads which has been reported worldwide. All results from previous studies in this respect pointed out by the current study support Pb emission from gasoline combustion as an important input to soils, especially road side soils. However, the application of the various contamination indexes did not confirmed Pb as a highly contaminated metal compared to others under the current work. Atiemo *et al* [67] revelation that leaded gasoline use in Ghana has supported the present findings in which lead is deficiently enriched in the road soil samples. Consequently, the appreciable concentration obtained in the study confirmed Pb as a stable isotope, hence it is likely to take considerable length of time before appreciable depletion of the element may occur in road side soils of the study area. However, the contributions from other sources like car tire, brake dust and other vehicular abrasions [68] to existing levels of Pb in road dust is undeniable.

4. CONCLUSION

The concentration of heavy metals As, Cr, Cu, Mn, Ni, Pb and Zn and their contamination level in street dust collected in the Ketu-South District in the Volta Region of Ghana have been studied in this work. Four contamination indexes namely, enrichment factor (EF), geo-accumulation index (I_{geo}), contamination factor (CF) and Pollution Load Index (PLI) were used in the assessment of level of metal contamination in the study area. The results of all the contamination indexes used agreed well in explaining the contaminated levels and possible sources of the metals present in the road soil dust samples. For instance, EF proved to be an effective tool in differentiating a natural origin from anthropogenic source of contamination for the various elements investigated under the study. The mean value of the EFs (Table 4) places the elements in an increasing order as Mn>Ni>Cu>Pb>Zn>As>Cr. The mean I_{geo} and CF (Table 5 and 6) provided the same trend of contamination levels as in the case of the EF. This is an indication that the analytical results of heavy metals are the same for all the three indexes of contamination (EF, I_{geo} and CF).

The concentrations of heavy metals in this work are compared with reported values from other cities. The results indicated that Cr is highly concentrated in the study area as compared with the other cities. On the other hand Pb concentration was found to be too low compared to other reported data in the study. The very low level for Pb in the present study was attributed to the fact that leaded gasoline which is an important input of Pb pollution in urban soil has been banned in Ghana. The inter-city comparison analysis also revealed that As contamination studies in road dust is virtually scanty. The study found that arsenic contamination is very significant in the dust samples therefore the current study suggest that researchers should give it much attention in their future investigations.

In conclusion, data obtained for the study demonstrated that the distribution of metal concentration in the study area has come about as a result of anthropogenic influences, in particular the cement factory and vehicular emissions. This situation has resulted from the highest metal concentrations which were located along roads of the cement factory and commercial areas between Denu and Aflao.

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