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Heavy Metals Concentration in Road Dust in the Bolgatanga Municipality, Ghana

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Abstract The study was conducted to assess the level of contamination of surface dust from roads in the Bolgatanga Municipality. Dust samples were collected from the major Trans-ECOWAS roads and less busy road in the municipality and was determined using the Atomic Absorption Spectrometer at Atomic Energy Laboratory, Accra. The mathematical models; Index of Geoaccumulation (Igeo), Enrichment Factors (EF), Pollution Load Index, Contamination Factor and Degree of Contamination were employed to identify possible levels of pollution from human activities. The Index of geoaccumulation gave values in the range of unpolluted indicating insignificant accumulation of heavy metals from anthropogenic sources. The analysis of variance shows that chromium (Cr), mercury (Hg), cobalt (Co), cadmium (Cd) and zinc (Zn) concentration levels were highly significant in road dust collected from zone A, B, C and D. Some elemental pairs such as Fe/Cr (0.72), Ni/Co (0.64), Cd/Mn (0.81), Fe/Mn (0.70), Fe/Co (0.71), and Ni/Cd (0.81) have strong correlation at 5% significant level. The source of Cd/ Ni, Cd/Mn, Cd/Cr and Co/Cd in the road dust might be accumulated from wear-and-tear of tyres, combustion of fuel and oil/lubricants, which are known to contain trace levels of cadmium. There should be periodic monitoring by Environmental Protection Agency since heavy traffic condition can contribute to high levels of heavy metals in the road dust.

Keywords: *road dust, enrichment factor, heavy metals, variance analysis, Bolgatanga Metropolis*

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1. Introduction

The dramatic increase in public awareness and concern about the state of the global and local environments which has occurred in recent decades has been accompanied and partly prompted by an ever growing body of evidence on the extent to which pollution has caused severe environmental degradation. The introduction of harmful substances into the environment has been shown to have many adverse effects on human health, agricultural productivity and natural ecosystems [1]. Urban soils act as a sink for heavy metals and other pollutants, possible sources of which are mainly from anthropogenic activities such as vehicular emissions [2], waste waters ludges and industrial wastes [3]. Uncontrolled development and urbanization has also resulted in accelerating input of heavy metals in urban soils. In the last few decades, anthropogenic activities like industrial and energy production, construction, waste disposal, domestic heating system and motor vehicles are continuously contributing towards an increase in the level of heavy metals in urban soils [4]. Roads are important infrastructure that plays a major role in stimulating social and economic activities. However, road construction has also resulted in heavy environmental pollution [5]. Several researchers have indicated the need for a better understanding of trace metal pollution of roadside soils [6,7].

Heavy metals are natural constituents of the Earth's crust. Human activities have drastically altered the balance and biochemical and geochemical cycles of some heavy metals. Therefore, the concentration of heavy metals in Soils has been an issue of great interest in the past few years not only to ecologists, biologists and farmers but also environmentalists. An assessment of the environmental risk due to soil pollution is of particular importance for agricultural and non-agricultural areas, because heavy metals, which are potentially harmful to human health, persist in soils for a very long time. In addition and according to soil parameters they may enter the food chain in significantly elevated amounts [8]. Heavy metals may chemically or physically interact with the natural compounds, which change their forms of existence in the environment. In general they may react with particular species, change oxidation states and precipitate [9]. The properties of heavy metals in urban soils, urban road dusts and agricultural soils are still topical. This fact can be well documented in enhancing the count of article in recent years [10].

The enhancement is probably attributed to the potential public health risk associated with intake of heavy metals.

In urban area, heavy metals in urban soils and urban road dusts can be accumulated in human body via directly inhalation, ingestion and dermal contact absorption [11]. In general many soils contain a wide range of heavy metals with varying concentration range depending on the surrounding geological environment and anthropogenic and natural activities occurring or once occurred. These metals can be Fe, Cr, Mn, Ni, Zn, Cu, Pb, Cd, Hg, among others [9]. According to some studies, the pollution sources of heavy metals in environment are mainly derived from anthropogenic sources. [12,13] reported that, human activities which result in heavy metal deposit in urban soil or urban road dusts 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, among others), domestic emission, weathering of building and pavement surface, atmospheric deposited among others. The health effects of toxic metals in air and dust from road deposited dust on humans is better appreciated if one considers the fact that an active person typically inhales 10,000 L to 20,000 L of air daily [14].

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 [15]. The Bolgatanga municipality lies along the ECOWAS International Highway. Most heavy duty vehicles that run on diesel or petrol use road networks in the metropolis so as to be able to reach land-locked countries such as Burkina Faso, Togo and the Tamale Metropolis. Although, most developing countries have no long histories of industrialization and extensive use of leaded gasoline yet there is a need for concern on the concentration of heavy metals in road dust. This study was to assess the heavy metal concentrations in road dust of major roads in the Bolgatanga Municipality.

2. Materials and Methods

2.1. Study Area

The Bolgatanga Municipality is one of the nine (9) districts in the Upper East Region of Ghana. Bolgatanga is the capital town of the Upper East Region. The climate is tropical with a rainy season from May to October and a long dry season with virtually no rainfall from October to April. Temperatures range between a maximum of 45 degrees in March / April and at least 12°C in December.

2.2. Sample Collection and Preparation

Samples were collected during the dry season (2012) from high traffic zone thus the trans ECOWAS road (labeled, Bolgatanga-Tamale (A), Bolgatanga-Navrongo (B); Bolgatanga-Togo (C) and low traffic zone (D) in Bolgatanga Municipality. At each sampling point about 2 kg of the road side soil were collected at surface level (0 - 10 cm in depth) at a distance of one metre away from the road and within an area of one square metre. A soil control sample at each point was also collected from a site about 500 m away from the sampling point bearing in mind that the distance from the road would make them to be less exposed to the pollutants. Two samples were collected at each point, thoroughly mixed in a clean plastic container to obtain a representative simple, crushed and sieved with 2 mm mesh before stored in labeled polythene bags and conveyed to the laboratory for analysis.

2.3. Digestion of Road Dust Samples and Analysis

Determination of heavy metals was done in according to protocols at National Nuclear Research Institute of the Ghana Atomic Energy Commission. The road dust collected were air dried to constant weight and then sieved. Sample of 0.5 g was weighed into a tuff in bucket and 6 ml H_2NO_3 acid, 3 ml HCl with 5 drops of H_2O_2 added to the samples on a hot plate (This step was carried out in the hood). The tuff in buckets was tightened and fix them in the rotar. The rotar was placed in the microwave oven and programme the machine to commence the digestion process. Each sample had its own programme. The digested samples were diluted to 20 mL and transfer into the appropriate test tube. The concentrations of trace metals such as Cr, Hg, Cu, Zn, Mn, Fe, Pb, Ni, As, Co and Cd in the filtrate were determined using Atomic Absorption Spectrometer.

2.4. Assessment of Trace Metal Contamination

2.4.1. Contamination Factor

To assess the extent of contamination of heavy metals in road dust, contamination factor and degree of Contamination has been used [16].

The C^if is the single element index which is determined by the relation:

$$C^i f = \frac{C^i_{o-1}}{C^i_n} \tag{1}$$

Where C^if is the contamination factor of the element of interest, C^i_{o-1} is the concentration of the element sample, C^i_n is the background concentration, in this study the continental crustal average has been used [17]. C^if is defined according to four categories: < 1 low contamination factor, 1-3 moderate contamination factors, 3-6 considerable contamination factors and > 6 very high contamination factor.

2.4.2. Enrichment Factor

For each sampling site, EF (enrichment factor) at one determined soil depth may be calculated as the:

EF= is as follows:

$$\mathrm{EF} = \left[\mathrm{Cx} / \mathrm{Cref}\right] \mathrm{sample} \left[\mathrm{Bx} / \mathrm{Bref}\right] \mathrm{Background} \tag{2}$$

Where: Cx = content t of the examined element in the examined environment

C*ref*= content of the examined element in the reference environment;

Bx = content of the reference element in the examined environment; and

Bref= content of the reference element in the reference environment; 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 significant enrichment, EF = 20-40 very high enrichment and EF> 40 extremely high enrichment [18,19].

2.4.3. Pollution Load Index

The road dust was assessed for the extent of metal pollution by employing the method based on the pollution load index (PLI) developed by [20] is as follows:

$$PLI = \sqrt[n]{(CF1 \times CF2 \times CF3 \times .\ .... CFn)} \quad (3)$$

Where *n* is the number of metals studied 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 [20].

2.4.4. Index of Geoaccumulation

The index of geoaccumulation (Igeo) is widely used in the assessment of contamination by comparing the levels of heavy metal obtained to a background levels originally used with bottom sediments [21].
It is calculated using the equation:

$$Igeo = \log2\left(C_n \ / \ 1.5B_n\right) \quad (4)$$

Cn is the measured concentration of the heavy metal in road dust and Bn is the geochemical background concentration of the heavy metal (crustal average) [17]. 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 [22]. The following classification is given for geoaccumulation index in Table 1 [21,23].

Table 1. Descriptive Classes for *Igeo* Values

Igeovalue	Igeoclass	Designation of soil quality
> 5	6	Extremely contaminated
4 – 5	5	Strongly to extremely contaminated
3 – 4	4	Strongly contaminated
2 – 3	3	Moderately to strongly contaminated
1 – 2	2	Moderately contaminated
0 – 1	1	Uncontaminated to moderately contaminated
0	0	Uncontaminated

2.5. Statistical Analysis

In order to study the characteristics of road dust, the concentrations of heavy metals content in road dust were subjected to Pearson's significant correlation analysis using SPSS version 16. Data collected were subjected with one-way analysis of variance (ANOVA) to assess whether heavy metals varied significantly between location and distances from the road, possibilities less than 0.05 ($p < 0.05$) will be considered statistically significant.

3. Results and Discussion

3.1. Heavy Metal Concentration of the Road Dust in the Bolgantanga Municipality

From the study conducted eleven heavy metals were identified thus Cr, Hg, Cu, Zn, Mn, Fe, Pb, Ni, As, Co and Cd in the ten road dust samples collected along the high and low traffic zone roads (Trans ECOWAS) in Bolgatanga Municipality in the Upper East Region of Ghana. The study revealed that, Iron (Fe) concentration in road dust was the highest thus 198.98 mg/kg and ranged from 188.80 - 198.98 mg/kg in all the samples collected. With cadmium (Cd) having the least contamination level of 0.07 mg/kg and ranged from 0.07- 0.65 mg/kg. The mean heavy metal concentrations (mg/kg) along road dust sampling site A1 to A3 are 4.19 (Cr), 0.08 (Hg), 12.58 (Cu), 4.13 (Zn), 76.22 (Mn), 190.25 (Fe), 4.85 (Pb), 2.30 (Ni), 0.16 (As), 2.35 (Co) and 0.12 (Cd) (Table 2). The mean heavy metal concentrations (in mg/kg) along road dust sampling site B1 to B3 are 3.79(Cr), 0.12 (Hg), 4.65 (Cu), 3.56 (Zn), 69.65 (Mn), 193.06 (Fe), 5.64 (Pb), 1.61 (Ni), 0.23 (As), 2.28 (Co) and 0.07 (Cd) (Table 2). The mean heavy metal concentrations (in mg/kg) along road dust sampling site C1 to C4 are 9.45(Cr), 0.04 (Hg), 7.66 (Cu), 3.65 (Zn), 78.13 (Mn), 193.48 (Fe), 7.43 (Pb), 2.58 (Ni), 0.12 (As), 2.64 (Co) and 0.31 (Cd) (Table 2).The values of heavy metals in sampling D which is the control sample are 7.80 (Cr), 0.17 (Hg), 4.89 (Cu), 2.20 (Zn), 61.06 (Mn), 190.83 (Fe), 4.28 (Pb), 1.85 (Ni), 0.08 (As), 3.23 (Co) and 0.24 (Cd) (Table 2).

Similar studies have been carried out on major roads in the cities (Accra, Tamale, and some trans-ECOWAS road) of Ghana. However this study was the first of its kind in the Upper East Region of Ghana with respect to heavy metal determination in road dust of the trans-ECOWAS in the region. The study observed high pollution load index in zone D, followed by zone B, with A and C being equal though their values were <1. However, the grand mean concentration of the various heavy metals (Cr, Cu, Zn, Mn, Pb, Ni, Co and Cd) from each zone were below normal value, alert value as well as intervention threshold as indicated in Lacatusu *et al.* [24] report. Hence, the levels of concentration of heavy metals revealed that there are no threat posed by these metals on the environment and human. Since some of the heavy are carcinogenic such as Cr [25]. According to [26] the source of Cu in street dust was indicate corrosion of metallic parts of cars derived from engine wear, thrust bearing, brushing and bearing metals. Hence, corrosion of metallic parts of cars on the roads in the municipality is minimal. The low concentration of Cd in the road dust samples might due to less burning of lorry tyre on the road since Cd is only present in the tyres of the vehicles and can only be released into the street soils in the event of burning of tyres of vehicles.

This is similar to results obtained by Essumang *et al.* [27] on heavy metals in the Kumasi Metropolis of Ghana. It was observed that the concentration of Pb in the road dust samples were of low concentration. Generally, high concentrations of Pb in street soil dust are often attributed to high vehicular traffic conditions, use of leaded fuels in vehicles that ply the roads before the ban and non adherent to the use of diethyl lead to prevent knocking [25]. Hence this study revealed that vehicular traffic conditions that increase the concentration of lead in street soil dust is insignificant in the Bolgatanga Municipality. Although natural processes and other human activities such as the use of Pb base paints to paint artefacts or buildings can contribute significantly to high Pb pollution in road dust in the Metropolis. Emission from automobiles can be said to be low in the municipality as the concentration of lead obtained in the various roadside soil were very low traffic. The might account for the low concentration of Fe, Ni, Co, Mn, Hg, and As.

Table 2. Shows Heavy Metal Level in the Road Dust Samples Collected from the Bolgatanga Municipality

Road dust	Heavy metals (mg/kg)									
	Cr	Hg	Cu	Zn	Mn	Fe	Pb	Ni	As	Co	Cd
A1	4.53	0.05	7.76	4.01	74.23	188.80	5.31	2.35	0.15	1.96	0.11
A2	3.64	0.08	4.41	4.24	74.84	191.06	3.55	2.33	0.11	2.21	0.15
A3	4.39	0.11	25.56	4.15	79.59	190.88	5.69	2.23	0.21	2.87	0.09
Mean	4.19	0.08	12.58	4.13	76.22	190.25	4.85	2.30	0.16	2.35	0.12
B1	3.11	0.08	4.11	3.12	66.80	191.79	3.63	1.27	0.12	2.27	0.07
B2	3.39	0.13	5.17	3.48	66.41	190.92	6.51	1.33	0.27	2.08	<0.002
B3	4.87	0.15	4.67	4.07	75.74	196.47	6.77	2.24	0.31	2.49	<0.002
Mean	3.79	0.12	4.65	3.56	69.65	193.06	5.64	1.61	0.23	2.28	0.07
C1	5.24	0.05	5.80	3.89	66.80	192.80	5.05	1.63	0.09	2.01	<0.002
C2	5.32	0.04	2.21	3.84	68.50	191.90	10.79	1.95	0.17	1.56	0.12
C3	6.27	0.04	15.53	4.03	72.62	190.26	4.68	2.87	0.07	1.76	0.15
C4	20.96	0.01	7.09	2.84	104.62	198.98	9.21	3.88	0.13	5.24	0.65
Mean	9.45	0.04	7.66	3.65	78.13	193.48	7.43	2.58	0.12	2.64	0.31
D4	7.80	0.17	4.89	2.20	61.06	190.83	4.28	1.85	0.08	3.23	0.24
Min	3.11	0.01	2.21	2.20	61.06	188.80	3.55	1.27	0.07	1.56	0.07
Max	20.96	0.17	25.56	4.24	104.62	198.98	10.79	3.88	0.31	5.24	0.65

Table 3. Contamination Factor in the Road Dust Samples Collected from the Bolgatanga Municipality

ID	Cr	Hg	Cu	Zn	Mn	Fe	Pb	Cd	Ni	As	Co
A 1	0.06	0.11	0.1	0.02	0.14	5.39	0.05	0.11	0.06	0.01	0.07
A 2	0.05	0.16	0.06	0.02	0.14	5.46	0.04	0.15	0.06	0.01	0.07
A 3	0.06	0.21	0.34	0.02	0.15	5.45	0.06	0.09	0.06	0.01	0.1
Mean	0.06	0.16	0.17	0.02	0.14	5.43	0.05	0.12	0.06	0.01	0.08
B 1	0.04	0.16	0.05	0.01	0.13	5.48	0.04	0.07	0.03	0.01	0.08
B 2	0.05	0.27	0.07	0.01	0.13	5.45	0.07	0.00	0.03	0.02	0.07
B 3	0.06	0.29	0.06	0.02	0.14	5.61	0.07	0.00	0.06	0.02	0.08
Mean	0.05	0.24	0.06	0.01	0.13	5.51	0.06	0.02	0.04	0.02	0.08
C 1	0.07	0.11	0.08	0.02	0.13	5.51	0.05	0.00	0.04	0.01	0.07
C 2	0.07	0.08	0.03	0.02	0.13	5.48	0.11	0.12	0.05	0.01	0.05
C 3	0.08	0.08	0.21	0.02	0.14	5.44	0.05	0.15	0.07	0.00	0.06
C4	0.28	0.03	0.09	0.01	0.2	5.69	0.09	0.65	0.10	0.01	0.17
Mean	0.13	0.08	0.10	0.02	0.15	5.53	0.08	0.23	0.07	0.01	0.09
D	0.10	0.35	0.07	0.01	0.12	5.45	0.04	0.24	0.05	0.01	0.11
Minimum	0.04	0.03	0.03	0.01	0.12	5.39	0.04	0.00	0.03	0.00	0.05
Maximum	0.28	0.35	0.34	0.02	0.20	5.69	0.11	0.65	0.10	0.02	0.18

3.2. Contamination Factor Assessment in Road Dust

The contamination factor for each element was computed and results presented in Table 4. The result sreveal that the elements Cr, Hg, Cu, Zn, Mn, Pb, Ni, As, Co, and Cd obtained values less than 1 signifying low contamination from anthropogenic sources from sample site (Table 3). However, considerable contamination was obtained for Fe from the samples at the Bolgatanga municipality indicating contamination from human activities or natural sources. In Addo *et al.* *[15]* study, CF values for elements such as As, Cr, Cu, Mn, Ni, Pb and Zn that generally ranged between 0.54 t 0 14.87 which are high than CF values recorded by this study. Similar study conducted, Atiemo *et al.* *[25]* in Accra recorded CF values ranging between 0.11 to 26.05 for road dust samples. Mmolawa *et al.* *[28]* reported contamination factor values that showed low and moderate contamination of the heavy metals across the major roadsides soils in Botswana. While these previous study revealed low, moderate and considerable contamination, this study generally showed low contamination of heavy metals.

3.3. Enrichment Factor (EF) Ratio of Roadside Dust from Bolgatanga Municipality

Assessment of metal and level of contamination in soils require pre-anthropogenic knowledge of metal concentrations to act as pristine values. As a result the degree of anthropogenic pollution was established by adapting enrichment factor ratios [29]. The study conducted revealed that Cr, Cu, Zn, Mn, Pb, Ni, Hg, As, Co, and Cd obtained enrichment factor less than 2 (EF < 2) suggesting that these metals indentified were deficiently to minimally enrich (Table 4). Basically, as the EF values increase the contribution of anthropogenic origins also increase [30]. According to [31], the EF value between 0.50-1.50 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. The study revealed that the main source of heavy metal concentration of the road dust in the Bolgatanga Metropolis is from natural processes and not due to human related activities.

Similar study conducted by Addo *et al.* *[15]* in Ketu South District recorded EF Values for Mn, Cu, Mn, Ni, Pb and Zn that were in deficient to minimal enrichment. However, in their study they recorded EF Values for As (EF=2.31) and Cr (EF=3.84) that were in the category of moderate enrichment which agrees with this study. Another study conducted, Atiemo *et al.* *[25]* in Accra recorded EF valves ranging between 0.10 (Ni) to 18.50 (Pb) for road dust samples. This indicates that the human related activities in the Boltagatanga Metropolis are still minimal. These results are contrary to those previously reported by Mmolawa et al. [28]. They reported moderate (Co, Cu, Fe and Ni) to extreme (Pb) enrichment in most roadside soils studied in Botswana. However, the study conform to findings by Mmolawa et al. [32] that reported deficiently to minimally enrich for major roadside soils studied in Botswana. These disparities may however, be ascribed to the different approaches used in the enrichment factor calculation methods. In their previous study, the employed a normalised enrichment factor approach for metal concentrations using world uncontaminated background soils values, and iron as a metal of normalization, an approach which is less reliable since it ignores the fact that some geologic materials may have naturally high element concentrations and that the world reference values could be higher or lower compared to local conditions.

Table 4. Enrichment Factor in the Road Dust Samples Collected from the Bolgatanga Municipality

ID	Cr	Hg	Cu	Zn	Mn	Fe	Pb	Cd	Ni	As	Co
A 1	0.01	0.02	0.02	0.003	0.02	1	0.01	0	0.01	0.002	0.01
A 2	0.01	0.03	0.01	0.003	0.02	1	0.01	0	0.01	0.001	0.01
A 3	0.01	0.04	0.06	0.003	0.02	1	0.01	0	0.01	0.003	0.01
Mean	0.01	0.03	0.03	0.003	0.02	1	0.01	0	0.01	0.002	0.01
B 1	0.01	0.03	0.01	0.002	0.02	1	0.01	0.01	0.01	0.001	0.01
B 2	0.01	0.05	0.01	0.003	0.02	1	0.01	0.02	0.01	0.003	0.01
B 3	0.01	0.05	0.01	0.003	0.02	1	0.01	0.02	0.01	0.004	0.01
Mean	0.01	0.04	0.01	0.003	0.02	1	0.01	0.02	0.01	0.003	0.01
C 1	0.01	0.02	0.01	0.003	0.03	1	0.01	0.02	0.01	0.001	0.01
C 2	0.01	0.02	0.01	0.003	0.03	1	0.02	0.03	0.01	0.002	0.02
C 3	0.02	0.02	0.04	0.003	0.03	1	0.01	0.03	0.01	0.001	0.02
C4	0.05	0.01	0.02	0.002	0.03	1	0.02	0.04	0.02	0.002	0.02
Mean	0.02	0.01	0.02	0.003	0.03	1	0.01	0.03	0.01	0.002	0.02
D 4	0.02	0.06	0.01	0.002	0.04	1	0.01	0.12	0.01	0.001	0.03

3.4. Pollution Load Index (PLI) for the Various Roadside Dusts in Bolgatanga Municipality

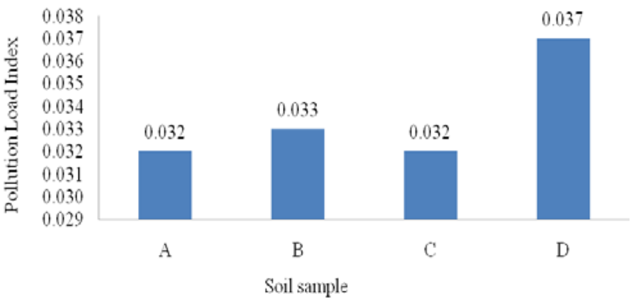

Figure 1. Pollution Load Index for Various Road Dust

The pollution load index was determined as described equation 3, to effectively compare whether the four sites suffer contamination or not. The PLI is aimed at providing a measure of the degree of overall contamination at a sampling site. Based on results presented in Figure 1, the overall degree of contamination by the eleven metals is of the order A = C > B > D. Despite the orderly manner of contamination, the PLI for the various sites were less than 1 thus PLI < 1 indicating perfection (that is no overall pollution).

3.5. Geoaccumulation Index (Igeo)

The calculated geoaccumulation (*I*geo) values are presented in Table 5. The study recorded *I*geo values that were less than 0 indicating uncontamination of heavy metals in the road dust.

Table 5. Geoaccumulation (*I*geo) Values of Heavy Metal in Roadside Dust

Road dust	A	B	C	D
Cr	-10.97	-11.14	-10.55	-10.08
Hg	-2.23	-1.64	-3.08	-1.1
Cu	-9.39	-10.83	-10.07	-10.76
Zn	-14.43	-14.71	-14.52	-15.35
Mn	-12.43	-12.57	-12.57	-12.76
Fe	-3.27	-3.25	-3.26	-3.27
Pb	-11.61	-11.39	-11.11	-11.77
Ni	-10.02	-10.55	-10.12	-10.35
As	-11.14	-10.56	-11.65	-12.14
Co	-9.17	-9.21	-9.57	-8.70
Cd	-5.97	-4.49	-4.06	-2.64

Table 6. Summary of Statistical Analysis of Variance of Heavy Metal Content ($Mgkg^{-1}$)

Elements	Grand mean	Standard deviation	Normal value	Alert value	Intervention threshold	F.pr
Cr	5.36	±1.55	30	100	300	0.01**
Hg	0.1	±0.09				0.02*
Cu	7.5	±2.09	20	100	200	0.64
Zn	3.45	±1.22	100	300	600	0.01**
Mn	69.06	±5.84	900	1500	2500	0.06
Fe	191.45	±0.58				0.45
Pb	5.4	±1.81	20	50	100	0.7
Ni	1.58	±1.35	20	75	150	0.41
As	0.15	±0.02				0.24
Co	2.41	±1.02	15	30	50	0.04*
Cd	0.12	±0.11	1.1	3	5	0.05

LSD at 5%, F.pr means Fischer probability, ** highly significant, *significant

3.6. Statistical Analysis of Heavy Metals

The analysis of variance shows that heavy metals such as chromium (Cr), mercury (Hg), cobalt (Co), cadmium (Cd) and zinc (Zn) concentration levels were highly significant in road dust collected from zone A, B, C and D. However, Cu, Mn, Fe, Pb, and Ni were not significantly different (Table 6).

3.7. Correlation Matrix of the Heavy Metals Road Dust in the Bolgatanga

Some elemental pairs such as Mn/Cr (0.81), Cd/Cr (0.99), Ni/Cr (0.80), Co/Mn (0.87), Ni/Co (0.77), Cr/Cu (0.89), Co/Cd (0.91), and Cd/Fe (0.91) have strong correlation with each other at 1% significant levels. Fe/Cr (0.72), Ni/Co (0.64), Cd/Mn (0.81), Fe/Mn (0.7), Fe/Co(0.71), Ni/Cd (0.81) have strong correlation with each other at 5% significant levels (Table 7). Although heavy metals concentration was low in the road dust. The correlation analysis shows that some of the elements correlated strongly indicating common source of anthropogenic pollution. According to Lu *et al.* [22], the source ofNi and Cr in street dust is believed to have come from corrosion of vehicular parts. This component can therefore be attributed to corrosion of motor vehicle parts. The results indicated that road dust contamination by the metals originated from a common natural source. The high rate of corrosion and wear from old vehicles (as a result of the high patronage in imported used cars) plying these roads could have accounted for the significant levels of anthropogenic contributions of Cr and Ni in the road dust. The source of Cd/ Ni, Cd/Mn, Cd/Cr and Co/Cd in the road dust in the Bolgatanga Metropolis is believed to come from wear-and-tear of tyres, combustion of fuel (especially diesel) and oil/lubricants, which are known to contain trace levels of cadmium.

Table 7. Correlation Matrix of the Heavy Metals in the Road Dust of Bolgatanga Metropolis

Parameter	Cr	Hg	Cu	Zn	Mn	Fe	Pb	Cd	Ni	As	Co
Cr	1										
Hg	-0.40	1									
Cu	-0.02	-0.04	1								
Zn	-0.49	-0.26	0.32	1							
Mn	0.81**	-0.50	0.24	-0.02	1						
Fe	0.72*	-0.16	-0.22	-0.23	0.70*	1					
Pb	0.47	-0.34	-0.16	-0.02	0.43	0.51	1				
Cd	0.99**	-0.33	-0.15	-0.51	0.81*	0.91**	0.45	1			
Ni	0.81**	-0.51	0.26	0.01	0.87**	0.52	0.35	0.81*	1		
As	-0.20	0.43	0.02	0.28	0.08	0.26	0.39	-0.10	-0.20	1	
Co	0.89**	-0.07	0.09	-0.58	0.77**	0.71*	0.25	0.91**	0.64*	-0.05	1

**. Correlation is significant at the 0.01 level (2-tailed)
Correlation is significant at the 0.05 level (2-tailed)

4. Conclusion

The study was carried out to determine heavy metal contents in road dust collected from selected major trans-ECOWAS roads in Bolgatanga Metropolis. The mean concentrations of Cr, Hg, Cu, Zn, Mn, Fe, Pb, Ni, As, Co and Cd were found to be lower than the alert values in all the soil samples collected. The enrichment factor calculated for the elements showed that Cr, Hg, Cu, Zn, Mn, Fe, Pb, Ni, As, Co and Cd are < 2 which signifies deficiency to minimal enrichment. The computed Index of geoaccumulation gave values in the range of unpolluted indicating insignificant accumulation of heavy metals from anthropogenic sources. The analysis of variance shows that heavy metals such as chromium (Cr), mercury (Hg), cobalt (Co), cadmium (Cd) and zinc (Zn) concentration levels were highly significant in road dust collected from zone A, B, C and D. Some elemental pairs such as Mn/Cr (0.81), Cd/Cr (0.99), Ni/Cr (0.8), Co/Mn (0.87), Ni/Co (0.77), Cr/Cu (0.89), Co/Cd (0.91), and Cd/Fe (0.91) have strong correlation with each other at 1% significant levels. Fe/Cr (0.72), Ni/Co (0.64), Cd/Mn (0.81), Fe/Mn (0.70), Fe/Co (0.71), Ni/Cd (0.81) have strong correlation with each other at 5% significant levels. Although heavy metals concentration was low in the road dust. The correlation analysis shows that some of the elements correlated strongly indicating common source of anthropogenic pollution.

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Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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