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Analysis of Roadside Dust for Heavy Metal Pollutants in Jimeta/Yola Adamawa State, Nigeria

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Author's contribution

This whole work was carried out by the author DYS.

Original Research Article

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ABSTRACT

A study of heavy metals in roadside soils is critical in assessing the potential environmental impacts of automobile emission on the soil. This study is aimed at analyzing heavy metal pollutants that may be present in roadside dust samples in Jimeta/ Yola, Adamawa State, Nigeria. Dust samples were collected around mechanical workshops (MWK), motor parks (MPK), market areas (MKA), roundabouts/highways (RHW) and residential areas (RDA). The dust samples were digested using aqua regia digestion method and Atomic Absorption Spectrophotometer was used for the heavy metal analysis. The change in concentration of most of the heavy metals determined from different sites decreases in the following order MWK>MPK>MKA>RHW>RDA. The heavy metals reveal a variation which indicates Fe>>Zn>Pb>As>Cu>Ni>Cr>Cd. Iron had the highest concentration in all the sampling areas with range of 3460±198 - 5800±50 µg/g. A lower value was observed for Cd with respective range of 0.48±0.05 - 1.74±0.06 µg/g. Cobalt and selenium were not detected in all the samples. Statistical analyses by ANOVA showed a significant difference (P<0.05) between the elements determined. This suggested that, the heavy metal pollutants in the roadside dust samples of Jimeta /Yola did not originate from common anthropogenic sources. Probably automobile emission due to traffic density, welding of metal and exhaust from power generators may have contributed to the presence of these elements in the roadside dust environment.

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1. INTRODUCTION

A study of heavy metals in roadside soils is critical in assessing the potential environmental impacts of automobile emission on the soil [1]. Heavy metal pollutant in urban street/roadside dust has become a growing concern in recent years [2]. Roads are important infrastructure that plays a major role in stimulating social and economic activities and their construction has also resulted in heavy environmental pollution [3].

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 [4]. 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 [5,6]. 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 [7,8,9]. A range of metals and chemical compounds such as lead dioxide and lead sulfate found in the roadside dust environment are harmful. Pollutants can attack specific sites or organs of the body and disease can develop as a consequence to such exposure [10,11]. 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 [12]. 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. Data on pollutant metal concentration of roadside dust in such areas are extremely scarce. In Jimeta/Yola roadside dust has become the major source of pollution in the metropolis due to bad roads, construction works and heavy vehicular traffic volume of about1100 vehicles per day along the major roads entering the state capital. The increase traffic volume is due to security checkpoints and banned of commercial motor cycles in the State capital especially during dry season.

This paper therefore reports the level of heavy metals in Jimeta/Yola roadside dust at different locations.

2. MATERIALS AND METHODS

2.1 Study Area

Jimeta/Yola capital of Adamawa State, is located in the central part of the state and is located on latitude 09º18'11" N and longitude 12º25'36" E. It record a lot of transportation activities due to high population density and traffic in the town. Consequently, gaseous pollutants from exhaust of cars, and trucks are emitted into the atmosphere. The lack of power supply in the state capital has compelled industries and small scale business activities to rely on power generators as an alternatives power supply. Welding and metal construction works by the roadside are common phenomena in the state capital. Through these activities, heavy metal pollutants are also emitted into the atmosphere or deposited in the roadside soil/dust.

2.2 Sampling Procedure

Roadside dust samples were taken from mechanical workshops, motor parks, market areas, roundabout and high ways and residential areas. The samples were sampled using brush and plastic scoop to collect the settled dust on polyethylene sheets placed along the roads in each of the study areas. Samples were collected from October, 2010 to April, 2011 to avoid rain-washing out the heavy metals.

2.3 Sample Preparation

Dust samples were collected and transferred to clean polyethylene bags and transported to the laboratory for onward analysis. All the samples were dried at 100 – 105^{o}C to drive out moisture.

2.4 Sample Digestion Procedure

All experiments were performed with analytical reagent grade chemicals. The digestions of the dust samples were done using aqua regia that is 3:1 ratio of hydrochloric acid to trioxonitrate (V) acid. Portions of two gram of each of each air-dried dust sample were ashed in a muffle furnace at 460^{o}C for 12 hours. The ash were digested in 10mL aqua regia in a digestion tube on heating blocks. After the digestion, the digests were first centrifuged and were acid washed to pass through whatman 540 filter paper and then filtered into 100ml volumetric flask then made up to the volume with distilled water. Calibration standards were prepared from the stock solution of the elements to be determined by serial dilution and were matrix matched with the acid concentration of the digested samples [13]. The digested samples were then analyzed for heavy metal using Atomic Absorption Spectrophotometer Unicam SP 969 [14]. All the measurements were in replicate analyses. Data obtained were subjected to analysis of variance (ANOVA) by SPSS version 16 to determine the differences in the concentration of each metal between different sites.

3. RESULTS AND DISCUSSION

Table 1 presents the concentrations of some heavy metal pollutants determined in the roadside dust samples in Jimeta/Yola from October, 2010 to April, 2011. High elemental concentration was observed in Fe, followed by Zn, Pb, As, Cu, Ni, Cr and Cd in all the five different sampling areas.

The high concentration of iron and zinc in the roadside dust samples may be attributed to metal construction works, iron bending and welding of metals, which is a common practice alone the major roads and mechanical workshops in Jimeta/Yola. The heavy metals in urban roadside dust take their origin from sources such as vehicles, road wear, activities of roadside artisans (battery charging, vehicle repairs, iron-bending, vehicle painting and panel beating) and emissions and or discharges from industries [1]. Zn, Pb, Cr and Ni come mainly from vehicular activities such as tyre wear, wear of brake linings and studded tyres may be the sources for Ni, Cr, and Pb [15] and Fe, Ni, Mo, Cr Co, Cd, Ti and Cu respectively [16]. These statement agrees with the result obtained in Tables 1 and 2. Corrosion of bushings, brake wires and radiators and the various types of deicing chemicals and friction materials used on road surfaces for slipperiness control could expose metals such Cu, Fe, Ni, Cr, and Co [16] and others into the environment.

In every mechanical workshop there are various sections that deal with either filling or welding of these metals and peeling of vehicle bodies. Iron fillings from this metal works, exhaust emissions from vehicles, oil spillage of gasoline, diesel, wastes from car batteries, engine oil and lubricating oils, coupled with rusting of non-coated metals have all collectively contributed to the presence of these elements Fe, Zn, Pb, Cu, Cr, As, Cd and Ni as shown in Table 1. Heavy metal pollution is a problem associated with areas of intensive industry, however, roadways and automobiles now are considered to be one of the largest sources of heavy metals. Zinc, copper, and lead are three of the most common heavy metals released from road travel, accounting for most of the heavy metals in road runoff [17,18]. Lead - concentrations, however, consistently have been decreasing since leaded gasoline was discontinued. Smaller amounts of many other metals, such as nickel and cadmium, are also found in road runoff and exhaust. About half of the zinc and copper contribution to the environment from urbanization is from automobiles. Brake linings release copper, while tyre wears releases zinc as shown in Tables 1 and 2.

Motor oil also tends to accumulate metals as it comes into contact with surrounding parts as the engine runs, so oil leaks become another pathway by which metals enter the environment. Iron, lead and zinc in this study area are higher compared to other studies in Mubi, Abuja, Amman, Hong Kong, Madrid [2,6,12] respectively as shown in Table 2. Studies have shown that, stainless steel and alloy steel contain Fe, Cr, Co, Al and/or Cu and that exhaust emission from both gasoline and diesel fueled vehicles contain variable quantities of these elements [19,20]. Chromium, cadmium and nickel are among the toxic listed elements by the International Agency for Research on Cancer (IARC) as carcinogenic [21].

Statistical analysis showed significant differences ($P<0.05$) between the elements as indicated in Table 1. This suggests that, the indicated heavy metal pollutants in street dust of Jimeta/Yola did not originated from common anthropogenic sources, probably automobile and the welding of metals as well as bad roads and construction works are the major sources of these metals.

The health implication of these heavy metals in street is quite obvious. Roadside dust with its high heavy metal contents has a high possibility of causing cough/breathing in both children and adults during inhalation. Leke [22]; reported that the inhalation of siliceous dust causes siliceous disease of the lungs. It has been observed that inhalation of some mineral particles can produce diseases in persons working in quarry sites, road construction, mines and welders. These mainly affect the lungs and the major pathogenic effect is the formation of fibrotic tissues in the lungs. The degree of incapacitation or loss of operational capacity of the lungs is dependent on the amount and type of mineral dust inhaled [23,24]. This response of lungs to mineral dust with attendant formation of fibrotic tissue is commonly referred to as pneumonomosis [24]. In addition to these toxic effects, it has also been suggested that cadmium may play a role in the development of hypertension and heart disease [25,23].

Table 1. Mean±SD of elemental concentrations of some heavy metals (µg/g) in roadside dust samples between October, 2010 to April, 2011 in Jimeta/Yola, Adamawa State, Nigeria

Sample	As	Cd	Cu	Co	Cr	Fe	Pb	Ni	Se	Zn
RDA	ND	$0.48±0.05^{a}$	$28.97±0.74^{a}$	ND	$2.07±0.15^{a}$	$3460 ± 198^{a}$	$47.50±8.56^{a}$	ND	ND	$125.74± 3.07^{a}$
RHW	ND	$0.66±0.03^{a}$	$90.08±1.63^{b}$	ND	$3.15±0.12^{a}$	$4500±103^{b}$	$340.13±26.30^{b}$	$10.05±1.80^{a}$	ND	$506.76±30.40^{b}$
MKA	$199.94±48.50^{a}$	$0.70±0.10^{a}$	$62.51±1.38^{c}$	ND	$6.56±0.20^{b}$	$5400±250^{b}$	$307.41±9.80^{c}$	$16.10±3.43^{a}$	ND	$452.88±36.00^{b}$
MPK	$105.48 ± 11.00^{b}$	$0.90±0.24^{a}$	$62.7±4.36^{c}$	ND	$5.90±0.40^{a}$	$5600± 498^{b}$	$364.26±26.30^{d,b}$	$20.08±2.00^{b}$	ND	$613.46±19.90^{c}$
MWK	$70.36 ± 9.80^{c}$	$1.74±0.06^{b}$	$106.04±5.23^{b}$	ND	$9.50±1.00^{c,b}$	$5800±50^{b}$	$448.74±43.40^{d,b}$	$30.30±8.83^{c}$	ND	$824.40±198.20^{c}$

All values represent mean ± SD (Standard Deviation). Comparison was done within the column and values with different superscripts are statistically different ($p<0.05$).ND: Not Detected; RDA = Residential Areas; RHW = Roundabouts and High Ways; MKA = Market Areas; MPK = Motor park; MWK = Mechanical Workshops

Table 2. Mean concentration of some heavy metals (µg/g) in roadside / street dust compared with other studies world wide

Place	Cu	Cd	Co	Pb	Zn	Fe	Reference
Yola	28.97 - 106.04	0.48 -1.74	ND	47.50 – 448.74	125.74 – 824.40	3460 – 5800	This study
Mubi	11.63 – 52.35	0.59 – 1.33	ND	20.37 – 241.34	102.22 – 705.80	5331 – 24100.00	[2]
Jos	1.01- 2.19	5.15 - 5.79	-	1.59- 12.10	5.67 - 12.88	141.80 - 159.00	[1]
Gwagwalada Abuja	97.00	3.40	-	210.00	79.00	120.00	[6]
Honkong	110.00	ND	ND	120.00	3840.00	14100.00	[12]
Madrid	188.00	ND	ND	247.00	476.00	ND	“
Auckland	27.00	0.40	6.41	1650.00	180.00	20900.00	“
London	-	4.20	73.00	1354.00	513.00	22800.00	“
Birmingham	ND	0.70	180.00	ND	205.00	ND	“
USA Differences	ND	0.89	ND	444.00	ND	ND	“
Ecuador	ND	0.36	ND	293.00	509.00	ND	“
Lancaster	199.00	5.20	ND	ND	530.00	ND	“
North Wales	24.00	6.90	ND	1779.00	1143.00	ND	“
Amman	29.70	0.75	ND	188.80	121.70	ND	“

ND: Not Detected

Chromium and its compounds are known to cause cancer of the lungs, nasal cavity and para nasal sinus and suspected to cause cancer of the stomach and larynx [26]. Apart from these direct effects of the dust on man, its effects are also felt indirectly. It settles on dried foodstuff such as rice, groundnut, maize, yam flour and dried cassava when the moisture contents of these foods are high. The dust dissolves in this moisture and become absorbed and thereby contaminates the foodstuff. Other foods such as sugar cane, roasted meat, beans cake, sugar, salt and vegetables may be contaminated by this dust, since must of the food items listed above are commonly sold along the roads of Jimeta/ Yola. Dust also settles on building, walls, roofs, windowpanes and doors causing mechanical abrasion and aesthetic blight. This can also lead to accumulation of the metal in the tissues of organisms that feed on the plant and other plants growing along the highway. This can be transferred to other consumers in the food chain [27]

4. CONCLUSION

This study has shown that the roadside dust in Jimeta/Yola is relatively contaminated with heavy metals. The heavy metal contaminations in roadside dust show a considerable decrease from place of high activities to a place of low activities (mechanical workshops to residential areas). This decrease might indicate aerial deposition of metal particulates in the roadside dust environment from extraneous sources and not only a function of soil type. Automobile and metal construction works could be responsible for the build up of the heavy metals in the roadside dust along the high ways and mechanical workshops through the emission of metal particulates. The roadside dust environment had a significantly high content of heavy metals, especially, Fe, Zn, Pb and Cu, and generally their levels increased with increasing traffic volume and welding of metals in urban areas. Hence, possible accumulation in the soil and transfer to plants growing along the edge of the highway could occur as a result continual usage of the road by automobile. This can also lead to accumulation of the metal in the tissues of organisms that feed on the plant and other plants growing along the highway.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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