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# AN ASSESSMENT OF URBAN ROAD CORRIDORS AND HEAVY METAL ACCUMULATION IN ZARIA, NIGERIA.

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**ABSTRACT**

The accumulation and hence contamination of any environment with heavy metals remains an issue of great concern considering the toxic nature of these elements. Amongst other anthropogenic sources of these toxic substances, emission from vehicular traffic on highways also constitutes the predominant source of these metals especially in urban environments. It is in the light of this that this paper examined the relative accumulation of selected heavy metals (Pb, Cr, and Cd) between urban road corridors of high and low vehicular traffic. To identify the nature of the vehicular traffic on the road corridors, a temporal survey of traffic count was conducted by simple manual tally method. The average vehicular traffic carried by the roads justifies the classification of roads as high (12,991) and low (3,956) traffic corridors respectively. Then road dust samples were collected from seven sites over each of the road corridors. Next, background soil samples of about 50m distance away from the road were also collected from seven sites along the high traffic roadside. The collected samples were analysed by the atomic absorption spectrophotometry to determine the relative proportion or accumulation of the considered heavy metals along the high traffic and low traffic roads. The mean concentrations of the considered heavy metals: Pb, Cd, and Cr are relatively higher (800mg/kg, 11.80mg/kg, and 17.82mg/kg) along the high vehicular traffic corridors in comparism to the low traffic corridors (328.57mg/kg, 1.31mg/kg and 5.94mg/kg) respectively. Also, the high traffic road dust samples showed significantly higher levels in the concentrations of Pb and Cd compared with the background soil samples taken 50m away from the road. The results of the study suggest that the road corridor with high vehicular traffic has the propensity to contaminate the environment than the low traffic road.

**KEYWORDS:** Heavy metals, accumulation, vehicular traffic, road corridors, Zaria, Nigeria

## INTRODUCTION

The ease of accessibility which urban transportation corridors provide also, gives some burden to its inhabitants. Increased motorization on roads contributes significant pollutants to the urban environment (Xanthopoulos and Hahn, 1990) with the primary contaminants being heavy metals (Batley, *et al.*, 1994, Birch, et.al, 2001). The primary sources of these heavy metals are mainly from automobile exhaust emissions, abrasion of tyres and brake lining as well as road surfaces, corrosion of vehicle body are the predominant sources of trace metals (Nageotte and Day, 1998; Paterson and Batley, 1992; Elik, 2003; Charlesworth, *et al.*, 2003; Sutherland and Tolosa, 2000).

Studies have indicated that countries like Austria, Brazil, Canada, Japan etc. have phased out leaded gasoline (Davidson 1999; Sutherland et al 2003). While some such as in European Economic Community (EEC), are slowly phasing out leaded fuels. Nigeria the most populous country in Africa still continues to use leaded gasoline despite its carcinogenic nature. For example a study carried out in Thailand, 1990 showed that about 70,000 children in Bangkok risked losing four or more points of intelligences quotient (IQ) due to heavy exposure to lead emissions from motor vehicles (Population Reports, 2000). Besides, reports have it that about 15 million children in Latin America under the age of two are considered to be at risk of ill health from lead pollution (UNDP, 1998). It has been noted by De Souza (2005) that 80% to 90% of lead in ambient air is derived from the combustion of leaded gasoline. In addition to lead, vehicles on urban roads also emit carbon dioxide and carbon monoxide all of which may have serious cumulative effects.

By and large, heavy metals pose serious health risks to man and his environment, yet, the emissions of these metals in the Nigerian urban centres via the road corridors appears unabated. In spite of the attention of environmentalist in this direction in other countries (Elik, 2003), Nigeria's attention to this anthropogenic contribution has not been impressive. Apparently, there is lack of attention received by road deposited sediments in the country, which perhaps, is surprising given that they are one of the most important contributors of source contaminants to urban environments (Birch and Scollen, 2003). It is worthy to note that even in cases where such studies are carried out, they tend to ignore vehicular emissions to road deposited sediments (Mashi, *et al.*, 2005).

In this current study however, we seek to assess the spatial variation of the selected heavy metals (Pb, Cr, Cd) since these metals are peculiar to vehicular traffic emission between the high and low traffic corridors in urban centre such as Zaria. Also, our objective is to establish the variation in concentration level between the high traffic corridor and 50m-background soil away from the road. This is with a view to pinpointing its implication for man's health in urban environments in Nigeria.

The study area is Zaria, located on latitude 11° 3'N and longitude 7° 42'E. (fig.1), and lies at an altitude of about 667m above sea level. The area is within the high plains of Northern Nigeria. Zaria is the second largest town in Kaduna State and has become a nodal point both in terms of road and rail transport. The city functions as institutional, educational, commercial, industrial and agricultural landuses, which in part has influenced the growth rate of the city. Urban Zaria comprises of four major sectors, which include Zaria City, Tudun-Wada, Samaru and PZ/GRA complex. Of these sectors, PZ/GRA was laid out by the colonial town planning policy with land use zonation, street layouts and laid out plots

Zaria lies between the tropical wet and dry climatic zone (Aw) characterised by strong seasonality in rainfall and temperature distribution. The mean annual rainfall can be as high as 2000mm in wet years and as low as 500mm in dry years. Mean annual temperature is about 35°C with mean monthly minimum of 12°C in December (Folorunsho, 2006)

The soils of the area belong to the class of the leached ferruginous tropical soils (Areola 1982). These soils support farming activities within and around the city especially the undeveloped plots in the city where market gardening and other crops are cultivated. Livestock farming such as cattle rearing is also practiced in the study area.

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This investigation comprised two parts: a temporal study of traffic count to identify the nature of the vehicular traffic on the road corridors; and the collection of soil samples for analysis so as to determine the spatial variation in the concentration of heavy metals. With regards to vehicular traffic count, it was done to allow for the determination of the proportion of vehicular traffic on each road on temporal basis. This was carried out by a simple manual tally method. This technique involves a continuous count of all vehicle types that passes through a predetermined point. The counts were done in two shifts to cover the period of 7.00 am to 6 pm for three alternate days in a week. Thus, the average vehicular traffic carried by the roads was used to classify the roads as high and low traffic corridors (Table 1). On the basis of this, two roads were sampled. These are Samaru–PZ–Tudu-wada, and GRA roads representing the high and low traffic corridors respectively.

Table 1: Average Vehicular Traffic for the sampled roads on temporal basis

| Time | HIGH TRAFFIC | | | | LOW TRAFFIC | | | | Total high traffic | Total low traffic | Grand total | % high | % low |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cars | Buses | Trailer /Truck | Motor-cycle | Cars | Buses | Trailer/ truck | Motor-cycle | | | | | |
| 7-8am | 263 | 214 | 17 | 286 | 84 | 5 | 0 | 74 | 780 | 163 | 943 | 82.7 | 17.3 |
| 8-9 am | 358 | 393 | 36 | 359 | 86 | 4 | 2 | 161 | 1146 | 253 | 1399 | 81.9 | 18.1 |
| 9-10 am | 374 | 330 | 31 | 472 | 111 | 4 | 8 | 219 | 1207 | 342 | 1549 | 77.9 | 22.1 |
| 10-11am | 499 | 404 | 25 | 446 | 211 | 8 | 4 | 288 | 1374 | 511 | 1885 | 72.9 | 27.1 |
| 11-12noon | 564 | 376 | 32 | 433 | 232 | 19 | 10 | 241 | 1405 | 502 | 1907 | 73.7 | 26.3 |
| 12-1pm | 489 | 336 | 29 | 239 | 277 | 8 | 10 | 278 | 1093 | 573 | 1666 | 65.6 | 34.4 |
| 1-2pm | 610 | 298 | 33 | 297 | 72 | 4 | 14 | 154 | 1238 | 244 | 1482 | 83.5 | 16.5 |
| 2-3pm | 636 | 301 | 34 | 304 | 92 | 3 | 12 | 218 | 1275 | 325 | 1600 | 79.7 | 20.3 |
| 3-4pm | 536 | 296 | 39 | 262 | 125 | 7 | 12 | 166 | 1133 | 310 | 1443 | 78.5 | 21.5 |
| 4-5pm | 591 | 276 | 30 | 268 | 135 | 3 | 8 | 183 | 1165 | 329 | 1494 | 78.0 | 22.0 |
| 5-6pm | 591 | 280 | 33 | 271 | 148 | 11 | 17 | 228 | 1175 | 404 | 1579 | 74.4 | 25.6 |
| **Total** | **5,511** | **3,504** | **339** | **3,637** | **1,573** | **76** | **97** | **2,210** | **12,991** | **3,956** | **16,947** | **76.7** | **23.3** |

**Source**: Field Survey, 2006

The second aspect of the data involves the collection of road dust and background soil samples. The sampling sites were divided into two categories. The first category consist of road dust samples of both the high and low traffic corridors while the second category dealt with the background soils of the high traffic compared with the road sediment samples of the high traffic corridor. As regards the first category, seven carefully selected roadside sites were sampled for each of the high and low traffic to provide a representative coverage of all the traffic levels expected on the road corridor. This is the first category that recorded 14 sampling sites. These samples were collected using a dustpan and brush that were cleaned with ethanol between sampling to avoid contamination. The samples were then placed in polythene bags. Also, the sites were purposefully selected in order to avoid the influence of urban activities like battery charging, mechanic workshop, panel bitters and waste dumps that are located along the road corridors.

For the second category, for each high traffic roadside site, background soils were sampled at a distance of 50m away from the road. These samples were also collected from seven sampling sites that served as control sites against the high traffic road dust samples. The fundamental purpose of this design is to show the spatial variation of the contaminants as distance increases away from the road. These samples were collected using auger-bore at a depth of 0-15cm. The sampling sites selected constitute mainly the undeveloped plots sometimes used for crop cultivation.

In all, 21 samples were collected. They were carefully labelled, later air dried, ground and sieved through a 2mm sieve to remove gravel fractions. The samples were then taken for laboratory analyses. Five grams of each of the sub-samples was first digested by subjecting to heat. In order to prevent sputtering, a few drops of distilled water were added. Thereafter, the sub-samples were then passed through a UNICAM 969 Atomic Absorption Spectrophotometer (AAS) using various standard lamps for each element. The absorbance in each of the selected extractant was then determined from the AAS.

## RESULTS AND DISCUSSION

The result of the analyses of the soil samples collected, reveal the concentrations of the heavy metals considered (Pb,Cd and Cr) for the two categories of road corridors with high and low traffic, as well as high traffic road dust samples compared with the background values (Tables 2 & 3).

**Table 2:** Relative concentration of selected heavy metals in the high and low traffic corridors (in mg/kg) : Category I

| Sampling Sites | Pb | | Cd | | Cr | |
|---|---|---|---|---|---|---|
| | HT | LT | HT | LT | HT | LT |
| A vs a | 500 | 200 | ** | ** | ** | ** |
| B vs b | 800 | 300 | 9.2 | ** | ** | ** |
| C vs c | 400 | 400 | 9.2 | ** | 62.40 | 20.8 |
| D vs d | 800 | 300 | 18.34 | 9.2 | 20.8 | ** |
| E vs e | 1,200 | 300 | 9.2 | ** | ** | ** |
| F vs f | 600 | 300 | 18.34 | ** | ** | 20.8 |
| G vs g | 1,300 | 500 | 18.34 | ** | 41.6 | ** |
| **Mean Concentrations** | 800.00 | 328.57 | 11.80 | 1.31 | 17.82 | 5.94 |

** Not detected HT – high traffic LT – low traffic

The result showed that the roadside dust of high traffic corridor has relatively high contents of Pb, Cd and Cr of the samples compared to samples obtained from low traffic corridor (Table 2). The mean values for high and low traffic are 800 and 328.57 mg/kg respectively. Similarly, the mean cadmium contents of the high and low traffic corridor showed a result of 11.8 and 1.3 mg/ kg respectively. The mean, chromium concentrations are 17.8 and 5.9 mg/ kg for high and low traffic corridors respectively. The result obtained in Table 2, therefore shows that all the metals under consideration display similar pattern across the sampled locations. This suggests that the road corridor with high vehicular traffic has the propensity to contaminate the environment than low traffic road.

Vehicular emissions are often fingered as the prime source of pollutants with the discharge of heavy metals into the environment. It is important to note that lead present in petrol as lead tetraethyl and tetra methyl is emitted from car exhaust as lead bromo-chloride (PbBrCl) in particulate form. Substantial portion of these is deposited within 50 meters of highways while smaller particles are carried several kilometres away (Mielke, 1994; Wild 1996; Elik, 2003).

**Table 3:** Relative concentration of selected heavy metals in the high traffic and background soil samples (in mg/kg) : Category II

| Sampling Sites | Pb HT Road dust | Pb 50m | Cd HT Road dust | Cd 50m | Cr HT Road dust | Cr 50m |
|---|---|---|---|---|---|---|
| A | 500 | 100 | ** | 9.2 | ** | ** |
| B | 800 | 100 | 9.2 | ** | ** | ** |
| C | 400 | ** | 9.2 | ** | 62.40 | ** |
| D | 800 | 100 | 18.34 | 9.2 | 20.8 | ** |
| E | 1,200 | 100 | 9.2 | ** | ** | ** |
| F | 600 | ** | 18.34 | 9.2 | ** | 20.8 |
| G | 1,300 | 1,200 | 18.34 | ** | 41.6 | 20.8 |
| **Mean Concentrations** | **800.00** | **228.57** | **11.80** | **3.94** | **17.82** | **2.97** |

**Note:** Common range of the metals in soils in mg/kg Pb (2-200); Cr (1-1000, 5-3000); Cd (0.01-0.7) **Source:** Balentine, (1995)

Furthermore, the results presented in Table 3, depict an interesting variation between the metal concentrations in the high traffic corridor and 50m background soils adjacent to the road sample sites. For instance, the mean concentration values of Pb, Cd and Cr for the road dust samples are 800, 11.80 and 17.82 mg /kg respectively. On the other hand, background soil samples recorded 228.57, 3.94, and 2.97 mg/kg respectively. It is therefore evident that the roadside sediments are relatively enriched compared to the background samples. This marked difference in concentration of the metals considered is consistent with the observations of Birch and Scollen (2003) and Hyo-Taek *et al.*, (1995). The relatively high concentration of these heavy metals in the roadside samples can be attributed to vehicular activities on the road corridor. Incidentally, the concentration of Pb and Cd in the high traffic sample far exceeds the common range of 2-200 mg/kg and 0.01-0.7 mg/kg (Balentine, 1995) for Pb and Cd respectively.

**Table 4:** Paired samples and Significance of the metals in mg/kg

| Paired Samples | N | Corrélation | Std Deviations | *t* | Df | Significant Difference |
|---|---|---|---|---|---|---|
| HT & LT (Pb) | 7 | 0.462 | 309.37 | 4.032 | 6 | Significant |
| HT & LT (Cd) | 7 | 0.416 | 6.32 | 4.387 | 6 | Significant |
| HT & LT (Cr) | 7 | 0.361 | 23.58 | 1.33 | 6 | Not significant |
| HT & BS (Pb) | 7 | 0.691 | 314.71 | 4.804 | 6 | Significant |
| HT & BS (Cd) | 7 | 0.057 | 8.26 | 2.517 | 6 | Significant |
| HT & BS (Cr) | 7 | 0.415 | 23.14 | 1.698 | 6 | Not significant |

Where critical *t* @ 0.05 is 1.9432; BS-background soil

The results were subjected to student t-test in order to determine the significance of the difference of the matched pairs of the samples. The basic thrust of this approach is to compare the differences in concentration level of each of the two categories for all the metals under consideration. Results of the test (Table 4) indicate that the difference between the paired samples of the road dust sites with the 50m samples for Pb and Cd maintain levels that are significantly higher than those of the background sites. Also, Pb and Cd concentration for the high traffic corridor equally maintained levels significantly higher than low traffic corridor. For Cr, the result showed that there are no significant differences between the paired samples for the two categories. Indeed, this suggests that the road corridor is a major source of Pb and Cd that contaminate the environment of the study area through emissions from vehicles.

**Heavy Metals and the Health of Urban Residents**

It is apparent from the results presented above that much of the trace metals introduced into the urban environments come via vehicular traffic. These metals when introduced into the environment constitute great danger to humans both by inhalation and consumption of food crops especially the leafy vegetable grown near road traffic corridors. *Stricto senso*, in the absence of human influences, background levels of such metals are normally low and thus pose little threat to human health (Wild 1996). Indeed, heavy metal when present in the environment beyond the permissible limit may enter food chain from soils and consequently result in adverse health hazards (Mashi, *et al.*, 2005).

The considered metals in this study (Pb, Cr, Cd) among others have been noted by Wild (1996), and Population

Reports (2000), as the most dangerous heavy metals known to man. The health implications of these toxic metals include malfunctioning of the nervous system, renal and reproductive systems; damage to the blood vessels; brain and bone damage or paralysis; behavioural abnormality; cardiovascular disease in adults; cancer and outright death occasioned by food poisoning (Essoka, *et al.*, 2006; Mashi, *et al.*, 2005; and Isirimah, 2000).

Road deposited sediments cannot be treated with lip service in this area for certain reasons. First, arising from the marked wet and dry harmattan climate of the area, these road deposited sediments are washed away as runoff towards the main rivers and streams during the wet season. This condition becomes aggravated during the harmattan season when road sediments become loose and unconsolidated and could possibly be freely inhaled. Finally, the deposited metals that are retained in the soils may find their way into the food chain when plants and crops take them up. Consequently, animals and humans that feed on such plants and crops are at great risks of health hazards.

Since a significant portion of the urban undeveloped plot adjacent to the roads are intensively cultivated on annual basis, there is the need for a pragmatic approach to urban land use policy to ameliorate the impact of such roads on farmlands. Above all, if progress is to be made in this direction, the use of leaded fuel should be phased out completely. On the short run, such farmlands or gardens should be located at least 50m away from heavily travelled roads. Also, the soils of such farmlands should be limed to keep the pH between 6.5 and 7.0, since a low pH (acidity) makes lead more available to plants leading to adverse effects. Also farm beds should be dug deeply so that roots can penetrate the less contaminated levels of the soil.

On the long run however, a major strand that should be infused into the National Urban Policy as well as the Federal Ministry of Environment (FMENV) objectives is to legislate against the cultivation of road right-of-way. Furthermore, a system should be evolved to ensure periodic soil metal remediation in such contaminated soils close to road traffic corridors.

## CONCLUSION

It is evident from this study that urban roads, and increasing motorization that sustains the economic fabric of urban societies has unintended consequences on the environment. It can thus be concluded that, the higher the traffic on urban roads, the greater the accumulation of heavy metals deposited on adjacent soils. This constitutes serious potential threat or danger to the populace. Consequently, this trend if left unattended to, the society and the government at large will bear the social and economic costs as sectoral allocation to health care delivery will increase with its attendant burden on a developing country like ours.

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