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Lead Accumulation in Surface Soils and Components of Balenites Aegyptica Specie in a Katsina Urban Area, Nigeria

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Objective The main objective of this paper is to assess the impact of various vehicular traffic densities on lead (Pb) accumulations in some environmental components in Katsina, a semi-arid urban area of Nigeria. **Methods** This was achieved by collecting and analyzing samples of surface soils, fruits, kernels, leaves, and barks of *Balenites aegyptica* from locations of different vehicular traffic densities in the area, and analyzing them for lead, using atomic absorption spectrophotometry. **Results** The results obtained revealed that the Pb concentration in the high, medium, low, and zero traffic density areas are, 75, 53, 35, and 12 $\mu g \cdot g^{-1}$ respectively for the fruit pulp. They are also16, 13, 8, and 6 $\mu g \cdot g^{-1}$ for fruit kernel and 44, 28, 17, and 9$\mu g \cdot g^{-1}$ respectively for leaves. For tree barks, the values are 138, 97, 64, and 18 $\mu g \cdot g^{-1}$ respectively while for under-tree-canopy soil samples the mean values are 99, 74, 44, and 17 $\mu g \cdot g^{-1}$. In the case of outside-canopy soil samples, the mean values are 113, 91, 50, and 18 $\mu g \cdot g^{-1}$ respectively for the various classes of vehicular traffic density. **Conclusion** These results indicate a strong influence of vehicular traffic density on Pb emission into surrounding atmosphere and its subsequent precipitation on soil and components of *B. aegyptica* specie in the area. Of all the samples, tree bark should be the best index of assessing Pb pollution in the area, as it maintains the closest contact with the surrounding atmosphere. Since Pb has no known lower limit for human tolerance, there is an urgent need for Pb pollution control in the area to be effectively enforced.

Key words: Lead; *Balenites aegyptica;* Soil; Pollution; Katsina; Health hazard

INTRODUCTION

Lead (Pb) is a highly toxic heavy metal that adversely affects the nervous, hemopoietic, cardiovascular, renal, and reproductive systems. Of most significance, as explained by the author[1], are its effects on the nervous system of young children, especially in terms of reduced intelligence, attention deficit and behavioural abnormality, as well as its contribution to cardiovascular disease in adults. All these can result even at low levels of exposure since there is no known lower threshold limit of Pb in the environment[2]. Then it is important that Pb concentration in the environment at all times should be of much concern to every community.

Human exposure to Pb can be attributed to many sources. Of particular note is lead emitted from vehicles as Pb additives are used in most fuel consumed by these vehicles. In Nigeria, it is erroneously being assumed that addition of Pb additives is the cheapest way for boosting the octane number of gasoline used by large number of old vehicles that ply roads in the country[3].

It is thus little surprising that a fairly recent worldwide gasoline survey[4] classifies Nigeria as being among the countries with high Pb usage in gasoline (>0.4 g/L). Onasanya *et al.*[5] have quantified Pb level in premium grade petrol being used in Nigeria as being between 0.8-0.4 g/L. Under such a circumstance, vehicular traffic is often the largest source of human exposure to Pb accounting for as much as 90% of all atmospheric emissions in many urban areas[6]. Atmospheric enrichment of Pb in this way promotes fall-out of the metal unto plants, soil, and water bodies through which it eventually enters the food chain[7]. A number of studies in Nigeria and elsewhere have accordingly observed how vehicular emissions have resulted in elevated Pb levels in soils and vegetation[8-17]. Soils and vegetation can therefore be relied upon in assessing the extent of atmospheric

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Pb pollution and fallout onto surface soils and vegetation, especially in areas of heavy vehicular traffic[18-22]. For vegetation a number of studies have demonstrated that trees are better indicators of Pb pollution than grasses and shrubs because they remain in fixed position over considerable period, which facilitates long term monitoring[23-28].

Balenites aegyptica is a tree specie that grows very well in semi arid areas of Nigeria. It has enormous resources which are so valuable to local people that nearly all built-up areas have appreciable populatio ns of such tree. Hall and Walker[29] have documented that both its fruits, kernels, leaves, and barks are being used widely for variety of purposes including human consumption, medicine, livestock pasture, and manufacturing of industrial chemicals. Therefore there are many sources by which heavy metals, if present in *B. aegyptica*, could find ways into human beings in the area.

This paper presents the results of work carried out to determine the level of lead concentration in surface soils and components (fruits, kernels, leaves and barks) of *B. aegyptica* in Katsina urban area. The area is of particular importance because it is one of the major urban areas within the semi arid region of Nigeria where the tree specie has been fully integrated into the urban ecosystem, with virtually every street littered with the specie.

MATERIALS AND METHOD

Selection of Sampling Sites

Katsina urban area has a total number of 57 motorable streets. Field visits were conducted to ascertain the relative vehicular traffic density of each street. Using vehicular passage counts per unit time as a basis, they were classified into high, medium, and low-density streets. Five streets each were subsequently chosen to represent the three traffic density categories. Five other streets that are non-motorable were chosen to serve as the control. Within every street, all the tree species that are located at or near road edges were selected to serve as sampling points. At every point surface soil samples (0-15 cm) were collected below and outside the canopy of every tree, while for every tree samples of fruits, barks and leaves were taken. The fruit samples were subsequently separated into fruit pulp and kernels before analysis.

Analysis of Vegetation Samples

The collected vegetation samples were oven dried at a temperature of 105℃ to obtain constant weight. The dried samples were then pulverized to uniform powder fractional sizes, using a thoroughly washed and dried laboratory mill. Two g sub-samples were then taken in crucibles, pre-ashed on a hot plate and then ashed at about 450℃-500℃ in a muffle furnace. 10% HNO_3 solution was then used to make the ashed samples into solution in a 100 mL volumetric flask. The flasks were then made to mark with distilled water. The solution was subsequently analysed using a Buck Scientific model 210 atomic absorption spectrophotometer.

Analysis of Soil Samples

The soil samples were oven-dried at 105℃ in order to obtain constant weights. The dried samples were then crushed and sieved through a 2 mm sieve to remove gravel fractions. One g sub-samples were taken into crucibles to which few drops of distilled water were added to prevent sputtering. EDTA extraction method[30] was then used in extracting Pb from the samples. The EDTA extraction method was used so that only plant-available Pb in the samples is extracted that is the lead that will enter the food chain in the area[31]. The extractants were then diluted to 100 mL and the concentration of the lead in the extractants was determined using atomic absorption spectrophotometry.

RESULTS

Table 1 presents data on Pb concentration in ($\mu g \cdot g^{-1}$) in samples of soil and components of *Balenites aegyptica* specie. Mean values are presented for the various categories of vehicular traffic density, and the control. Table 2 on other hand assesses the influence of variation in traffic density on Pb accumulation in the samples of soil and of components of *Balenites aegyptica* specie. The table compares the mean Pb values of pairs of vehicular density classes. The aim of this comparison is to identify the main vehicular traffic classes that are significantly different from each other in terms of the mean Pb values.

Pb Concentration in B. aegyptica Samples

It could be observed from Table 1 that Pb levels of tree bark samples are consistently higher in all the four sampling areas (high, medium, low and zero density), followed by the fruit pulp, then leaves and least in the fruit kernel samples. This thus suggests the following as the pattern of Pb accumulation in components of the specie in the area:

Tree Bark > Fruit Pulp > Leaves > Fruit Kernel. Similarly, in all the components of the specie, Pb levels show some decreases with the decrease in density of vehicular traffic. In fact, the mean Pb

TABLE 1

Pb Concentration in *B. aegyptica* and Soil Samples in Urban Katsina (μg • g^{-1})

Sampling Street	Vehicular Traffic Density	*Balenites aegyptica* Samples				Soil Samples	
		Fruit Pulp	Fruit Kernel	Tree Leaves	Tree Barks	Under Canopy	Outside Canopy
SS1	High	82.3±10.2	19.5±3.2	42.5±8.3	132.5±16.0	96.5±12.3	123.0±11.2
SS2	High	78.4±5.6	9.0±1.5	36.7±4.1	152.0±10.2	105.2±10.0	126.5±9.3
SS3	High	83.2±6.9	12.3±4.2	52.5±7.2	98.6±12.3	86.4±6.9 9	96.2±4.9
SS4	High	64.0±7.8	16.2±3.0	39.2±4.3	163.2±7.9	92.5±8.3	83.5±11.2
SS5	High	69.3±9.2	23.5±1.8	48.2±7.9	145.6±20.3	112.4±6.5	136.3±7.2
Mean		75.4	16.1	48.3	138.4	98.6	113.1
S.D		7.9	2.7	6.4	13.4	8.8	6.9
CV%		10.5	17.0	14.5	9.6	8.9	7.8
SS6	Medium	54.6±3.2	12.5±1.6	26.2±5.2	115.2±12.3	54.3±9.6	98.7±12.3
SS7	Medium	69.3±2.5	20.3±1.6	36.5±4.3	98.7±8.2	49.7±4.2	89.5±7.6
SS8	Medium	52.0±6.2	7.8±0.8	29.2±4.9	103.5±6.0	98.3±12.5	120.3±4.2
SS9	Medium	49.5±5.2	10.3±2.1	16.2±5.2	78.9±5.8	79.8±15.2	58.2±7.5
SS10	Medium	39.6±6.3	13.2±6.3	32.5±6.3	89.9±12.3	16.7±9.2	8.2±4.9
Mean		53.0	12.8	28.1	97.2	73.7	91.0
S.D.		4.9	2.2	5.2	8.9	10.1	7.3
CV%		8.8	17.0	18.4	9.2	13.8	8.0
SS11	Low	43.6±5.8	13.2±3.6	12.3±2.6	78.6±9.2	32.1±4.0	54.3±5.2
SS12	Low	34.2±8.6	5.8±1.0	22.0±4.2	62.3±3.4	23.2±3.8	23.2±5.8
SS13	Low	36.5±7.8	7.2±2.0	12.9±1.6	32.8±7.6	62.5±9.2	65.2±4.3
SS14	Low	29.5±1.8	5.6±0.9	8.3±0.8	86.4±5.8	49.6±5.8	36.5±2.9
SS15	Low	32.3±7.4	8.3±0.5	28.4±10.2	60.0±8.1	50.2±6.7	42.1±0.3
Mean		35.2	28.0	16.8	60.0	43.5	49.5
S.D.		6.3	1.6	3.9	6.8	5.9	5.7
CV%		17.8	20.0	23.1	10.6	13.6	11.5
SS16	Zero	12.3±4.0	5.6±1.2	20.2±5.6	32.3±4.1	20.5±5.6	16.3±2.6
SS17	Zero	8.6±1.3	3.9±0.6	9.3±2.8	28.5±5.2	8.9±2.3	21.5±4.8
SS18	Zero	10.2±2.0	9.2±3.0	6.7±3.0	6.3±4.2	12.3±4.8	15.2±6.3
SS19	Zero	13.4±1.9	6.7±2.2	2.8±1.2	28.5±6.3	25.2±6.3	19.7±2.3
SS20	Zero	6.5±0.8	2.6±0.8	7.5±0.7	12.8±9.2	18.9±2.2	15.2±4.0
Mean		12.2	5.6	9.3	18.5	17.2	17.6
S. D.		2.0	1.6	2.7	5.8	4.2	4.0
CV%		19.6	27.9	28.6	31.4	24.7	22.8

Note. The mean values fifty (50) samples per vehicular traffic density class sampling category. S. D.=Standard Deviation; CV%=Coefficient of Variation Percentage.

TABLE 2

Influence of Traffic Density on Pb Levels in Soil and *B. aegyptica* Samples

Sample	Difference Between Mean Pb Levels for Pairs of Traffic Density[a]					
	High Den. Vs Medium Den.	High Den. Vs Low Den.	Low Den. Vs Medium Den.	Zero Den. Vs High Den.	Zero Den. Vs Medium Den.	Zero Den. Vs Low Den.
Fruit Pulp	22.4*	40.22*	-17.78*	-65.24*	-42.8*	-25.02*
Fruit Kernel	3.3	8.08*	-4.78	-10.5*	-7.2*	-2.42
Tree Leaves	15.72*	27.04*	-11.32	-34.52**	-18.8*	-7.48
Tree Barks	41.18**	74.36**	-33.18**	-119.9**	-78.72**	-45.54**
Under Canopy	24.86*	55.08**	-30.21*	-81.44**	-56.68**	-26.36
Outside Canopy	22.12*	63.56**	-41.44**	-95.52**	-73.4**	-1.96**

Note. [a] Difference between mean Pb levels of the density areas being compared (e.g. for the first pair: mean for High Density minus that for the Medium Density area). The asterisks denote the differences that are statistically significant (by T-Test) at 0.05(*) and 0.001(**) probability levels. Negative sign means that the first density area of a pair has lower mean Pb value than the other density area in the same pair. Positive sign denotes opposite.

values for each of the areas with traffic density are at least 100% higher than those in areas of zero traffic density (i.e. the control).

Pb Concentration in Soil Samples

EDTA extractable Pb content of the soil samples collected in all the sampling areas has remained higher outside than under canopy of the *B. aegyptica* specie in the area. The difference is however only by a factor of about 0.25. There is also a well marked difference in mean Pb values of the various classes of traffic density and the control site, with the values for the control being at least 50% lower than those of the various classes of traffic density .

Relationship Between Pb Concentration and Traffic Density in the Samples

An attempt was made to examine the influence of traffic density on Pb concentration in the soil and plant samples collected in the area. It is clear that the concentrations increase as one moves from the zero through low, to medium and high traffic density areas (Table 1). In fact it is clear that the high and medium density areas in general have significantly higher Pb levels than all the other areas, while zero traffic density area (the control) has significantly lower Pb levels than all other areas (Table 2). This implies that increase in traffic density in the area is associated with increase in Pb accumulation in soil samples as well as in the various components of the *B. aegyptica* specie.

DISCUSSION

The fact that the tree barks are having the highest Pb concentration is expected since the *B. aegyptica* specie has a rough back. Trees with rough barks are particularly noted for accumulating metals at proportions higher than what obtains either in trees with smooth barks or smooth surfaces like those of leaves[23]. In addition the *B. aegyptica* specie has leaves with relative narrow surface areas[29]. This may also partly account for the higher Pb concentration in fruit pulps (which are larger in surface areas) than leaves of the specie. Since fruit kernel is completely wrapped-up by the fruit pulp it is little surprising that it was observed to have lowest Pb content. In Abeokuta urban area of Nigeria, Odukoya *et al.*[3] observed that a tree with rough bark (*Azadirachta indica*) has accumulated heavy metals in proportions that are about two to four times greater than those of other species with smooth barks (*Ficus* spp, *Gmelina abosea*, *Acacia* spp, *Baobab*, *Spondiamon*, and *Hurascrepitants*). In this study, tree barks were observed to have Pb levels that are about two times greater in proportion than those of fruit pulp, nine times more than those of fruit kernel and about three times more than those of leaves. On the other hand, fruit pulp levels of the metal are about two to six times more than those of the fruit kernels, but only about one to two times more than those of the tree leaves.

Soils under the tree canopy in most cases enjoy some buffer from aerial fallout of heavy metals[7]. It is thus little surprising that Pb levels were found to be higher in the soil samples collected from outside the *B. aegyptica* canopy. Lead concentrations in the soil samples are generally higher in mean values than all other sample except for the tree bark samples of the *B. aegyptica* specie.

In separate studies, Osibanjo and Ajayi[32] in Ibadan, and Fatoki and Ayodele[15], Fatoki[17] in Ile-Ife, and Odukoya *et al.*[3] in Abeokuta areas of southwestern Nigeria have observed a positive correlation between soil and plant concentration of some heavy metals and vehicular traffic density.

Comparison of Pb Levels in the study area with those of elsewhere indicates that mean Pb levels of the study area, varying between about 12-75 $\mu g \cdot g^{-1}$ for leaves, 6-16 $\mu g \cdot g^{-1}$ for fruit kernels, 18-139 $\mu g \cdot g^{-1}$ for tree barks, 17-99 $\mu g \cdot g^{-1}$ for under canopy soil samples and 18-113 $\mu g \cdot g^{-1}$ for outside tree canopy soil samples are lower than those of several urban areas in the developing world, and much lower than those of urban areas in developed countries. In Ibadan area of southwestern Nigeria, Onasanya *et al.*[5] reported mean values of between 12-312 $\mu g \cdot g^{-1}$ in leaves of some tree specie in areas of varying traffic densities. Before the use of Pb-containing gasoline was phased out in developed countries, values of between 100-300 $\mu g \cdot g^{-1}$ were reported in leaves of some trees in Canada[33]. In France, values of between 50 and 400 $\mu g \cdot g^{-1}$ were also reported[34], and in Britain between 100 to 700 $\mu g \cdot g^{-1}$[23]. These high values no doubt reflect high levels of consumption of Pb and its compounds in vehicles and generating plants in those areas. Also in Bahrain, a rapidly industrialising developing country, lead concentration of 9-420 $\mu g \cdot g^{-1}$ have been reported by Madany *et al.*[35]. In Abeokuta area of South Western Nigeria, Odukoya *et al.*[3] have reported Pb levels in barks of some tree species of between 17-659 $\mu g \cdot g^{-1}$. In Nairobi, Kenya, Odero *et al.*[31] have reported EDTA-extractable soil Pb levels of between 23-2 300 mg/kg. In Abuja, Nigeria, Kakulu[36] has studied the levels of cadmium, copper, lead, nickel and zinc in surface soil and tree barks in order to determine the atmospheric trace metal input in the area and has observed Pb levels of 281±39 $\mu g \cdot g^{-1}$ in tree bark samples and 133±32 $\mu g \cdot g^{-1}$ in soil samples. A major conclusion of the study by Kakulu[36] was that although there is an evidence of automobile emissions related elevations of levels of especially Pb and Zn in the samples analysed, the levels of the metal at Abuja were relatively low compared to levels found in some larger and older cities in various countries worldwide.

CONCLUSION

It is apparent therefore that although there is evidence of the effect of traffic density on Pb accumulation in soil and plant samples in the area under the present study, the levels are comparatively lower than those reported elsewhere in the world. However, since lead even in minute concentration is harmful and dangerous to human beings, there is an urgent need for the adoption of strategies aimed at reducing Pb emission in the area. In particular, usage of vehicles could be restricted to only those employing catalytic converters in their engines. Such converters are designed to reduce tailpipe emissions of various pollutants. Introduction of such converters-bearing vehicles would force vehicle users to resort to consumption of unleaded fuel only so as to protect the converters. This will also make the demand for leaded fuel become very low, which can consequently go a long way in discouraging its production in the country.

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