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Full Length Research Article

ASSESSMENT OF SOME HEAVY METALS ACCUMULATION IN *BORRERIA VERTICILLATA* (L.) FOUND ALONG ZARIA-GIWA ROAD, KADUNA STATE, NIGERIA

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ABSTRACT
The levels of some heavy metals (lead, cadmium, copper and zinc) were assessed in roadside soils and different organs of *Borreria verticillata* (L.) plants along Zaria-Giwa road, Kaduna state, Nigeria. The soils and plants samples were collected at distances of 0, 5, 10, 20, 40 and 100 m from the roadside at four different locations namely: Ahmadu Bello University Teaching Hospital (ABUTH), National Animal Production Research Institute (NAPRI Shika), Marabar Guga and Ahmadu Bello University Dam Quarters. The samples were digested following the standard procedure. Atomic absorption spectrophotometer (A.A.S.) was used in the determination of the metal ions concentration in the samples. The data obtained were subjected to Analysis of Variance (ANOVA) and Duncan's Multiple Range Test (DMRT) where necessary. The result showed that, the heavy metals in the soil and plant samples had higher concentration at 0 m and decreased progressively with increase in distance from the roadside. The range of the elements levels in *B. verticillata* were Pb (4.82-22.34 mg/kg), Cd (1.02-4.29 mg/kg), Cu (5.03-62.18 mg/kg) and Zn (10.22-95.05 mg/kg). Pb and Cd were above the permissible limit set by FAO/WHO. All the highest metal concentrations were observed in the roots of the plant at ABUTH except for Pb. Heavy metal concentrations in soil and plant samples from ABU Dam quarters (control) were significantly lower than those of other locations. In conclusions, distance from the roadside and vehicular densities had a significant effect on the heavy metal concentrations in the samples.

Keywords: Heavy metals, Roadside, Permissible limit, Soils, *B. verticillata,* Vehicular density.

INTRODUCTION
The term "heavy metals" refers to any metallic element with a relatively high density of approximately 4 g/cm^3, or 5 times or more, greater than water and has a characteristic poisonous ability (Lenntech, 2004) and they include lead (Pb), cadmium (Cd), zinc (Zn), mercury (Hg), arsenic (As), silver (Ag) chromium (Cr), copper (Cu) iron (Fe), and the platinum group elements.
Heavy metals are important environmental pollutants which have received great attention in developed countries in recent years from both public and scientific section by focusing on its contamination and effects on human and other living creatures (Wang *et al.,* 2005). urban roadside soils have been recognized as the major ''recipients'' of large amounts of heavy metals from a variety of sources including vehicle emissions, coal burning waste and other activities (Saeedi *et al*., 2009).

Metals are released in significant levels during different transport activities by different processes such as combustion, components wear, fluid leakage and corrosion of metal (Dolan *et al*., 2006). Contamination of agricultural soil by heavy metals has become a critical environmental concern due to their potential adverse ecological effects.

Borreria verticillata (L.) belongs to the family Rubiaceae and is commonly known as "Shrubby false button weed" or "Shrubby false button wood" (Burkill, 2000) and has many medicinal characteristics such as antipyretic and analgesic (Moreira *et al.,* 2010), inhibition of *Escherícha coli* and *Staphylococcus aureus* and treatment of various skin diseases including psoriasis, eczema, ring worm, scabies, skin itches etc. (Lisowski, 2009).

Environmental pollution has become a major problem of great concerns for both government and private sectors particularly in developing countries like Nigeria where little has been achieved in this area. Zaria-Giwa road is a very important busy highway as it serves as the major route to many important cities in north western Nigeria. There has been an increase in the density of vehicles plying the road which can eventually increase the load of vehicular emissions on the road and by extension directly affects road side soils and plants that remain in contact with these pollutants. Equally, Zaria populace are well known for their farming activities close to roadside and excessive heavy metal accumulation in agricultural land may result in elevated heavy metal uptake by plants (Garcia & Millan, 1998). According to Al-Khashman, (2007), these metals through consumption of plant produce may lead to serious health challenges. Therefore, the determination of heavy metals in environmental samples such as soils and plants is very necessary for monitoring environmental pollution. The aim of this study was to evaluate the concentrations of lead, cadmium, copper and zinc in the different organs of *Borreria verticillata* along Zaria-Giwa road.

MATERIALS AND METHODS

Description of Study Area
This study was carried out along Zaria-Giwa road. Zaria metropolis located at latitude 11° 3'N and longitude 07° 40'N. As at 2007 Census, it had a population of 1,018,827 (TWG, 2007). The major activity of the populace is farming. Four sampling locations were selected across the study and they include ABUTH, NAPRI-Shika, Maraba-guga and ABU Dam Quarters (control).

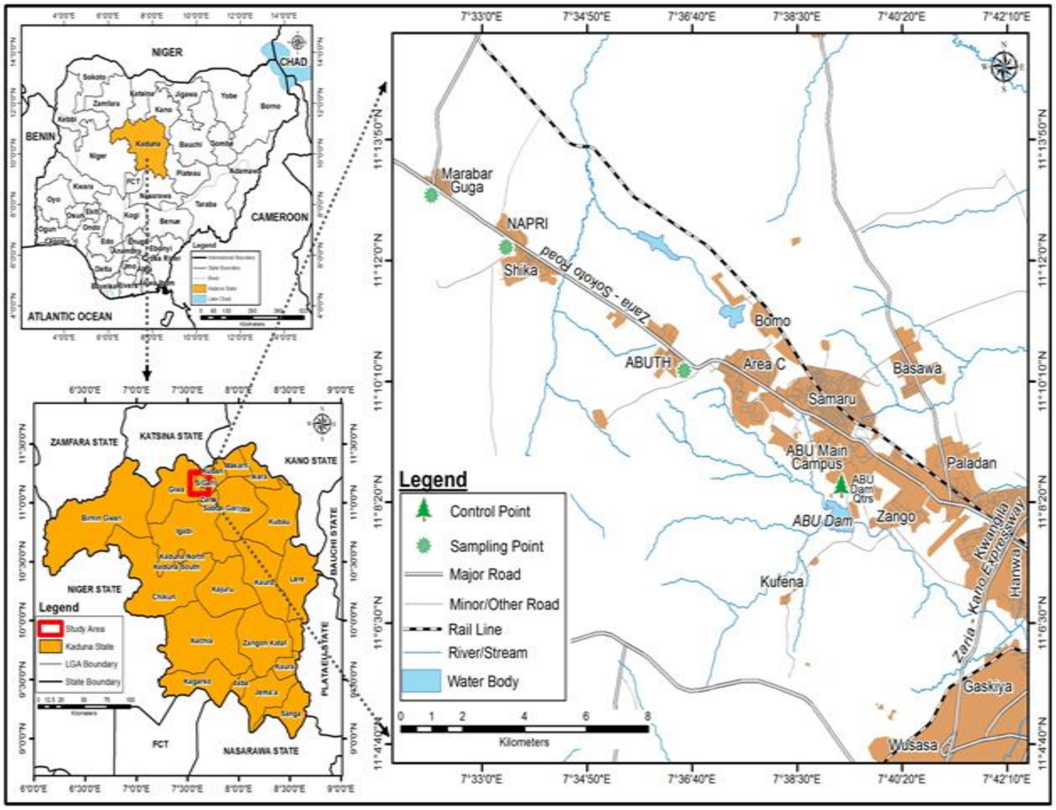

Figure 1: Map of Sabon Gari/Zaria showing Sampling Locations
Source: Modified from the Administrative Map of Sabon Gari/Zaria L.G.A

Sample Collection and Preparation

The soil and plant materials of *Borreria verticillata* were collected from four different sampling locations along Zaria-Giwa road and along Ahmadu Bello University Dam Quarters, namely: Ahmadu Bello University Teaching Hospital (ABUTH-Shika), National Animal Production Research Institute (NAPRI-Shika), Maraba-guga and ABU Dam Quarters (control). The interval of separation between the sampling areas is about 3-5 km. Samples were collected at each of the sampling location at a distance of 0, 5, 10, 20, 40 and 100 m away from the edge of the road. At each sampling point, three topsoil samples were collected at a depth of 0-5 cm and thoroughly mixed to form a composite sample, and transferred immediately into labeled polythene bags. Equally, whole plant of *Borreria verticillata* was carefully uprooted and labeled with a masking tape. Both samples were transported to the laboratory in the Department of Biology, A B U, Zaria where the samples were washed with tap water and rinsed with distilled water. This was followed by cutting of the samples with a clean knife into different parts (roots, stems and leaves). The samples in labeled envelopes were transferred into oven set at 70 ^{0}C and allowed to dry to constant weight before grounding to powdered form (Nuonom *et al.,* 2000).

Digestion and Estimation of Heavy Metal Concentrations in *B. verticillata* and Roadside Soils

Samples were digested at the Analytical Research Laboratory in the Department of Agronomy, A B U, Zaria. Soil and plant samples were digested using the method of Ogunfowokan *et al.* (2009) and (Erwin & Ivo, 1992) respectively. About 0.5 g of the powdered plant samples was mixed with 20 mL of the acid mixture containing concentrated sulphuric acid, perchloric acid and concentrated nitric acid in ratio of 1:4:40 by volume respectively. Thereafter the flasks were heated moderately at 70 ^{o}C for about 40 mins. Then the heat was increased to 120 ^{o}C. The mixture turned black for a while after which the solution became clear and white fumes appear signifying the end of digestion. After cooling, the sample solutions were then filtered through a whatman no. 1 filter paper into 50 ml volumetric flask and diluted up to the mark with distilled water. The Cd, Pb, Cu and Zn concentrations in the soil and plant samples were determined using Atomic Absorption Spectrophotometer (AAS) at the Multi User Science Laboratory, Department of Chemistry, A B U, Zaria.

Determination of Vehicular Density

Visual counting of vehicles plying the entire sampling sites including the control site was done for 2 hours daily for a period of one week and the average vehicular density per hour was computed (Akpan & William, 2014)

Determination of Transfer Factor

The Transfer factor (TF) of the heavy metals from soils to the leaves of *Borreria verticillata* was computed in order to assess the extent of transfer of soil heavy metals into the plant. The transfer factor for the plant was calculated following the method of

Lokeshwari and Chandrappa (2006) as follows: TF = $\frac{\text{C leaves (mg/kg)}}{\text{C soil (mg/kg)}}$ Where C leaves and C soil represent the concentrations of the metal in the leaves and soils respectively.

Statistical Analysis
The means of the data obtained for heavy metal concentrations were subjected to Analysis of variance (ANOVA) using SAS version 9.1. Where there was significant difference in means, Duncan's multiple range test (DMRT) at (P≤0.05) was used to separate the means.

RESULTS

Heavy Metal Concentrations in Roadside Soils of the Study Area
The concentrations of all the elements were observed to decrease with increase in distance from the road with the highest and lowest concentrations recorded at 0 and 100 m respectively in most cases (Table 1). However, with respect to locations, ABUTH showed higher concentrations for all the elements with the exception of Cu, while that, at ABU Dam site (control) was significantly lower than those of all the other locations (Table 2). The concentrations of the elements in the roadside soil were in the order of: Pb > Zn > Cu > Cd

Table 1: Heavy Metal Concentrations of Roadside Soils based on distance across the study area

Source	Distance (m)	Heavy metal Concentrations (mg/kg) Pb	Cd	Cu	Zn
Soil	0	63.76ᵃ	2.73ᵃ	42.39ᵃ	43.05ᵃ
	5	62.66ᵃ	2.58ᵃ	18.78ᵇ	27.87ᵇ
	10	54.37ᵇ	2.33ᵃ	10.79ᶜ	23.38ᶜ
	20	47.93ᶜ	2.28ᵃ	10.09ᶜ	17.58ᵈ
	40	44.12ᶜᵈ	2.28ᵃ	8.78ᶜ	15.06ᵉ
	100	40.10ᵈ	1.71ᵇ	6.17ᵈ	14.11ᵉ
	Mean	**52.16**	**2.32**	**16.17**	**23.51**
	SEM±	**4.91**	**0.58**	**3.12**	**3.00**
	P value	**0.000****	**0.002****	**0.000****	**0.000****

NB: Means with the same letter(s) within each column are not significantly different (P≤0.05), using DMRT. ns= non-significant *=significant at P<0.05 **= highly significant at P<0.01.

Table 2: Heavy Metal Concentrations of Roadside Soil across the study area.

Source	Location	Heavy metal Concentrations (mg/kg) Pb	Cd	Cu	Zn
Soil	ABUTH	64.35ᵃ	3.33ᵃ	21.85ᵃ	23.64ᵇ
	NAPRI Shika	55.86ᵇ	2.35ᵇ	23.24ᵃ	23.25ᵇ
	Marabar Guga	52.98ᵇ	2.39ᵇ	12.18ᵇ	27.22ᵃ
	ABU Dam Quarters	35.44ᶜ	1.20ᶜ	7.39ᶜ	19.93ᶜ
	Mean	**52.16**	**2.32**	**16.17**	**23.51**
	SEM±	**4.91**	**0.58**	**3.12**	**3.00**
	P value	**0.000****	**0.000****	**0.000****	**0.000****

NB: Means with the same letter(s) within each column are not significantly different (P≤0.05), using DMRT. ns= non-significant *=significant at P<0.05 **= highly significant at P<0.01.

Heavy Metal Concentrations in the Roots, Stems and Leaves of *B. verticillata*
In all the organs of *B. verticillata,* the concentrations of elements were generally observed to decrease with increase in distance from the roadside as the highest and lowest concentrations of all the heavy metals were observed at 0 and 100 m from the roadside in most cases. The concentrations of heavy metals in *B. verticillata,* roots were in the order of: Zn > Cu > Pb > Cd while that of stems and leaves were in the order of Zn > Pb > Cu > Cd.

Lead Level in the Roots, Stems and Leaves of *B. verticillata*
The level of lead at 0 m in *B. verticillata* roots was significantly higher than those recorded at all the other distances in all locations except that it was comparable to 5 and 10 m at NAPRI Shika and 5, 10 and 20 m at Marabar Guga. Also, the lowest concentration at 100 m was significantly lower than all the other distances in each location except at ABUTH and NAPRI Shika were it was comparable with the value recorded at 40 m from the roadside (Table 3).

In the stems of *B. verticillata*, the lead recorded at 0 m was significantly higher than all other distances in all the locations except ABU Dam quarters were it was only significantly higher than the least concentration at 100 m. Although, it was comparable with that observed at 5 m at ABUTH and Marabar Guga. (Table 4). Also, in the leaves of *B. verticillata*, the concentrations of lead at 0 m at each location was significantly higher than all other distances with the exception of Marabar Guga were it was comparable with those at 5 and 10 m. The least lead level which occurred at 100 m was comparable with that at 40 m at Marabar Guga and those at 20 and 40 m at NAPRI Shika and ABU Dam quarters (Table 5).

The pooled data analysis of lead level in all the organs of *B. verticillata* with respect to distance revealed that, there was high significant difference among each distance from 0 to 100 m with the highest and lowest concentration of Pb recorded at 0 and 100 m respectively (Table 6).

The data analysis based on locations showed that, the highest concentration of Pb in *B. verticillata* roots and leaves were recorded at Marabar Guga while that of stems was at NAPRI Shika and they were all significantly higher than other locations. However, the highest level for stems and roots were comparable to that observed at ABUTH. Also, the least concentrations of Pb recorded at ABU Dam quarters in all the plant organs were significantly lower than all other locations in the study area (Table 7).

Cadmium Level in the Roots, Stems and Leaves of *B. verticillata*
Cadmium level in the roots and stems followed similar pattern in the sense that the highest concentration recorded at 0 m was significantly higher than all other distances at each of the locations except ABU Dam quarters where it was comparable with the values observed at 5, 10 and 20 m. the lowest concentration observed at 100 m in the two organs was comparable with those at 10, 20 and 40 m at ABUTH and NAPRI Shika. However, the least concentration at 100 m observed in the roots at Marabar Guga was only significantly lower than the highest concentration recorded at 0 m from the roadside (Table 3 and 4). Also, the highest concentration of Cd observed at 0 m in the leaves was significantly higher than all other distances at each location but comparable with

those at 5 m at NAPRI Shika and ABU Dam quarters and 5 and 10 m at Marabar Guga. However, the least concentration recorded at 100 m in all the locations was only significantly lower to the highest concentration at 0 m at ABUTH but comparable with those observed at 20 and 40 m at NAPRI Shika and Marabar Guga (Table 5).

The pooled data based on distance showed that, the Cd level recorded at 0 m in all the organs was significantly higher than all other distances from the roadside. The least concentration recorded at 100 m was significantly lower than all other distances in the stem but comparable with those at 10, 20 and 40 m in the roots and 20 and 40 m in the leaves (Table 6). The data based on location showed that, the highest concentration at ABUTH was significantly higher than all other locations in the roots but comparable with that at NAPRI Shika in the stems. Also, the least concentration at ABU Dam quarters was significantly lower than all other locations in all the organs of the plant (Table 7).

Table 3: Heavy Metal Concentrations in the roots of *Borreria verticillita* across the study area

Location	**Distance (m)**	**Heavy metal Concentrations (mg/kg)**			
		Pb	**Cd**	**Cu**	**Zn**
ABUTH	0	26.85^{a}	9.23^{a}	106.70^{a}	123.81^{a}
	5	17.22^{b}	5.98^{b}	79.20^{b}	122.32^{a}
	10	15.91^{bc}	2.91^{c}	61.91^{c}	98.22^{b}
	20	15.82^{bc}	2.72^{c}	61.85^{c}	91.61^{b}
	40	12.12^{cd}	2.72^{c}	42.12^{d}	75.41^{c}
	100	11.32^{d}	2.22^{c}	21.30^{e}	58.91^{d}
	Mean	**16.54**	**4.29**	**62.18**	**95.05**
	SEM±	**2.24**	**1.08**	**6.34**	**6.78**
	P value	**0.000****	**0.000****	**0.000****	**0.000****
NAPRI Shika	0	18.66^{a}	7.49^{a}	45.52^{a}	97.82^{a}
	5	17.34^{ab}	5.45^{b}	25.03^{b}	83.77^{b}
	10	17.34^{ab}	2.11^{c}	25.01^{b}	82.01^{b}
	20	14.62^{bc}	2.02^{c}	16.65^{c}	77.11^{c}
	40	11.92^{c}	2.01^{c}	8.32^{d}	68.20^{c}
	100	11.92^{c}	1.56^{c}	6.22^{d}	27.22^{d}
	Mean	**15.30**	**3.44**	**21.13**	**72.69**
	SEM±	**1.64**	**0.79**	**1.42**	**5.75**
	P value	**0.001****	**0.000****	**0.000****	**0.000****
Marabar Guga	0	21.22^{a}	7.11^{a}	14.21^{a}	92.59^{a}
	5	18.22^{ab}	3.51^{b}	8.92^{b}	88.23^{ab}
	10	17.82^{ab}	2.45^{b}	8.91^{b}	90.71^{ab}
	20	17.82^{ab}	2.45^{b}	7.88^{b}	85.56^{b}
	40	15.88^{b}	2.08^{b}	7.87^{b}	85.42^{b}
	100	10.52^{c}	1.91^{b}	4.02^{c}	30.22^{c}
	Mean	**16.91**	**3.25**	**8.64**	**78.79**
	SEM±	**1.77**	**0.89**	**0.67**	**3.49**
	P value	**0.000****	**0.000****	**0.000****	**0.000****
ABU Dam Quarters	0	11.66^{a}	1.81^{a}	8.61^{a}	17.61^{a}
	5	8.33^{b}	1.75^{a}	6.51^{b}	14.22^{b}
	10	8.22^{b}	1.21^{ab}	6.20^{b}	12.66^{bc}
	20	5.62^{c}	1.21^{ab}	5.61^{b}	12.31^{c}
	40	5.38^{c}	0.95^{bc}	5.22^{b}	10.41^{d}
	100	3.33^{d}	0.45^{c}	3.33^{c}	8.50^{e}
	Mean	**7.09**	**1.23**	**5.91**	**12.62**
	SEM±	**0.62**	**0.37**	**0.79**	**0.97**
	P value	**0.000****	**0.011***	**0.000****	**0.000****

NB: Means with the same letter(s) within each column, at each site are not significantly different ($P \leq 0.05$), using DMRT. ns= non-significant *=significant at $P<0.05$ **= highly significant at $P<0.01$.

Table 4: Heavy Metal Concentrations in the stems of *Borreria verticillita* across the study area.

Location	**Distance (m)**	**Heavy metal concentrations (mg/kg)**			
		Pb	**Cd**	**Cu**	**Zn**
ABUTH	0	24.76^{a}	7.22^{a}	53.11^{a}	113.11^{a}
	5	24.48^{a}	2.84^{b}	18.21^{b}	85.71^{b}
	10	18.43^{b}	2.45^{bc}	15.35^{c}	79.51^{bcd}
	20	15.02^{bc}	2.39^{bc}	15.16^{c}	81.23^{bc}
	40	15.24^{bc}	2.41^{bc}	14.93^{c}	74.91^{cd}
	100	12.40^{c}	1.51^{c}	12.44^{c}	72.10^{d}
	Mean	**18.39**	**3.14**	**21.53**	**84.43**
	SEM±	**1.82**	**0.66**	**1.57**	**4.66**
	P value	**0.000****	**0.000****	**0.000****	**0.000****
NAPRI Shika	0	25.91^{a}	7.12^{a}	18.55^{a}	92.20^{a}
	5	22.88^{b}	5.11^{b}	10.81^{b}	58.65^{b}
	10	22.55^{b}	1.96^{c}	10.78^{b}	51.22^{bc}
	20	21.89^{b}	1.31^{c}	7.72^{c}	45.50^{c}
	40	11.99^{c}	1.92^{c}	7.51^{c}	34.51^{d}
	100	9.02^{d}	1.04^{c}	3.23^{d}	25.51^{e}
	Mean	**19.04**	**3.08**	**9.77**	**51.27**
	SEM±	**0.98**	**0.50**	**0.94**	**4.62**
	P value	**0.000****	**0.000****	**0.000****	**0.000****
Marabar Guga	0	25.21^{a}	4.41^{a}	12.89^{a}	80.42^{a}
	5	23.34^{a}	2.34^{b}	8.32^{b}	56.55^{b}
	10	20.22^{b}	1.91^{bc}	5.91^{c}	52.55^{c}
	20	15.11^{c}	1.59^{c}	5.24^{c}	43.84^{d}
	40	12.11^{d}	1.47^{cd}	5.45^{c}	43.56^{d}
	100	8.03^{e}	0.98^{d}	3.17^{d}	25.11^{e}
	Mean	**17.34**	**2.12**	**6.83**	**50.34**
	SEM±	**1.14**	**0.29**	**0.52**	**1.12**
	P value	**0.000****	**0.000****	**0.000****	**0.000****
ABU Dam Quarters	0	5.66^{a}	1.91^{a}	5.95^{a}	11.54^{a}
	5	5.66^{a}	1.78^{a}	5.62^{a}	11.33^{a}
	10	5.47^{a}	1.68^{a}	5.54^{a}	11.15^{a}
	20	5.47^{a}	1.65^{a}	5.62^{a}	9.91^{b}
	40	4.55^{a}	0.95^{b}	4.51^{b}	9.16^{bc}
	100	2.11^{b}	0.45^{c}	4.21^{b}	8.22^{c}
	Mean	**4.82**	**1.40**	**5.24**	**10.22**
	SEM±	**0.90**	**0.27**	**0.56**	**0.68**
	P value	**0.004****	**0.000****	**0.017***	**0.000****

NB: Means with the same letter(s) within each column, at each site are not significantly different ($P \leq 0.05$), using DMRT. ns= non-significant *=significant at $P<0.05$ **= highly significant at $P<0.01$.

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Table 5: Heavy Metal Concentrations in the leaves of *Borreria verticillata* across the study area

Location	Distance (m)	Heavy metal concentrations (mg/kg) Pb	Cd	Cu	Zn
ABUTH	0	18.42^{a}	5.75^{a}	57.41^{a}	77.81^{a}
	5	14.76^{bc}	2.22^{b}	18.88^{b}	63.55^{b}
	10	15.61^{b}	2.11^{b}	15.60^{c}	58.88^{c}
	20	13.61^{c}	2.22^{b}	14.45^{c}	55.23^{c}
	40	13.51^{c}	2.11^{b}	14.35^{c}	49.32^{d}
	100	10.11^{d}	2.01^{b}	3.66^{d}	45.10^{d}
	Mean	**14.34**	**2.74**	**20.72**	**58.32**
	SEM±	**0.96**	**0.59**	**1.72**	**2.35**
	P value	**0.000****	**0.000****	**0.000****	**0.000****
NAPRI Shika	0	40.88^{a}	7.52^{a}	22.65^{a}	72.31^{a}
	5	15.93^{b}	7.45^{a}	15.51^{b}	60.91^{ab}
	10	15.83^{b}	2.92^{b}	10.71^{c}	70.45^{ab}
	20	10.08^{c}	1.53^{c}	9.62^{c}	60.45^{ab}
	40	9.68^{c}	1.22^{c}	9.49^{c}	56.65^{b}
	100	7.71^{c}	0.88^{c}	9.42^{c}	21.11^{c}
	Mean	**16.68**	**3.59**	**12.90**	**56.98**
	SEM±	**1.71**	**0.59**	**1.11**	**7.57**
	P value	**0.000****	**0.000****	**0.000****	**0.000****
Marabar Guga	0	27.93^{a}	1.88^{a}	7.93^{a}	48.83^{a}
	5	25.92^{ab}	1.66^{ab}	6.73^{ab}	25.41^{b}
	10	25.48^{ab}	1.67^{ab}	6.39^{ab}	25.41^{b}
	20	22.92^{b}	1.18^{bc}	5.92^{b}	22.43^{bc}
	40	15.99^{c}	1.01^{bc}	2.22^{c}	19.51^{c}
	100	15.81^{c}	0.98^{c}	1.22^{c}	10.22^{d}
	Mean	**22.34**	**1.39**	**5.07**	**25.30**
	SEM±	**1.95**	**0.35**	**0.94**	**2.78**
	P value	**0.000****	**0.036***	**0.000****	**0.000****
ABU Dam Quarters	0	18.66^{a}	1.55^{a}	6.50^{a}	19.61^{a}
	5	16.11^{b}	1.45^{a}	6.34^{a}	18.62^{a}
	10	8.55^{c}	1.01^{b}	5.42^{ab}	12.19^{b}
	20	5.83^{d}	1.01^{b}	4.77^{ab}	12.19^{b}
	40	5.56^{d}	0.66^{c}	4.44^{b}	10.22^{c}
	100	3.95^{d}	0.46^{c}	2.70^{c}	8.10^{d}
	Mean	**9.78**	**1.02**	**5.03**	**13.49**
	SEM±	**1.35**	**0.17**	**0.91**	**1.01**
	P value	**0.000****	**0.000****	**0.005****	**0.000****

NB: Means with the same letter(s) within each column, at each site are not significantly different ($P \leq 0.05$), using DMRT. ns= non-significant *=significant at $P<0.05$ **= highly significant at $P<0.01$

Table 6: Heavy metal concentrations in the different organs of *Borreria verticillata* based on distance from the roadside

Source	Distance (m)	Heavy metal Concentrations (mg/kg) Pb	Cd	Cu	Zn
Roots	0	19.59^{a}	6.41^{a}	43.76^{a}	82.96^{a}
	5	15.28^{b}	4.17^{b}	29.92^{b}	77.14^{b}
	10	14.82^{bc}	2.17^{c}	25.51^{c}	70.90^{c}
	20	13.47^{c}	2.10^{c}	22.99^{c}	66.61^{d}
	40	11.32^{d}	1.94^{c}	15.88^{d}	59.89^{e}
	100	9.27^{e}	1.54^{c}	8.72^{e}	31.21^{f}
	Mean	13.96	3.05	24.46	64.79
	SEM±	1.68	0.89	3.54	4.80
	P value	0.000**	0.000**	0.000**	0.000**
Stem	0	20.39^{a}	5.17^{a}	22.54^{a}	74.27^{a}
	5	19.04^{b}	2.92^{b}	10.82^{b}	53.11^{b}
	10	16.67^{c}	2.09^{c}	9.40^{c}	48.61^{c}
	20	14.42^{d}	1.74^{cd}	8.44^{cd}	45.05^{d}
	40	10.97^{e}	1.69^{d}	8.09^{d}	40.61^{e}
	100	7.89^{f}	0.99^{e}	5.76^{e}	32.74^{f}
	Mean	14.89	2.43	10.84	49.06
	SEM±	1.33	0.44	1.21	3.57
	P value	0.000**	0.000**	0.000**	0.000**
Leaves	0	26.47^{a}	4.18^{a}	23.62^{a}	54.64^{a}
	5	18.18^{b}	3.19^{b}	11.87^{b}	42.12^{b}
	10	16.38^{c}	1.93^{c}	9.53^{c}	41.73^{b}
	20	13.04^{d}	1.49^{cd}	8.67^{cd}	37.58^{c}
	40	11.25^{e}	1.25^{d}	7.65^{d}	33.93^{d}
	100	9.39^{f}	1.08^{d}	4.25^{e}	21.13^{e}
	Mean	15.78	2.19	10.93	38.52
	SEM±	1.49	0.55	1.29	4.28
	P value	0.000**	0.000**	0.000**	0.000**

NB: Means with the same letter(s) within each column, at each site are not significantly different ($P \leq 0.05$), using DMRT. ns= non-significant *=significant at $P<0.05$ **= highly significant at $P<0.01$

Table 7: Heavy metal concentrations in different organs of *Borreria verticillata* based on locations across the study area

Source	Location	Heavy metal Concentrations (mg/kg) Pb	Cd	Cu	Zn
Root	ABUTH	16.54^{a}	4.29^{a}	62.18^{a}	95.05^{a}
	NAPRI Shika	15.30^{b}	3.44^{b}	21.13^{b}	78.79^{b}
	Marabar Guga	16.91^{a}	3.25^{b}	8.63^{c}	72.69^{c}
	ABU Dam Quarters	7.09^{c}	1.23^{c}	5.91^{d}	12.62^{d}
	Mean	13.96	3.05	24.46	64.79
	SEM±	1.68	0.83	3.54	4.80
	P value	0.000**	0.000**	0.000**	0.000**
Stem	ABUTH	18.39^{a}	3.14^{a}	21.53^{a}	84.43^{a}
	NAPRI Shika	19.04^{a}	3.08^{a}	9.77^{b}	51.27^{b}
	Marabar Guga	17.34^{b}	2.12^{b}	6.83^{c}	50.34^{b}
	ABU Dam Quarters	4.82^{c}	1.40^{c}	5.24^{d}	10.22^{c}
	Mean	14.89	2.43	10.84	49.06
	SEM±	1.33	0.44	1.21	3.57
	P value	0.000**	0.000**	0.000**	0.000**
Leaves	ABUTH	14.34^{c}	2.74^{b}	20.72^{a}	58.32^{a}
	NAPRI Shika	16.68^{b}	3.59^{a}	12.90^{b}	56.98^{a}
	Marabar Guga	22.34^{a}	1.39^{c}	5.07^{c}	25.30^{b}
	ABU Dam Quarters	9.78^{d}	1.02^{d}	5.03^{c}	13.49^{c}
	Mean	15.78	2.19	10.93	38.52
	SEM±	1.49	0.55	1.29	4.28
	P value	0.000**	0.000**	0.000**	0.000**

NB: Means with the same letter(s) within each column, at each site are not significantly different ($P \leq 0.05$), using DMRT. ns= non-significant *=significant at $P<0.05$ **= highly significant at $P<0.01$

Copper Level in the Roots, Stems and Leaves of *B. verticillata*

The highest copper concentration in *B. verticillata* roots and stems recorded at 0 m was significantly higher than all the other distances from the roadside in all the locations except ABU Dam quarters where it was comparable with those at 5, 10 and 20 m in the stems. Also, the least concentration at 100 m in all the locations was significantly lower than all other distances except that it was comparable with those at 10, 20 and 40 m at ABUTH and 40 m at Abu Dam quarters in the stems of the plant (Table 3 and 4). However, in the leaves of B. *verticillata,* the concentration at 0 m was significantly higher than all other distances in all the locations except that it was comparable with those at 5 and 10 m at Marabar Guga and 5, 10 and 20 m in ABU Dam quarters. The least concentration at 100 m was comparable with those at 10, 20 and 40 m at NAPRI Shika and that at 40 m in Marabar Guga but significantly lower than all other distances in other locations (Table 5).

The pooled data analysis of Cu level in all the organs of *B. verticillata* based on distance revealed that, there was high significant difference among each distance from 0 to 100 m with the highest and lowest concentration of Pb recorded at 0 and 100 m respectively. However, the value at 40 m was comparable to that at 20 m in the stems and leaves of the plant (Table 6). Also, the pooled data based on locations showed that, the concentration at ABUTH was significantly higher than all other locations in all the organs, while the least concentration at ABU Dam quarters was significantly lower than all other locations but comparable to that at Marabar Guga in the leaves of *B. verticillata* (Table 7).

Zinc Level in the Roots, Stems and Leaves of *B. verticillata*

The highest concentration of zinc at 0 m in *B. verticillata* roots was significantly higher than all other distances in all the locations except that it was similar to that at 5 m at ABUTH and 5 and 10 m at Marabar Guga (Table 3). In the stems, the concentration was equally significantly higher than all other distances except that it was comparable to those at 5 and 10 m at ABU Dam quarters (Table 4) However, the highest concentration at 0 m was only comparable with those at 5, 10 and 20 m at NAPRI Shika and 5 m at ABU Dam quarters in the leaves (Table 5). The least concentration observed at 100 m was significantly lower than all other distances in all the organs of *B. verticillata* except that it was similar to that at 40 m a in the stems and leaves of the plant.

The pooled data analysis of Zn level in all the organs of *B. verticillata* based on distance revealed that, there was high significant difference among each distances from 0 to 100 m with the highest and lowest concentration of Pb recorded at 0 and 100 m respectively (Table 6). Also, the pooled data based on locations showed that, the concentration at ABUTH was significantly higher than all other locations in all the organs but comparable with that at NAPRI Shika in the leaves, while the least concentration at ABU Dam quarters was significantly lower than all other locations in the study area (Table 7).

Vehicular Density

In general, the overall highest vehicular density of 1105 per hour was observed at ABUTH while ABU Dam Quarters (Control) had 46 vehicular density per hour (Table 8).

Transfer factor of soil heavy metals into the Leaves of *B. verticillata*

Table 9 shows the Transfer factor of soil heavy metals into the Leaves of *B. verticillata.* Generally, among the elements, Zinc and lead showed the highest and lowest bio-concentration factor of 2.47 and 0.22 in *B. verticillata* respectively. Bio-concentration factor (BCF) >1 indicates heavy metal accumulators.

Correlation between heavy metals in the soil and the different organs of *B. verticillata*

The correlations matrix of the heavy metals in the soil and the different organs of *B. verticillata* showed positive correlation for all the elements between the soil and all the organs of the plant. The soil Pb was strongly and positively correlated to the concentration of Pb in the leaves, stems and roots, this was also the case for Cu. Soil Cd was moderately correlated to the different organs of the plant. However, the relationship between soil and the organs of the plant with respect to zinc concentration was weak (Table 10).

Table 8: Vehicular density and GPRS across sampled locations in the study area.

Location	Vehicular density/hr.	Latitude	Longitude
ABUTH	1105	11°10'28.52"N	7°36'31.70"E
NAPRI Shika	893	11°12'15.35"N	7°33'31.98"E
Marabar guga	834	11°13'5.52"N	7°32'8.16"E
ABU Dam Quarters	46	11° 8'35.13"N	7°39'16.06"E

Table 9: Transfer factor of soil heavy metals into the leaves of *B. verticillata*

		Transfer Factor			
Plant (leaves)	location	Pb	Cd	Cu	Zn
B. verticillata	ABUTH	0.22	0.82	0.95	2.47
	NAPRI Shika	0.30	1.53	0.56	2.45
	Marabar guga	0.42	0.58	0.42	0.93
	ABU Dam Quarters	0.28	0.85	0.68	0.68

NB: Plants with TF>1 denotes metal accumulators

Table 10: Correlation of heavy metals between soils and different organs of *B. verticillata*

Var	Pb_LB	Cd_LB	Cu_LB	Zn_LB	Pb_SB	Cd_SB	Cu_SB	Zn_SB	Pb_RB	Cd_RB	Cu_RB	Zn_RB	Pb_S	Cd_S	Cu_S	Zn_S
Pb_LB	1															
Cd_LB	0.800**	1														
Cu_LB	0.806**	0.809**	1													
Zn_LB	0.822**	0.730**	0.698**	1												
Pb_SB	0.768**	0.640**	0.538**	0.792**	1											
Cd_SB	0.790**	0.706**	0.772**	0.684**	0.668**	1										
Cu_SB	0.791**	0.803**	0.959**	0.692**	0.546**	0.755**	1									
Zn_SB	0.777**	0.743**	0.692**	0.836**	0.831**	0.699**	0.759**	1								
Pb_RB	0.803**	0.624**	0.640**	0.682**	0.859**	0.691**	0.649**	0.798**	1							
Cd_RB	0.820**	0.804**	0.747**	0.677**	0.729**	0.841**	0.757**	0.773**	0.751**	1						
Cu_RB	0.761**	0.850**	0.859**	0.755**	0.558**	0.619**	0.877**	0.813**	0.588**	0.664**	1					
Zn_RB	0.714**	0.660**	0.570**	0.782**	0.891**	0.570**	0.603**	0.898**	0.845**	0.683**	0.681**	1				
Pb_S	**0.823****	0.832**	0.743**	0.727**	**0.827****	0.633**	0.734**	0.777**	**0.811****	0.754**	0.756**	0.828**	1			
Cd_S	0.658**	**0.594****	0.566**	0.719**	0.736**	**0.538****	0.615**	0.798**	0.698**	**0.549****	0.699**	0.793**	0.721**	1		
Cu_S	0.725**	0.761**	**0.865****	0.618**	0.579**	0.868**	**0.816****	0.616**	0.626**	0.790**	**0.643****	0.535**	0.678**	0.432**	1	
Zn_S	0.557**	0.401**	0.444**	**0.254***	0.488**	0.647**	0.449**	**0.328****	0.518**	0.604**	0.206	**0.282***	0.426**	0.222	0.620**	1

NB: Values with (*) and (**) are significantly different at P≤0.05 and P≤0.01 respectively.
Pb= Lead, Cd= Cadmium, Cu= Copper, Zn= Zinc
LB=Leaves of *B. verticillata,* SB= Stems of *B. verticillata*, RB= Roots of *B. verticillata*, S= Soil

DISCUSSION

Concentration of heavy metals in roadside soils and Organs of *B. verticillata*

The high level of elements recorded in soil could be from the automobile exhaust which is as a result of the presence of these elements in fuel and lubricating oils (Atayese *et al.,* 2009). They are released from vehicular emissions in the form of gaseous particulate matter into the atmosphere which eventually dissolves and fall as rain. This observation suggests that, roadside soils may be contaminated from anthropogenic activities such as vehicle exhaust and fuel combustion. However, sites with less concentrations of metal may be attributed to the less vehicular density recorded in such locations.

The combined data on these heavy metals analyzed in the different organs of the plant based on distance from roadside showed that, Pb, Cd, Cu and Zn level decreased significantly with increasing distance from the road in the roots, stems and leaves of *B. verticillata*. This is an indication that, the distribution of these metals in the environment is strongly but inversely correlated with the increase in the distance from road (Werkenthin *et al.,* 2014).

Lead Concentration in different organs of *B. verticillata*

The range of Lead level for *B. verticillata* was found highest in the leaves which ranged from 9.78-22.34 mg/kg and these concentrations were in the order of Marabar Guga > NAPRI Shika > ABUTH > ABU Dam Quarters. However, the lowest was found in the roots which ranged from 7.09-16.91 mg/kg with the concentrations in the order of Marabar Guga > ABUTH > NAPRI Shika > ABU Dam Quarters. From the distribution of this element with respect to location, it was observed that there is a strong and direct relationship between the concentrations of Pb and vehicular densities. This high Pb level may be attributed to vehicular emissions since there was no other visible source of pollution in the study area and this conforms to the report of Tuzen (2003) who reported that Pb pollution in roadside environmental samples comes from combustion of gasoline that contains tetraethyl lead as anti-knock agent. The installation of catalytic converter in some vehicles is another source of Pb into the environment due to abrasion within the vehicular components (Zereni & Alt, 2000). All these values are above the standard safe limit of 0.3 mg/kg as recommended by WHO/FAO (2001). Comparing these values with others, it was observed to be lower than the mean values reported by Omale, (2010) who recorded 30-40 mg/kg in leaves of *Saba florida* in Nigeria. However, the values were higher than that observed in a study by Adu *et al.* (2012) who recorded 0.043 mg/kg and 0.007 mg/kg of Pb in the root and leaf of *Lactuca sativa* respectively.

Cadmium Concentration in the different organs of *B. verticillita*

The range of cadmium level for *B. verticillata* was found highest in the roots (1.23- 4.29mg/kg) in the order of ABUTH > NAPRI Shika > Marabar Guga > ABU Dam Quarters and lowest in the stems (1.40-3.14mg/kg) in the order of ABUTH > NAPRI Shika > Marabar Guga > ABU Dam Quarters. All these values are above the standard safe limit of 0.2 mg/kg recommended by WHO/FAO (2001). These concentrations observed in the different organs of the plant were consistent with vehicular densities. The source of this Cd may be attributed to lubricants, wearing of paints on vehicles bodies as well as tear and wear of tyres (Ogbonna & Okezie, 2011). The observed high level of this element in the root organ may be due to the fact that, roots are the major entry point of heavy metals that ultimately affects different physiological processes, therefore high level of this metal accumulate in the top layer of the soil which are accessible for uptake by the roots of plants. Comparing these values with other studies, it was observed to be lower than the mean value of plant obtained by Uba *et al.* (2008) (5.95- 65.48 mg/kg) but higher than those reported by Afshin *et al*. (2008) (0.20-0.65 mg/kg).

Copper Concentration in the different organs of *B. verticillita*

The data revealed that, the range of copper level for *B. verticillata* was found highest in the roots (5.91- 62.18 mg/kg) in the order of ABUTH > NAPRI Shika > Marabar Guga > ABU Dam Quarters and lowest in the leaves (5.03-20.72mg/kg) ABUTH > NAPRI Shika > Marabar Guga > ABU Dam Quarters. All the values were below the standard safe limit of 73.30 mg/kg recommended by WHO/FAO (2001). These concentrations observed in the different organs of the plants were consistent with vehicular densities, the high values observed in the organs of *B. verticillata* may be due to vehicular pollution which is in tandem with the report of Hassan (2013), who related high concentration of copper to increased vehicular pollution. Also, the level of copper observed in the roadside soil may be derived from engine wear and electrical wirings as well as spillage of lubricants from vehicles which are eventually washed down by runoff into surrounding environment. Cu concentrations observed in this study were lower than the mean value of Cu in plant as reported by 28.55 to 115.2 mg/kg in plant reported by Ogundele *et al.* (2015) in a similar study. However, the results were higher when compared to Adu *et al.* (2012) who recorded mean values of 0.051 mg/kg and 0.015 mg/kg of Cu in roots and leaves of *Lactuca sativa* respectively.

Zinc Concentration in the different organs of *B. verticillita*

The mean values of zinc recorded in the plant were higher than all other heavy metals assessed in this study and this could be ascribed to vehicle body paints, automobile exhaust, as well as lubricating oils (Adriano, 2001) that are deposited on the different organs of the plant. The range of zinc level for *B. verticillata* was found highest in the roots (12.62- 95.05 mg/kg) in the order of ABUTH > NAPRI Shika > Marabar Guga > ABU Dam Quarters and lowest in the leaves (13.49-58.32 mg/kg) in the order of ABUTH > NAPRI Shika > Marabar Guga > ABU Dam Quarters. However, the highest concentrations in most of the study areas were below the standard safe limit of 99.40 mg/kg recommended by WHO/FAO (2001). The observed high level of zinc in the roots of this plant may be due to the fact that zinc metals are actively absorbed from the soil by roots before it is eventually translocated to other parts of the plant. Comparing this result with others, it was found to be lower than 23.91-147.8 mg/kg recorded in plants in a similar study by Ogundele *et al.* (2015) but higher than 0.02-0.06 mg/g in *Saba florida* in Nigeria (Omale, 2010).

Transfer Factor/ Bio-concentration Factor of Heavy Metals

Generally, the result showed that, Bio-concentration Factor (BCF) value was in the order of Zn > Cd > Cu> Pb. This observation shows that, among all the metals studied, Zinc is easiest to migrate. This observation contradicts Mbong *et al*. (2014) who reported that, Pb had the highest bio-concentration value than all other heavy metals in his study and also more easily available for plant uptake. Also, *B. verticillata* recorded BCF >1 values in Cd and Zn, which is an indication that, the plant had the potential of accumulating metals from the roadside soil which may eventually be transferred into the food chain through the consumption of roadside plants.

Correlation coefficient of heavy metals between soil and plant organs

The result of the correlation matrix between heavy metals in the soil and different organs of *B. verticillata* showed that, there was a general positive correlation between the soils and all the organs of the plant which is in agreement with the findings of Ogbonna and Okezie (2011) who stated that, there was a positive relationship among these heavy metals in soil and plants. This positive correlation between metals in soils and *B. verticillata* indicate a possible common pollution source which could be as a result of anthropogenic activities of which vehicular emissions have been implicated as there are no any other major industries in the study locations.

Conclusions and Recommendations

In conclusion, the concentrations of all the heavy metals assessed across the study locations were found to be significantly higher than the control (ABU Dam Quarters). Also, the heavy metal concentrations in soils and all the organs of *B. verticillata* decreased with increasing distance from the roadside, with the highest and lowest concentration observed at 0 and 100 m respectively and with marked significant difference between each distance in most cases. Therefore, Distance from the roadside and vehicular densities of the sampled locations had a significant effect on the heavy metal concentrations in the different organs of *B. verticillata*.

Also, there was a significant positive relationship between the heavy metal level in the soil and the different organs of the plant. These suggest anthropogenic origins which confirm the effect of vehicular emissions on the roadside environment.

In view of these findings, there is need for regular monitoring of heavy metal concentrations in both soil and different organs of plants because of the possibility of being transferred to man through food chain, it is also recommended that, the plant should be subjected for further research and assessment on their phyto-remediation abilities.

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