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Assessment of Vehicular Emissions Effect on Some Heavy Metal Content of *Hyptis Suaveolens* (L.) Found along Zaria-Giwa Road, Kaduna State, Nigeria

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Abstract

Studies on lead, cadmium, copper and zinc content in different parts of *Hyptis suaveolens* were carried out along Zaria-Giwa road, Kaduna state, Nigeria. The different organs of the plants (roots, stems and leaves) were collected at four different locations namely: Ahmadu Bello University Teaching Hospital (ABUTH), National Animal Production Research Institute (NAPRI Shika), Marabar Guga and along Ahmadu Bello University Dam Quarters (control), which were characterized by dense, high, medium and low traffic densities respectively. The samples were collected at distances of 0, 5, 10, 20, 40 and 100 m away from the edge of the road. The metal ions concentration in the samples were determined using Atomic Absorption Spectrophotometer (AAS) The data obtained were subjected to Analysis of Variance (ANOVA), Pearson correlation was employed in determining the correlation between the heavy metals in the soil and the different organs of the plants. The heavy metals had higher concentration at the roadside (0) m and this decreased progressively with increase in distance away from the roadside. However, the region of higher concentration was mostly at 0 and 5 m from the roadside. The ranges of the metal concentrations in *H. suaveolens* were: Pb (7.51-29.11 mg/kg), Cd (0.80-9.21 mg/kg), Cu (1.15-26.98 mg/kg) and Zn (3.21-105.11 mg/kg). Highest metal concentrations in *H. suaveolens* were recorded at ABUTH, however, the high level of Pb and Cd were observed in the roots while Cu and Zn were observed in leaves. The concentrations of the heavy metals in all the organs of the plant were in the order of: Zn > Pb > Cu > Cd. Heavy metal concentrations in the plant samples from ABU Dam quarters (control) were significantly lower than those of other locations. In conclusion, distance from the roadside and vehicular densities of the sampled locations had a significant effect on the lead, cadmium, copper and zinc concentrations in the different organs of *H. suaveolens.* Also, there was a significant positive relationship between the heavy metal concentrations in the soil and the different organs of the plant species.

Introduction

Heavy metals are important environmental pollutants desirous of significant attention. They are non-biodegradable and cannot be detoxified or removed by metabolic activities which may eventually accumulate in significant amount and result in metal poisoning (Yahaya *et al.*, 2025).

Heavy metals are released in significant levels during transport activities by different processes including combustion, components wear, fluid leakage and corrosion of metal (Upahi *et al.*, 2021). Emission from vehicles on roads contain Lead (Pb), Cadmium (Cd), Zinc (Zn) and Copper (Cu), which are present in fuel as anti-knock agents and these metal pollutants may be deposited on soils, transformed and transported to vegetation (Sodimu *et al*., 2021).

Plant species, physiological stage, uptake capability as well as growth rate are major determinants of metal transfer from soil to plants (Yahaya *et al.*, 2025). It is a known fact that plants require certain heavy metals for their growth and upkeep, however, excessive amounts of these metals can become toxic to plants through the inhibition of cytoplasmic enzymes and damage to cell structures due to oxidative stress (Cui *et al.*, 2004; Upahi *et al.*, 2021).

Hyptis suaveolens commonly called Bush mint is a highly medicinal plant found along roads with medicinal characteristics such as anti-inflammatory (Grassi *et al*., 2006), antinociceptive (Santos *et al*., 2007), antiulcer (Das *et al*., 2009), antioxidant (Gavani and Paarakh 2008), insecticidal (Aina *et al*., 2024) and antibacterial (Aina *et al*., 2024). The leaves being the plant's important part have been reported to contain volatile oils, alkaloids and terpenes (Aina *et al*., 2024).

There has been an increased density of vehicles plying Zaria-Giwa road due to rapid urbanization, increased population and increased income of the populace. Also, 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 (Upahi *et al.*, 2024).

With the global heavy metal contamination on the rise, it is pertinent to assess the bio-accumulation index of plants in order to identify suitable and efficient plants that might be utilized in phytoremediation. Therefore, this study was aimed at assessing the concentrations of some heavy metals in the different organs of *Hyptis suaveolens* along Zaria-Giwa road, Kaduna state, Nigeria.

Materials and Methods

Area of Study

This study was conducted along Zaria-Giwa road, located at latitude 11º 3'N and longitude 07º 40'N. As at 2006 Census, it had a population of 1,018,827 (TWG, 2007). The major activity of the people within the area is farming. Three sampling locations were selected along Zaria-Giwa road and the fourth location was selected along ABU Postgraduate School due to its low vehicular site to serve as control. The locations include ABUTH (Latitude 11°10'28.52"N and Longitude 7°36'31.70"E), NAPRI-Shika (Latitude 11°12'15.35"N and Longitude 7°33'31.98"E), Marabar-Guga (Latitude 11°13'5.52"N and Longitude 7°32'8.16"E) and ABU Dam Quarters (control) (Latitude 11° 8'35.13"N and Longitude 7°39'16.06"E).

Sample Collection

Whole plant of *Hyptis suaveolens* was collected from four different sampling locations along Zaria-Giwa road and along Ahmadu Bello University Dam Quarters, namely: location A (ABUTH-Shika), location B (Shika-NAPRI) location C (Marabar-Guga) and location D (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, whole plants of *Hyptis suaveolens* were carefully uprooted so as to keep

the roots, stems and leaves of the plant intact. The samples were collected in polythene bags and labeled with a masking tape and transported to the laboratory in the Department of Biology, Ahmadu Bello University, Zaria, for sample preparation and further analysis.

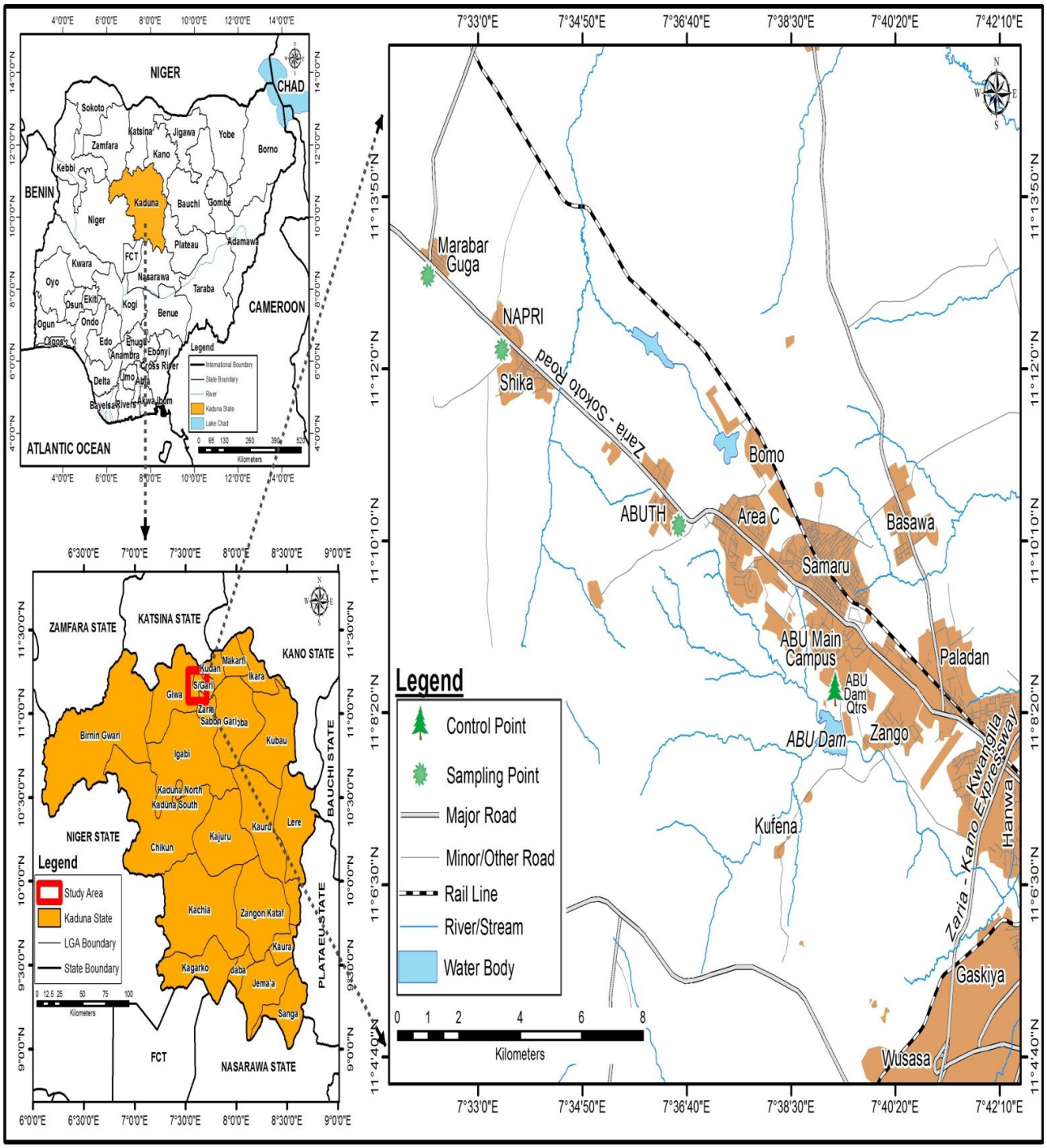

Figure 1: Map of Sabon Gari/Zaria showing Sampling Points
Source: Modified from the Administrative Map of Sabon Gari/Zaria L.G.A.

Sample Preparation

Plant samples obtained were properly washed and rinsed with distilled water to remove any residues of impurities. This was followed by cutting of the samples with a clean knife into different parts (roots, stems and leaves) and smaller portions for easy grounding to powder form when dried. The samples were placed in labeled envelopes and transferred into oven set at 70 ^{0}C and allowed to dry to constant weight. The dried plant samples were ground into fine particles using clean acid washed mortar and pestle.

Digestion of plant samples

Plant samples were digested at the Analytical Research Laboratory in the Department of Agronomy, Ahmadu Bello University, Zaria. Plant samples were digested according to the method described by Akinyele and Shokunbi (2015). 0.5 g of the powdered plant samples were weighed out into flasks mixed with 20 ml of the acid mixture containing concentrated sulphuric acid, perchloric acid and concentrated nitric acid in ratio of 1:2:9 by volume respectively. Thereafter the flasks were heated moderately at 70 ^{o}C for about 40 minutes. 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 appeared 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. A blank determination was carried out using the procedure described above but without the plant sample. The Cd, Pb, Cu and Zn concentrations in the plant samples were determined using AAS at the Multi User Science Laboratory, Department of Chemistry, Ahmadu Bello University, Zaria.

Data Analysis

Data obtained from the laboratory analysis 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. Also, Pearson correlation was employed in determining the correlation between the heavy metals in the soil and the different organs of the plant.

Results and Discussion

Results

Heavy Metal Concentrations in the Roots of *Hyptis suaveolens*

The highest and lowest concentrations of all the metals assessed in the roots of *H. suaveolens* were generally observed at 0 and 100 m from the roadside respectively (Table 1). This shows that the elemental concentration of this plant organ followed the same pattern with respect to distance and location. This was also the case in the pooled data analysis based on distance from the road (Table 2). Most of the heavy metals were at highest level at ABUTH, followed by that at NAPRI Shika and the least at ABU Dam Quarters (the control). Among the elements, the concentration of Zn was higher than all the other elements at each location with the exception of ABU Dam Quarters (Table 3). Generally, the concentration of heavy metals in *Hyptis suaveolens* roots were in the order of: Zn > Pb > Cu > Cd.

Lead Level in *Hyptis suaveolens* Roots along Zaria-Giwa road

The highest lead concentration in *H. suaveolens* roots occurred at 0 m at each location while the least was observed at 100 m from the roadside. The highest lead at 0 m from the roadside was comparable with that at 5, 10 and 20 m at ABUTH, 5 and 10 m at both Marabar Guga and ABU Dam Quarters (control). However, at ABUTH, the least Pb concentration observed at 100 m was significantly lower than those observed at all the other distances from the roadside (Table 1). At NAPRI Shika, the lowest concentration of Pb observed at 40 and 100 m was only significantly lower than the highest recorded at 0 m from the roadside (Table 1). At

Marabar Guga, the lowest concentration observed at 100 m was comparable to that observed at 20 and 40 m from the roadside (Table 1). Also, at ABU Dam Quarters, the lowest concentration observed at 100 m was similar to that observed at 40 m from the roadside in roots of *H. suaveolens* (Table 2).

The combined data analysis of lead level in *H. suaveolens* roots with respect to distance indicated that, the highest concentration of Pb recorded at 0 m was significantly higher than those recorded at all the other distances from the roadside. This was followed by the Pb values observed at 5 and 10 m from the roadside. The least Pb concentration observed at 100 m was significantly lower than those observed at all other the distances from the roadside (Table 2). Also, the combined analysis of Pb concentration in the roots of *H. suaveolens* based on locations showed that, the highest concentration of lead recorded at ABUTH was significantly higher than those recorded at all the other locations in the study area. This was followed by that observed at NAPRI Shika, equally, the lowest concentration observed at ABU Dam Quarters was significantly lower than those recorded at all other locations along Zaria-Giwa road (Table 3).

Cadmium Level in *Hyptis suaveolens* Roots along Zaria-Giwa road

The highest cadmium concentration was observed in *H. suaveolens* roots at 0 m at each location while the least was recorded at 100 m from the roadside. However, distance had no significant effect on Cd concentration at Marabar Guga. The lowest concentration of cadmium recorded at 100 m was only significantly lower than the highest value observed at 0 m from the roadside in ABUTH (Table 1). At NAPRI Shika, cadmium concentration was found to be significantly higher at 0 m than those recorded at all the other distances from the roadside. This was followed by the Cd value observed at 5 m, which was similar to the values at 10 and 20 m from the roadside. The least Cd concentration observed at 100 m was comparable to that recorded at 40 m from the roadside (Table 1). At Marabar Guga, there was no significant difference observed at all distances from the roadside (Table 1). Also, at ABU Dam Quarters, the lowest concentration of Cd recorded 100 m was comparable to that observed at 10, 20 and 40 m but significantly lower than the highest concentrations observed at both 0 and 5 m from the roadside.

The combined data analysis of cadmium level in *H. suaveolens* roots with respect to distance revealed that, the highest concentration of Cd recorded at 0 m was significantly higher than those recorded at all the other distances from the roadside. This was followed by the Cd value observed at 5 and 10 m from the roadside. The least Cd concentration observed at 100 m was similar to that observed at 20 and 40 m from the roadside (Table 2). Also, the combined analysis of Cd level in *H. suaveolens* roots based on locations showed that, the highest concentration of Cd recorded at ABUTH was significantly higher than those recorded at all the other locations in the study area. This was followed by that observed at NAPRI Shika. The lowest concentration observed at ABU Dam Quarters was significantly lower than those recorded at all the other locations along Zaria-Giwa road (Table 3).

Copper Level in *Hyptis suaveolens* Roots along Zaria-Giwa road

The highest copper concentration observed at 0 m in most locations was comparable with that at 5 m from the roadside, while the least recorded at 100 m was significantly lower than that at most distances from the roadside in most cases. The highest concentration of copper in *H. suaveolens* roots observed at 0 m was similar to that observed at 5m from the roadside but significantly higher than those recorded at all the other distances in ABUTH. This was followed by the Cu values observed at 10, 20 and 40 m from the roadside. The least Cu concentration observed at 100 m was significantly lower than all the other distances from the roadside (Table 1).

Table 1: Heavy Metal Concentrations of *Hyptis suaveolens* Roots at four Locations along Zaria-Giwa road.

Location	Distance (m)	Heavy metal concentrations (mg/kg)			
		Pb	**Cd**	**Cu**	**Zn**
ABUTH	0	29.11^{a}	9.21^{a}	26.22^{a}	90.30^{a}
	5	27.82^{a}	2.92^{b}	26.22^{a}	75.72^{b}
	10	27.79^{a}	2.12^{b}	21.40^{b}	62.45^{c}
	20	27.21^{a}	2.12^{b}	21.22^{b}	59.91^{c}
	40	21.50^{b}	2.14^{b}	21.52^{b}	45.11^{d}
	100	12.40^{c}	1.81^{b}	14.81^{c}	41.30^{e}
	Mean	**24.31**	**3.39**	**21.89**	**62.47**
	SEM±	**1.52**	**0.65**	**1.96**	**1.90**
	P value	**0.000****	**0.000****	**0.000****	**0.000****
NAPRI Shika	0	25.01^{a}	4.92^{a}	25.01^{a}	88.95^{a}
	5	21.47^{b}	2.92^{b}	18.31^{b}	88.95^{a}
	10	21.50^{b}	2.92^{b}	14.01^{c}	65.71^{b}
	20	19.61^{b}	2.71^{b}	13.11^{c}	64.71^{b}
	40	18.70^{b}	1.42^{c}	9.32^{d}	53.60^{c}
	100	18.70^{b}	1.01^{c}	6.72^{e}	38.90^{d}
	Mean	**20.83**	**2.65**	**14.41**	**66.80**
	SEM±	**1.48**	**0.65**	**1.09**	**2.82**
	P value	**0.003****	**0.000****	**0.000****	**0.000****
Marabar Guga	0	21.20^{a}	2.11^{a}	21.20^{a}	63.55^{a}
	5	20.22^{a}	2.11^{a}	21.20^{a}	61.22^{ab}
	10	20.22^{a}	2.13^{a}	14.31^{b}	60.35^{ab}
	20	14.22^{b}	1.86^{a}	13.31^{b}	57.51^{b}
	40	13.08^{b}	1.85^{a}	12.33^{b}	57.51^{b}
	100	11.66^{b}	1.85^{a}	12.46^{b}	47.32^{c}
	Mean	**16.77**	**1.99**	**15.80**	**57.91**
	SEM±	**1.59**	**0.30**	**1.46**	**2.59**
	P value	**0.000****	**0.639ns**	**0.000****	**0.000****
ABU Dam Quarters	0	19.32^{a}	2.52^{a}	11.43^{a}	20.22^{a}
	5	18.88^{ab}	2.52^{a}	11.42^{a}	15.45^{b}
	10	18.88^{ab}	1.85^{ab}	10.33^{b}	14.23^{b}
	20	16.56^{b}	0.80^{b}	9.31^{c}	14.22^{b}
	40	10.11^{c}	0.80^{b}	8.65^{d}	10.45^{c}
	100	8.11^{c}	0.80^{b}	6.50^{e}	10.45^{c}
	Mean	**15.31**	**1.55**	**9.61**	**14.17**
	SEM±	**1.24**	**0.59**	**0.28**	**1.17**
	P value	**0.000****	**0.007****	**0.000****	**0.000****

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

Table 2: Heavy Metal Concentrations of *Hyptis suaveolens* Roots (Pooled data) Based on distance from the roadside at four Locations along Zaria-Giwa road.

Source	Distance (m)	Heavy metal Concentrations (mg/kg)			
		Pb	**Cd**	**Cu**	**Zn**
Roots of *H. suaveolens*	0	23.66^{a}	4.69^{a}	20.97^{a}	63.76^{a}
	5	22.09^{b}	2.62^{b}	19.29^{b}	60.12^{b}
	10	22.09^{b}	2.26^{bc}	15.01^{c}	50.90^{c}
	20	19.40^{c}	1.87^{cd}	14.24^{c}	49.09^{c}
	40	15.85^{d}	1.55^{d}	12.95^{d}	41.67^{d}
	100	12.72^{e}	1.37^{d}	10.12^{e}	34.49^{e}
	Mean	**19.30**	**2.39**	**15.43**	**50.34**
	SEM±	**1.41**	**0.60**	**1.34**	**2.64**
	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= not significant *=significant at P<0.05 **= highly significant at P<0.01

Table 3: Heavy Metal Concentrations of *Hyptis suaveolens* Roots (Pooled data) Based on Locations along Zaria-Giwa road.

Source	Location	Heavy metal Concentrations (mg/kg)			
		Pb	**Cd**	**Cu**	**Zn**
Roots of *H. suaveolens*	ABUTH	24.31^{a}	3.39^{a}	21.89^{a}	62.47^{b}
	NAPRI Shika	20.83^{b}	2.65^{b}	15.80^{b}	66.80^{a}
	Marabar Guga	16.77^{c}	1.99^{c}	14.41^{c}	57.91^{c}
	ABU Dam Quarters	15.31^{d}	1.55^{d}	9.61^{d}	14.17^{d}
	Mean	**19.30**	**2.39**	**15.43**	**50.34**
	SEM±	**1.41**	**0.60**	**1.34**	**2.64**
	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= not significant *=significant at P<0.05 **= highly significant at P<0.01

At NAPRI Shika, the highest concentration of Cu observed at 0 m was significantly higher than those recorded at all the other distances from the roadside. This was followed by the Cu value observed at 5 m from the roadside which was also significantly higher than those observed at 10 to 100 m from the roadside. The least Cu concentration observed in *H. suaveolens* roots at 100 m was equally significantly lower than all the other distances from the roadside (Table 1). At Marabar Guga, the lowest Cu concentration observed at 40 m was only significantly lower than the highest concentrations observed at both 0 and 5 m from the roadside (Table 1). At ABU Dam Quarters, the highest Cu concentration recorded in *H. suaveolens* roots at 0 m was similar to that at 5 m but significantly higher than those observed at all the other distances from the roadside. This was followed by the value recorded at 10 m from the roadside. However, the lowest concentration of Cu observed at 100 m was significantly lower than those observed at all the other distances from the roadside (Table 1).

The pooled data analysis of copper level in *H. suaveolens* roots with respect to distance revealed that, the highest concentration recorded at 0 m was significantly higher than those recorded at all the other distances from the roadside. This was followed by the Cu value observed at 5 m which was also significantly higher than the values recorded at 10 to 100 m from the roadside. The least Cu concentration observed at 100 m was

significantly lower than those observed at all the other distances from the roadside (Table 2).

Also, the combined data analysis based on locations revealed that, the highest level of copper recorded at ABUTH was significantly higher than those recorded at all the other locations. This was followed by that observed at NAPRI Shika. The least level observed at ABU Dam Quarters was significantly lower than that observed at all the other locations along Zaria-Giwa road (Table 3).

Zinc Level in *Hyptis suaveolens* Roots along Zaria-Giwa road

The highest Zinc concentration was observed at 0 m at each location while the least was recorded at 100 m from the roadside. At ABUTH, the highest concentration of zinc recorded in *H. suaveolens* roots at 0 m was significantly higher than those recorded at all the other distances from the roadside. This was followed by the Zn value observed at 5 m which was also significantly higher than the values recorded at 10 to 100 m. The least Zn concentration observed at 100 m was significantly lower than the values recorded at all the other distances from the roadside (Table 1). At NAPRI Shika, the highest concentration of zinc recorded at 0 and 5 m were significantly higher than those recorded at all the other distances from the roadside. This was followed by the value observed at 10 m which was similar to that at 20 m from the roadside. The least Zn concentration observed at 100 m was significantly lower than that observed at all the other distances from the roadside (Table 1). The highest concentration of Zn observed at 0 m in Marabar Guga was similar to that observed at 5 and 10 m. However, the lowest concentration of Zn observed at 100 m in this location was significantly lower than that observed at all the other distances from the roadside (Table 1). Also, at ABU Dam Quarters, the concentration of Zn recorded at 0 m in the roots of *H. suaveolens* was significantly higher than those recorded at all the other distances. This was followed by the value recorded at 5, 10 and 20 m from the roadside. The least value observed at 100 m was similar to that at 40 m from the roadside (Table 1).

The combined data analysis of Zinc level with respect to distance in *H. suaveolens* roots revealed that, the highest concentration of Zn recorded at 0 m was significantly higher than those recorded at all the other distances from the roadside. This was followed by the Zn value observed at 5 m. The least Zn concentration observed at 100 m was significantly lower than that observed at all the other distances from the roadside (Table 2). Also, the combined data analysis of Zn concentration in *H. suaveolens* roots based on location revealed that, the highest concentration of zinc recorded at NAPRI Shika was significantly higher than those recorded at all the other locations in the study area. This was followed by that observed at ABUTH. ABU Dam Quarters (control) recorded the lowest concentration which was significantly lower than those observed at all the other locations along Zaria-Giwa road (Table 3).

Heavy Metal Concentrations in the Stems of *Hyptis suaveolens*

The concentrations of elements in the stems of *H. suaveolens* were generally observed to follow same pattern with respect to distance and location .The highest concentrations of lead, cadmium, copper and zinc assessed in the stems of *H. suaveolens* across all distances and locations were observed at 0 m from the road while the lowest concentrations were recorded at 100 m away from the road in most cases (Table 4). Variation in Cd concentration with distance was low. This was also the case in the pooled data analysis based on distance from the road (Table 5) which is an indication that the concentration of elements decrease with increase in distance from the roadside. Most of the elements were at highest concentration at ABUTH, next to this was that at NAPRI Shika while ABU Dam Quarters had the least. Among the elements, the concentration of Zn was higher than that of all the other elements at each location (Table 6). The concentrations of the heavy metals in *H. suaveolens* stems were in the order of: Zn > Pb > Cu > Cd.

Lead Level in *Hyptis suaveolens* Stems along Zaria-Giwa road

The highest lead concentration in *H. suaveolens* stems was observed at 0 m at each location while the least was recorded at 100 m from the roadside. At ABUTH, the highest concentration of lead recorded at 0 m was comparable to that observed at 5 m but significantly higher than those recorded at all the other distances from the roadside. This was followed by that observed at 10 m from the roadside. However, the least Pb concentration observed at 100 m was significantly lower than that observed at all the other distances from the roadside (Table 4). At NAPRI Shika, the highest level of Pb recorded at 0 m was significantly higher than that observed at all the other distances. This was followed by that observed at 5 and 10 m from the roadside. The lowest concentration of Pb observed at 100 m was similar to that observed at 20 and 40 m from the roadside (Table 4). The highest concentrations of Pb recorded at 0 m in Marabar Guga was comparable to that at 5 m but significantly higher than those recorded all the other distances from the roadside. However, the lowest concentration observed at 100 m was comparable to that observed at 10, 20 and 40 m from the roadside (Table 4). Also, at ABU Dam Quarters (control), the highest concentrations of Pb recorded at 0 and 5 m were significantly higher than that recorded at all the other distances. This was followed by that observed at 10 m. The lowest concentration observed at 100 m was similar to that observed at 40 m from the roadside in *H. suaveolens* stems (Table 4).

The combined data analysis of lead level with respect to distance indicated that, the highest concentration of Pb recorded at 0 m was significantly higher than those recorded at all the other distances from the roadside. This was followed by the Pb value observed at 5 m which was also significantly higher than the value recorded at 10 to 100 m from the roadside. The least Pb concentration observed at 100 m was significantly lower than that observed at all the other distances from the roadside (Table 5).

The combined analysis of Pb concentration in the stems of *H. suaveolens* based on locations showed that, the highest level of lead recorded at ABUTH was comparable to that recorded at NAPRI Shika, but significantly higher than that observed at the other locations. However, the lowest concentration observed at ABU Dam Quarters was significantly lower than all the other locations along Zaria-Giwa road (Table 6).

Cadmium Level in *Hyptis suaveolens* Stems along Zaria-Giwa road

The concentration of cadmium in *H suaveolens* stems at ABUTH, NAPRI Shika and Marabar Guga followed similar pattern in the sense that, even though the highest concentration was recorded at 0 m but there was no significant difference at all distances in the three locations (Table 4). However, at ABU Dam Quarters, the highest concentration recorded at 0 and 5 m were similar to that observed at 10 m from the roadside. The lowest concentration observed at 100 m was similar to that observed at 20 and 40 m from the roadside (Table 4).

The combined data analysis of cadmium level with respect to distance in *H. suaveolens* stems revealed that, the highest concentration recorded at 0 and 5 m were similar to that observed at 10 m from the roadside. The lowest concentration observed at 100 m was similar to that observed at 20 and 40 m from the roadside (Table 5). Also, the combined data analysis of Cd concentration in *H. suaveolens* stems based on locations showed that, the highest concentration of Cd recorded at ABUTH was only significantly higher than the lowest concentration observed at ABU Dam Quarters (control) (Table 6).

Copper Level in *Hyptis suaveolens* Stems along Zaria-Giwa road

The highest copper concentration in *H. suaveolens* stems was observed at 0 m at each location while the least was recorded at 100 m from the roadside. At ABUTH, The least copper concentration in the stems of *H. suaveolens* observed at 100 m was only significantly lower

than the highest observed at 0 m which was comparable to that at 5 m from the roadside (Table 4).

Table 4: Heavy Metal Concentrations of *Hyptis suaveolens* stems at four Locations along Zaria-Giwa road

Location	Distance(m)	Heavy metal Concentrations (mg/kg)			
		Pb	Cd	Cu	Zn
ABUTH	0	22.21^{a}	2.11^{a}	21.11^{a}	90.71^{a}
	5	19.80^{ab}	2.11^{a}	19.82^{a}	62.91^{b}
	10	17.44^{bc}	2.11^{a}	13.55^{b}	50.40^{c}
	20	16.62^{cd}	1.82^{a}	11.95^{b}	41.44^{d}
	40	14.22^{d}	1.82^{a}	11.94^{b}	41.11^{d}
	100	11.12^{e}	1.65^{a}	11.92^{b}	35.21^{e}
	Mean	**16.90**	**1.94**	**15.05**	**53.63**
	SEM±	**1.62**	**0.29**	**1.14**	**1.29**
	P value	**0.000****	**0.299ns**	**0.000****	**0.000****
NAPRI Shika	0	22.21^{a}	2.32^{a}	22.81^{a}	88.60^{a}
	5	17.90^{b}	2.32^{a}	18.92^{b}	84.31^{b}
	10	17.73^{b}	1.85^{a}	11.21^{c}	77.71^{c}
	20	13.11^{c}	1.61^{a}	11.28^{c}	52.30^{d}
	40	12.92^{c}	1.61^{a}	11.25^{c}	40.92^{e}
	100	12.77^{c}	1.61^{a}	9.10^{d}	30.41^{f}
	Mean	**16.11**	**1.89**	**14.09**	**62.38**
	SEM±	**1.23**	**0.46**	**0.88**	**1.14**
	P value	**0.000****	**0.217ns**	**0.000****	**0.000****
Marabar Guga	0	19.11^{a}	1.91^{a}	13.70^{a}	61.81^{a}
	5	16.88^{ab}	1.91^{a}	9.12^{b}	61.81^{a}
	10	14.91^{bc}	1.91^{a}	5.42^{c}	45.71^{b}
	20	14.81^{bc}	1.84^{a}	5.42^{c}	38.71^{c}
	40	13.76^{c}	1.78^{a}	4.91^{c}	32.53^{d}
	100	13.75^{c}	1.22^{a}	4.70^{c}	12.72^{e}
	Mean	**15.54**	**1.76**	**7.21**	**42.21**
	SEM±	**1.50**	**0.36**	**0.73**	**1.73**
	P value	**0.009****	**0.213ns**	**0.000****	**0.000****
ABU Dam Quarters	0	15.62^{a}	1.91^{a}	9.20^{a}	18.43^{a}
	5	15.62^{a}	1.91^{a}	5.89^{b}	15.01^{ab}
	10	12.22^{b}	1.90^{a}	5.89^{b}	15.01^{ab}
	20	9.99^{c}	1.21^{b}	5.61^{b}	11.12^{cd}
	40	8.56^{cd}	1.21^{b}	5.61^{b}	14.21^{bc}
	100	7.12^{d}	1.05^{b}	1.15^{c}	8.34^{d}
	Mean	**11.52**	**1.53**	**5.56**	**13.69**
	SEM±	**1.15**	**0.28**	**1.34**	**1.82**
	P value	**0.000****	**0.006****	**0.000****	**0.000****

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

Table 5: Heavy Metal Concentrations of *Hyptis suaveolens* Stems (Pooled data) Based on distance from the roadside at four Locations along Zaria-Giwa road

Source	Distance (m)	Heavy metal Concentrations (mg/kg)			
		Pb	Cd	Cu	Zn
Stems of *H. suaveolens*	0	19.79^{a}	2.06^{a}	16.71^{a}	64.89^{a}
	5	17.55^{b}	2.06^{a}	13.44^{b}	56.01^{b}
	10	15.58^{c}	1.94^{a}	9.02^{c}	47.21^{c}
	20	13.28^{d}	1.62^{b}	8.57^{c}	35.81^{d}
	40	12.72^{d}	1.61^{b}	8.43^{c}	32.28^{e}
	100	11.19^{e}	1.38^{b}	6.72^{d}	21.67^{f}
	Mean	**15.02**	**1.78**	**10.48**	**42.98**
	SEM±	**1.35**	**0.37**	**1.13**	**2.59**
	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= not significant *=significant at P<0.05 **= highly significant at P<0.01

Table 6: Heavy Metal Concentrations of *Hyptis suaveolens* Stems (Pooled data) Based on Locations along Zaria-Giwa road.

Source	Location	Heavy metal Concentrations (mg/kg)			
		Pb	Cd	Cu	Zn
Stems of *H. suaveolens*	ABUTH	16.90^{a}	1.94^{a}	15.05^{a}	53.63^{b}
	NAPRI Shika	16.11^{ab}	1.89^{a}	14.09^{b}	62.37^{a}
	Marabar Guga	15.54^{b}	1.76^{ab}	7.21^{c}	42.21^{c}
	ABU Dam Quarters	11.52^{c}	1.53^{b}	5.56^{d}	13.69^{d}
	Mean	**15.02**	**1.78**	**10.48**	**42.98**
	SEM±	**1.35**	**0.38**	**1.13**	**2.59**
	P value	**0.000****	**0.009****	**0.000****	**0.000****

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

At NAPRI Shika, the highest concentration of Cu observed at 0 m was significantly higher than those recorded at all the other distances from the roadside. This was followed by the Cu value observed at 5 m which was also significantly higher than the values recorded at 10 to 100 m from the roadside. The least Cu Concentration observed at 100 m was significantly lower than that at all the other distances from the roadside (Table 4). At Marabar Guga, the highest concentration of Cu observed in *H. suaveolens* stems at 0 m was significantly higher than those recorded at all the other distances. This was followed by the value observed at 5 m. The least Cu concentration observed at 100 m was similar to that observed at 10, 20 and 40 m from the roadside (Table 4). At ABU Dam Quarters (control), the highest concentration recorded at 0 m was significantly higher than those observed at all the other distances in *H. suaveolens* stems. This was followed by the value recorded at 5 m which was similar to that at 10, 20 and 40 m from roadside. The least Cu concentration recorded at 100 m was significantly lower than that at all the other distances from the roadside (Table 4)

The pooled data analysis of copper level in *H. suaveolens* stems with respect to distance revealed that, the highest concentration recorded at 0 m was significantly higher than those recorded at all the other distances from the roadside. This was followed by the value observed at 5 m. The

least Cu concentration observed at 100 m was significantly lower than that observed at all the other distances from the roadside (Table 5). Also, the combined data analysis based on locations revealed that, the highest level of copper recorded at ABUTH was significantly higher than that recorded at all the other locations. This was followed by that observed at NAPRI Shika. However, the least level observed at ABU Dam Quarters was significantly lower than that observed at all the other locations along Zaria-Giwa road (Table 6).

Zinc Level in *Hyptis suaveolens* Stems along Zaria-Giwa road

The highest Zinc concentration in *H. suaveolens* stems was observed at 0 m at each location while the least was recorded at 100 m from the roadside. At ABUTH, the highest concentration of zinc recorded at 0 m was significantly higher than those recorded at all the other distances from the roadside. This was followed by the Zn value observed at 5 m which was also significantly higher than the values recorded at 10 to 100 m. The least Zn concentration observed at 100 m was significantly lower than the values recorded at all the other distances from the roadside (Table 4). At NAPRI Shika, the highest concentration of zinc recorded at 0 m was significantly higher than those recorded at all the other distances from the roadside. This was followed by the Zn value observed at 5 and 10 m which was also significantly higher than that observed at 20 to 100 m. However, the least Zn concentration observed at 100 m was significantly lower than those observed at all the other distances from the roadside (Table 4). The highest concentration of Zn observed at both 0 and 5 m in Marabar Guga was significantly higher than those observed at all the other distances. This was followed by the Zn value recorded at 10 m. However, the lowest concentration of Zn observed in *H. suaveolens* stems at 100 m in this location was significantly lower than those observed at all the other distances from the roadside (Table 4). Also, at ABU Dam Quarters, the concentrations of Zn recorded in the stems of *H. suaveolens* at 0 m was comparable to that at 5 and 10 m but, significantly higher than those recorded at all the other distances. The lowest concentration observed at 100 m was only similar to that observed at 20 m distance from the roadside (Table 4).

The combined data analysis of Zinc level in *H. suaveolens* stems with respect to distance revealed that, the highest concentration of Zn recorded at 0 m was significantly higher than those recorded at all the other distances from the roadside. This was followed by the Zn values observed at 5 and 10 m from the roadside. The least Zn concentration observed at 100 m was significantly lower than those observed at all the other distances from the roadside (Table 5).

The combined data analysis of Zn concentration in *H. suaveolens* stems based on location revealed that, the highest concentration of zinc recorded at NAPRI Shika was significantly higher than those recorded at all the other locations in the study area. This was followed by that observed at ABUTH. ABU Dam Quarters recorded the lowest concentration which was significantly lower than those observed at all the other locations along Zaria-Giwa road (Table 6).

Heavy Metal Concentrations in the leaves of *Hyptis suaveolens*

Generally the highest concentrations of lead, cadmium, copper and zinc in *Hyptis suaveolens* leaves across all distances and locations were observed at 0 m from the road while the lowest concentrations were recorded at 100 m in most cases. This was equally observed in the pooled data analysis based on distance which shows that, the concentration of each element decreased with increase in distance from the roadside (Table 7). All the heavy metals were at highest concentration in *H. suaveolens* leaves at ABUTH, followed by that at NAPRI Shika while the least was observed at ABU Dam quarters. The concentrations of the heavy metals in *H. suaveolens* leaves were in the order of: Zn > Pb > Cu > Cd.

Lead Level in *Hyptis suaveolens* Leaves along Zaria-Giwa road

The highest lead concentration in *H. suaveolens* leaves was observed at 0 m at each location while the least was recorded at 100 m from the roadside. Distance had a significant effect on Pb concentration at each of the locations in most cases. Lead concentration at ABUTH, Marabar Guga and ABU Dam Quarters followed the same pattern in the sense that the concentration observed at 0 m from the roadside was significantly higher than that observed at all the other distances from the roadside. This was followed by Pb concentration at 5 m from the roadside (Table 7). However, the least Pb concentration observed at 100 m was significantly lower than those of the other distances. At NAPRI Shika, the least Pb concentration observed at 100 m was only significantly lower than the highest observed at 0 m from the roadside (Table 7)

The combined analysis of the data based on distance showed that, the highest Pb concentration observed in *H. suaveolens* leaves at 0 m was significantly higher than those observed at all the other distances from the roadside and this was followed by concentrations at 5 and 10 m. The least Pb concentration observed at 100 m was significantly lower than those of the other distancefrom the roadside (Table 8). Also, the pooled data analysis of Pb concentrations in the leaves of *H. suaveolens* based on locations showed that, the highest concentration of Pb observed at ABUTH was similar to that observed at NAPRI Shika but significantly higher than that observed at the other locations. However, the least Pb concentration observed at ABU Dam Quarters was significantly lower than those observed at all the other locations (Table 9).

Cadmium Level in *Hyptis suaveolens* leaves along Zaria-Giwa road

Cadmium concentrations in *H. suaveolens* leaves observed at both NAPRI Shika and Marabar Guga followed similar pattern in the sense that there was no significant difference at all distances from the roadside (Table 7). However, at ABUTH, the highest Cd concentration observed at 0 m was comparable to that at 5 and 10 m from the roadside. The least Cd concentration observed at 100 m from the road was similar to that observed at 20 and 40 m from the roadside (Table 7). Also, at ABU Dam Quarters, the highest concentration recorded at 0 m was only significantly higher than the least observed at 100 m from the roadside (Table 7).

The pooled analysis of the data based on distance showed that, the highest concentration recorded at 0 m was only significantly higher than that observed at 40 and 100 m from roadside. The least Cd concentration observed at 100 m was comparable with that at 40 m from the roadside (Table 8). However, the combined analysis of the data based on location showed that, the least Cd concentration in *Hyptis suaveolens* leaves observed at ABU Dam Quarters (control) was only significantly lower to the highest concentration at ABUTH (Table 9).

Copper Level in *Hyptis suaveolens* leaves along Zaria-Giwa road

Copper concentration in *Hyptis suaveolens* leaves found at ABUTH was significantly higher at 0 and 5 m than that at the other distances from the roadside. However, the lowest Cu concentration observed at 100 m was significantly lower than those observed at the other distances from the roadside (Table 7). At NAPRI Shika, the highest concentration recorded at 0 m was only significantly higher than the least observed at 100 m from the roadside (Table 7). At Marabar

Guga, the highest copper concentration recorded at 0 m was similar to that at 5 m from the roadside. This was followed by the Cu value recorded at 10 m which was also significantly higher than the values observed at 20 to 100 m. However, the lowest copper concentration at this location observed at 100 m was significantly lower than those observed at all the other distances from the roadside (Table 7). At ABU Dam Quarters, the highest concentration observed at 0 m was significantly higher than the

value recorded at all the other distances from the roadside. This was followed by the Cu values recorded at 5 and 10 m from the roadside. The least concentration of copper recorded at 100 m was similar to that observed at 20 and 40 m from the roadside (Table 7).

Table 7: Heavy Metal Concentrations of *Hyptis suaveolens* Leaves at four Locations along Zaria-Giwa road.

Location	Distance(m)	Heavy metal Concentrations (mg/kg)			
		Pb	**Cd**	**Cu**	**Zn**
ABUTH	0	26.90^{a}	3.22^{a}	26.98^{a}	105.11^{a}
	5	23.81^{b}	2.61^{abc}	26.97^{a}	75.11^{b}
	10	23.81^{b}	2.91^{ab}	22.61^{b}	67.11^{c}
	20	20.51^{c}	2.11^{bc}	20.55^{b}	65.11^{c}
	40	20.81^{c}	1.71^{c}	20.82^{b}	50.10^{d}
	100	14.22^{d}	1.65^{c}	16.21^{c}	50.10^{d}
	Mean	**21.67**	**2.37**	**22.35**	**68.77**
	SEM±	**0.97**	**0.53**	**1.28**	**4.33**
	P value	**0.000****	**0.021***	**0.000****	**0.000****
NAPRI Shika	0	24.22^{a}	1.71^{a}	22.22^{a}	54.01^{a}
	5	22.22^{ab}	1.33^{a}	21.91^{a}	53.61^{a}
	10	20.41^{b}	1.22^{a}	21.91^{a}	53.61^{a}
	20	20.41^{b}	1.61^{a}	20.71^{a}	32.81^{b}
	40	19.82^{b}	1.61^{a}	20.41^{a}	30.81^{b}
	100	19.82^{b}	1.22^{a}	7.52^{b}	15.40^{c}
	Mean	**21.15**	**1.45**	**19.11**	**40.04**
	SEM±	**1.72**	**0.28**	**1.28**	**2.36**
	P value	**0.006****	**0.188ns**	**0.000****	**0.000****
Marabar Guga	0	28.11^{a}	2.01^{a}	18.62^{a}	60.11^{a}
	5	18.68^{b}	2.01^{a}	18.55^{a}	56.83^{ab}
	10	20.43^{b}	1.88^{a}	13.71^{b}	52.32^{b}
	20	15.44^{c}	1.65^{a}	9.75^{c}	34.32^{c}
	40	14.56^{c}	1.33^{a}	8.41^{c}	24.44^{d}
	100	11.78^{d}	1.22^{a}	4.81^{d}	20.50^{d}
	Mean	**18.17**	**1.68**	**12.31**	**41.42**
	SEM±	**1.42**	**0.46**	**1.34**	**3.01**
	P value	**0.000****	**0.227ns**	**0.000****	**0.000****
ABU Dam Quarters	0	18.66^{a}	2.01^{a}	9.20^{a}	18.40^{a}
	5	15.45^{b}	1.91^{ab}	6.11^{b}	14.25^{b}
	10	15.42^{b}	1.91^{ab}	4.51^{b}	14.23^{b}
	20	11.01^{c}	2.01^{a}	2.41^{c}	7.34^{d}
	40	10.31^{c}	1.21^{ab}	2.41^{c}	11.12^{c}
	100	7.51^{d}	1.05^{b}	1.80^{c}	3.21^{e}
	Mean	**13.06**	**1.68**	**4.41**	**11.43**
	SEM±	**0.82**	**0.45**	**1.10**	**1.31**
	P value	**0.000****	**0.082ns**	**0.000****	**0.000****

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

Table 8: Heavy Metal Concentrations of *Hyptis suaveolens* Leaves (Pooled data) Based on distance from the roadside at four Locations along Zaria-Giwa road.

Source	Location	Heavy metal Concentrations (mg/kg)			
		Pb	**Cd**	**Cu**	**Zn**
Leaves of *H. suaveolens*	ABUTH	21.67[a]	2.37[a]	22.35[a]	68.77[a]
	NAPRI Shika	21.15[a]	1.68[b]	19.11[b]	40.04[b]
	Marabar Guga	18.17[b]	1.68[b]	12.30[c]	41.42[b]
	ABU Dam Quarters	13.06[c]	1.45[b]	4.41[d]	11.43[c]
	Mean	**18.51**	**1.80**	**14.55**	**40.42**
	SEM±	**1.43**	**0.47**	**1.46**	**3.09**
	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= not significant *=significant at P<0.05 **= highly significant at P<0.01

Table 9: Heavy Metal Concentrations of *Hyptis suaveolens* Leaves (Pooled data) Based on Locations along Zaria-Giwa road

Source	Distance(m)	Heavy metal Concentrations (mg/kg)			
		Pb	**Cd**	**Cu**	**Zn**
Leaves of *H. suaveolens*	0	24.47[a]	2.24[a]	19.24[a]	59.41[a]
	5	20.04[b]	1.97[a]	18.40[a]	49.95[b]
	10	20.02[b]	1.98[a]	15.69[b]	46.82[c]
	20	16.84[c]	1.85[ab]	13.36[c]	34.90[d]
	40	16.37[c]	1.47[bc]	13.01[c]	29.12[e]
	100	13.33[d]	1.29[c]	7.59[d]	22.30[f]
	Mean	**18.51**	**1.8**	**14.55**	**40.42**
	SEM±	**1.43**	**0.47**	**1.46**	**3.09**
	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= not significant *=significant at P<0.05 **= highly significant at P<0.01

The pooled data analysis of Cu concentration in *H. suaveolens* leaves based on distance revealed that, the highest copper concentration observed at 0 m was similar to that at 5 m but significantly higher than those observed at all the other distances from the roadside. This was followed by the value recorded at 10 m from the roadside. However, the lowest copper concentration observed at 100 m was significantly lower than those observed at all the other distances from the roadside (Table 8). Equally, the pooled data analysis of Cu concentrations in *H. suaveolens* leaves based on locations showed that, the highest concentration observed at ABUTH was significantly higher than the Cu values recorded at all the other locations in the study area and this was followed by the value recorded at NAPRI Shika. The least concentration of copper recorded

at ABU Dam Quarters was significantly lower than those observed at all the other locations along Zaria-Giwa road (Table 9)

Zinc Level in *Hyptis suaveolens* leaves along Zaria-Giwa road

The highest zinc concentration in H. suaveolens leaves was observed at 0 m at each location while the least was recorded at 100 m from the roadside. At ABUTH, the highest concentration recorded for zinc at 0 m was significantly higher than those at all the other distances from the roadside. This was followed by the Zn value observed at 5 m which was significantly higher than the value observed at 10 to 100 m. However, the lowest Zn concentrations observed at 100 m was similar to that at 40 m from the roadside (Table 7). At NAPRI Shika, the highest Zn concentration observed at 0 m was similar to that at 5 and 10 m but significantly higher than those observed at all the other distances from the roadside. The least concentration recorded at 100 m was significantly lower than that at all the other distances from the roadside (Table 7). The highest Zn concentration observed at 0 m in Marabar Guga was comparable to that at 5 m but significantly higher than those observed at all the other distances from the roadside. This was followed by the Zn value recorded at 10 m from the roadside. However, the least concentration recorded at 100 m was similar to that observed at 40 m from the roadside (Table 7). At ABU Dam Quarters, the highest value of Zn recorded at 0 m was found to be significantly higher than the values observed at all the other distances from the roadside. This was followed by the values recorded at 5 and 10 m, which were also significantly higher than that observed at 20 to 100 m. The least concentration recorded at 100 m was significantly lower than that at all the other distances from the roadside (Table 7).

The pooled data analysis of Zn concentration in *H. suaveolens* leaves based on distance revealed that, the highest zinc concentration recorded at 0 m was significantly higher than those observed at all the other distances from the roadside. This was followed by that recorded at 5 and 10 m which were also highly significant than the values recorded at 20 to 100 m. However, the least Zn concentration recorded at 100 m was significantly lower than those recorded at all the other distances from the roadside (Table 8).

Also, the combined analysis of the data on Zn concentration in the leaves of *Hyptis suaveolens* based on locations revealed that, the highest concentration of zinc recorded at ABUTH was significantly higher than those observed at all the other locations in the study area. This was followed by the Zn concentrations recorded at NAPRI Shika and Marabar Guga. However, the least Zn concentration observed at ABU Dam quarters was significantly lower than those recorded at all the other locations along Zaria-Giwa road (Table 9).

Correlation between heavy metals in the soil and the different organs of the plants

Soil Pb was strongly correlated to the concentration of Pb in the leaves, stems and roots with correlation coefficent values of 0.722, 0.752 and 0.684 respectively, also, strong correlation coefficients was observed for Cu with values of 0.730, 0.602 for stems and roots respectively but moderately correlated to leaves (0.525). Soil Cd was moderately correlated to the different organs of the plant with values of 0.468, 0.487 and 0.495 respectively. Equally, the relationship between soil to the leaves and roots of the plant with respect to zinc concentration were weak with values 0.394 and 0.312 respectively but moderately correlated to the stems with a value of 0.503 (Table 10).

Table 10: Correlation matrix of heavy metals between soils and different organs of *H. suaveolens*

Variable	Pb_LH	Cd_LH	Cu_LH	Zn_LH	Pb_SH	Cd_SH	Cu_SH	Zn_SH	Pb_RH	Cd_RH	Cu_RH	Zn_RH	Pb_S	Cd_S	Cu_S	Zn_S
Pb_LH	1															
Cd_LH	0.460**	1														
Cu_LH	0.824**	0.416**	1													
Zn_LH	0.782**	0.550**	0.883**	1												
Pb_SH	0.819**	0.468**	0.733**	0.758**	1											
Cd_SH	0.628**	0.339**	0.531**	0.523**	0.638**	1										
Cu_SH	0.786**	0.387**	0.841**	0.768**	0.758**	0.548**	1									
Zn_SH	0.796**	0.292*	0.867**	0.829**	0.796**	0.570**	0.842**	1								
Pb_RH	0.834**	0.590**	0.776**	0.763**	0.768**	0.568**	0.754**	0.682**	1							
Cd_RH	0.560**	0.499**	0.578**	0.690**	0.687**	0.432**	0.675**	0.672**	0.597**	1						
Cu_RH	0.723**	0.528**	0.796**	0.877**	0.772**	0.534**	0.787**	0.746**	0.757**	0.631**	1					
Zn_RH	0.748**	0.284*	0.839**	0.817**	0.761**	0.524**	0.764**	0.912**	0.636**	0.605**	0.744**	1				
Pb_S	**0.722****	0.509**	0.786**	0.840**	**0.752****	0.482**	0.740**	0.822**	**0.684****	0.704**	0.740**	0.808**	1			
Cd_S	0.685**	**0.468****	0.799**	0.798**	0.634**	**0.487****	0.669**	0.664**	0.679**	**0.495****	0.746**	0.726**	0.721**	1		
Cu_S	0.542**	0.382**	**0.525****	0.612**	0.665**	0.419**	**0.730****	0.719**	0.517**	0.870**	**0.602****	0.642**	0.678**	0.432**	1	
Zn_S	0.499**	0.350**	0.275*	**0.394****	0.567**	0.303**	0.404**	**0.503****	0.403**	0.538**	0.449**	**0.312****	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

LH=Leaves of *H.suaveolens* SH= Stems of *H. suaveolens*, RH= Roots of *H.suaveolens*, S= Soil

Discussion

Concentration of heavy metals in *Hyptis suaveolens* Organs

The result based on distance from roadside showed that, all the metal levels decreased significantly as distance increases from the road in the roots, stems and leaves of *H. suaveolens.* This is an indication that, the distribution of these metals in the environment is inversely corelated with increase in distance from road (Upahi *et al.*, 2021).

The data from the different organs of the plant based on location revealed that, the roots had the highest concentration of all the heavy metals with the exception of Pb and this was followed by the stems and leaves respectively. The concentrations of the heavy metals in *H. suaveolens* with respect to location revealed that, they were significantly higher at ABUTH in all the organs of the plant with the exception of zinc whose highest concentrations of 62.37 mg/kg and 66.80 mg/kg were observed in the stems and roots respectively at NAPRI Shika. The observed high concentrations at ABUTH in all the organs could be a pointer to the fact that, the heavy metals are products of vehicular emissions. However, the observed high zinc concentration in the stems and roots of *H. suaveolens* at NAPRI Shika, could be due to the physico-chemical properties of the roadside soil in that location, which might have led to the high absorption of the element from the soil and this is in tandem to the report of Masarovičová *et al.* (2010) who demonstrated that, pH, conductivity and organic matter of the soil influence the absorption and migration of heavy metals such as Zinc and copper in plants. The result equally showed that, ABU Dam quarters (control) recorded the lowest concentration of the heavy metals in all the organs of *H.suaveolens* which could be attributed to the low vehicular density in the site.

The data from the different organs of the plant based on location revealed that the roots had the highest concentration of all the heavy metals than the stems and leaves. This observation may be due to the slightly acidic nature of the roadside soil which makes the metals more bioavailable to the plant roots thereby contributing more to the root of the plant than the deposition of the air carried particles unto the plant foliage (stems and leaves). The observed lower concentration of these elements in the stems and leaves could also be due to the inability of the roots of these plants to translocate high level of some of the metals to

the shoot region. In this plant, Cu and Zn fell below the permissible level, while Pb and Cd were above the permissible level given by FAO/WHO (2020).

Lead Concentration in *H. Suaveolens* Organs

In this study, Pb level was found highest in the roots which ranged from 15.31-24.31 mg/kg and ranked in the order of ABUTH > NAPRI Shika > Marabar Guga > ABU Dam Quarters and lowest in the stems which ranged from 11.52-16.90 mg/kg in the order of ABUTH > NAPRI Shika > Marabar Guga > 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. This conforms to the report of Ogbonna & Okezie (2011); Ogundele *et al.* (2017) 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 (Sodimu *et al.,* 2021).

The observed high concentration of the metal in the roots compared to other parts in *H. suaveolens* might be due to the fact that, the roadside soils were contaminated with the metal which was eventually absorbed by the roots of the plants either passively with the mass flow of water into the roots or through active transport crossing the plasma membrane of roots epidermal cells (Ogundele *et al.,* 2017). Therefore, the metal burden of plant is strongly dependent on the uptake by the root system. Also, the observed low concentrations in the stems of *H. suaveolens* could be due to the inability of the plant to translocate Pb from the roots to the stems. It is evident from the result that, *H. suaveolens* accumulate more lead than *B. verticillata* which may be attributed to the genetic capacity of plant species to acquire certain metals. All these values are above the standard safe limit of 0.3 mg/kg as recommended by FAO/WHO (2020).

Cadmium Concentration *H. Suaveolens* Organs

The data based on locations, revealed that, the range of cadmium in *H. suaveolens*, was found highest in the roots (1.55- 3.39 mg/kg) in the order of ABUTH > NAPRI Shika > Marabar Guga > ABU Dam Quarters and lowest in the stems (1.53-1.94 mg/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 as recommended by FAO/WHO (2020). From the result, high and low traffic sites recorded high and low metal concentrations respectively. Therefore, this observation confirms that, there is a direct relationship existing between roadside vehicular emissions and the level of heavy metals observed in this plant species. The source of this Cd level in all the organs of the plants may be attributed to lubricants, wearing of paints on the body of vehicles as well as tear and wear of tyres (Ogbonna and Okezie, 2011; Okpanachi *et al.,* 2018).

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 accumulates in the top layer of the soil which is accessible for uptake by the roots of plants. Also, the observed low concentration in the level of Cd accumulated in the stems of the two plant species may be attributed to the inability of the plants to translocate Cd as well as the genetic capacity of the plant species to accumulate atmospheric derived metals into their tissues. The absorption of Cd compounds may vary greatly depending upon the particle sizes, their solubility as well as plant species (Upahi *et al.,* 2024).

Copper Concentration *H. Suaveolens* Organs

Cu level was found highest in the leaves (4.41-22.35mg/kg) in the order of ABUTH > NAPRI Shika > Marabar Guga > ABU Dam Quarters and lowest in the stems (5.56-15.05mg/kg) in the order of ABUTH > NAPRI Shika > Marabar Guga > ABU Dam Quarters. All the values were significantly different from each other across locations and were within the standard safe limit of 73.30 mg/kg recommended by FAO/WHO (2020). These concentrations observed in the different organs of the plants were consistent with vehicular densities in the sense that, ABUTH had the highest concentration of the element in all the organs while ABU Dam Quarters, recorded the lowest concentration in all the organs. This high values observed in the organs of plant species may be due to vehicular pollution. It may also be derived from engine wear and electrical wirings (Ogundele *et al.,* 2015) as well as spillage of lubricants from vehicles, most especially heavy trucks which are eventually washed down by runoff into surrounding environment. The observed high level of the element in the leaves of *H. suaveolens* could be due to the broadness of the leaf organ which act as sink to all atmospheric deposition in addition to the translocation from the roots to the shoot.

Zinc Concentration *H. Suaveolens* Organs

Zn level was found highest in the roots (11.43-68.77 mg/kg) in the order of NAPRI Shika > ABUTH > Marabar Guga > ABU Dam Quarters and lowest in the stems (13.69-62.37 mg/kg) in the order of NAPRI Shika > ABUTH > Marabar Guga > ABU Dam Quarters. The observed high concentration of Zn in the roots and leaves of *H. suaveolens* at NAPRI Shika (a site with lesser vehicular density than that of ABUTH) could be ascribed to the combined effect of vehicular emissions as well as the physicochemical properties of the roadside soil in that location. This is because the mobility of the metal depends on soil pH, organic matter and granulometric composition of the soil (Upahi *et al.,* 2024). All the values were highly significant from each other across all locations. However, the highest concentrations in most of the study areas were below the standard safe limit of 99.40 mg/kg recommended by FAO/WHO (2020). Zn is used in brake linings because of their heat conducting properties and as such released during mechanical abrasion of vehicles, also, engine oil combustion and tyres of motor vehicle are also source of depositing vehicle related zinc into the environment. This is in tandem with the report of Ogundele *et al*. (2015) who stated that, zinc concentration in roadside soil and plants might be due to the number of trucks and other vehicles that pass through these roads as there are no major industries existing in the study area. The observed high level of zinc in the roots of the two plants may be due to the fact that zinc are actively absorbed from the soil by roots (Sodimu *et al.,* 2021) before it is eventually translocated to other parts of the plant. Also, the stems and leaves of the plant had higher concentrations of zinc than all the other heavy metals which could be attributed to the ability of the roots of this plant species to translocate the metal to the shoot region as well as the direct assimilation of the deposited metal on the stems and leaves of this plants through the atmosphere. It may also be due to the tolerance abilty of the plants to accumulate high zinc concentrations because of its utilization and function as it is an essential micronutrient that affects several metabolic activities of plants.

Correlation coefficient of heavy metals in soil and plant organs

The correlation matrix of heavy metals in the soil and different organs of the two plants were analyzed to check if the heavy metals in the soil were interrelated with plant organs. The result showed that, there was a general positive correlation between the soils and all the organs of the plant species. The general positive correlation between metals in soils and plants is in agreement with the findings of Upahi *et al.,* (2021) who reported a positive relationship among these heavy metals in soil and plants. This positive correlation between metals in soils and

plants 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 (Ogundele *et al.,* 2015).

Conclusion

Distance from the roadside and vehicular densities had a significant effect on lead, cadmium, copper and zinc concentrations in the different organs of *H. suaveolens* as the highest and lowest values were observed at 0 and 100 m respectively across the study area. Also, there was a significant positive relationship between the heavy metal concentrations in the soil and the different organs of the plant species which suggests a common pollution source for both the roadside soils and different organs of the plant species.

Recommendations

In view of these findings, Farmers are advised to keep some distance (at least 100 m) away from the roadside before planting crops in order to reduce the accumulation of heavy metals by crops. Similarly, herdsmen are advised to feed their animals with plants that are far away from the roadside.

Traditional herbalists are equally advised to avoid the collection of medicinal plants that are close to the roadside. Further research should be conducted on other roadside plants in order to compare their effectiveness for phytoremediation.

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Conflict of Interest

The authors unanimously declare that there is no conflict of interest regarding the publication of this article.

Author Contribution

Upahi, L. drafted the research, analysed and interpreted the data, Aina, O. A. revised the work. All authors reviewed the findings and approved the final version of the manuscript.

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