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Heavy Metal Level and Macronutrient Contents of Roadside Soil and Vegetation in Umuahia, Nigeria

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ABSTRACT

This study investigated the metal level and macronutrient content of roadside soil and vegetation as influenced by vehicular emission. Soil and plant samples were collected from 1, 5 and 10 m sampling positions in a randomized complete block design (RCBD) from FRIN, NRCRI, ISIALA and control. Levels of Pb, Cd and Ni in soil and plants were 0.20–28.8, 0.08–8.90, 0.20–4.10 mg/kg and 0.01–11.10, 0.07–2.70, 0.02–0.83 mg/kg, respectively. The concentrations of Pb, Ni, and Cd were significantly ($P < 0.05$) higher in leaves of *Gmelina arborea* (11.10, 0.83 and 2.70 mg/kg) followed by *Psidium guajava* (9.00, 0.50 and 1.80 mg/kg) sampled at FRIN. Soil N (0.34 cmol/kg) was highest ($P < 0.05$) in 10 m at NRCRI, K (146.0 cmol/kg) in 10 m at ISIALA while P (71.0 cmol/kg) was highest in 10 m at NRCRI and ISIALA. In plant leaves, P (42.0 cmol/kg) and K (81.0 cmol/kg) were highest ($P < 0.05$) in *Alchornea cordifolia* and *Harungana madascariensis*, respectively. The result shows that the concentration of Cd in soil was substantially high and must have affected litter decomposition, mineralization and nutrient characteristics of the soil and uptake by plants.

Keywords: heavy metal, macronutrient, roadside soil, vegetation, vehicular emission

INTRODUCTION

Heavy metals from anthropogenic sources have caused serious damage to forest ecosystems in areas close to a number of emission sources. Emissions from heavy traffic on roads contain lead (Pb), cadmium (Cd), zinc (Zn), and nickel (Ni), which are present in fuel as anti-knock agents (Suzuki *et al*. 2008; Atayese *et al*. 2009). The deposition of vehicle derived metal and the relocation of metals deposited on road surface by air and run off water have led to contamination of roadside soil (Viard *et al*. 2004; Nabuloa *et al*. 2006). Consequently, studies have been carried out on heavy metal contamination in soils along major roads (EPA 1999; Turer and Maynard 2003). This interest is due to the toxicity of metals, their bioaccumulation and biomagnification in food chains and their potential effects on both human health and ecosystem functions. The consumption of plants produced in contaminated areas, in addition to ingestion or inhalation of contaminated particles (Zhuang *et al*. 2008) from vehicular emissions, are two principal factors contributing to human exposure to metals.

Accumulation of heavy metals in roadside soil along major roads is of great ecological concern since it can alter biological activities in the soil. Increased level of metals in soil affects enzymatic activity of microorganisms such as urease and phosphate (Doelman and Haanstra 1979; Hughes *et al*. 1980; McGrath 1994). Soil constitutes part of vital environmental, ecological and agricultural resources that need to be protected from further degradation for adequate supply of healthy food needed for the world's increasing population (Rashad and Shalaby 2007).

In recent times, there has been global concern about the health of the ecosystem *vis-à-vis* climate change. There is also a concern for better understanding urban soil pollution (Manta *et al*. 2002) and vegetation present on verges of roads (Okonkwo and Maribe 2004; Chimuka *et al*. 2005). Thus, in areas with increase agricultural and industrial activities and high population density, roadside verges are the only habitats that sustain natural vegetation (Ansari *et al*. 2003) and plants growing on verges of roads are probably considered as the oldest form of anthropogenic vegetation (Ullmann and Heindle 1989).

For over two decades, commercial activity such as transportation has been alarming in Umuahia due to the cost of fairly used vehicles and high level of unemployed youth in Nigeria. Consequently, vehicular emission of Pb and other metals may have accumulated in soil and vegetation along the highway. Road transportation is the oldest and most common means of transportation in a developing country such as Nigeria. Research has been carried out on metal availability in roadside soil and plants; however, the majority of these studies have been carried out in advance countries with known history of industrialization and extensive use of leaded gasoline (Albasel and Cottenie 1985; EPA 1999; Turer and Maynard 2003; Viard *et al*. 2004; Nabuloa *et al*. 2006; Bai *et al*. 2008; Pirzada *et al*. 2009). Very limited work has been published on heavy metal content of roadside soil and plants, including *Amaranthus cruenthus* (Okunola *et al*. 2007) and *Sida acuta* burm f. (Atayese *et al*. 2009) in Nigeria. In assessing environmental pollution, knowledge of the total amount of an element is not sufficient, as it indicates the degree of pollution, but does not provide information about bioavailability and toxicity with respect to specific biotic components. In Nigeria, data on the influence of vehicular emission on heavy metals and macronutrient contents in soil and woody plants growing naturally along the highways are not available. Woody plants that have grown on the roadside verges over a period of time have the height (unlike crops) that favour the exposure of their leaves to air contaminated with vehicular emission; thus, will give a better understanding of the effect of vehicular emissions on roadside soil and biota as well as the nutrient characteristics of the ecosystem. Hence, the objectives of the present study were to provide data on concentrations of heavy metals in roadside ecosystems and to evaluate their impact on nutrient characteristics in the ecosystem.

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MATERIALS AND METHODS

Study area and sampling

The research on heavy metal level and macronutrient content of roadside soil and vegetation was carried out in Umuahia, Nigeria. It is located on the lowland rainforest zone of Nigeria (Keay 1959), which lies on latitude 05°29′ to 05°42′ N and longitude 07°24′ to 07°33′ E with an average rainfall of 2238 mm per annum that is distributed over a 7-months rainy season (Nzegbule and Ogbonna 2008). The minimum and maximum temperatures are 23 and 32°C, respectively, and relative humidity of 60-80% (Ogbonna and Nzegbule 2010).

Soil samples were randomly collected from the Forestry Research Institute of Nigeria (FRIN), the National Root Crops Research Institute (NRCRI), Isiala Local Government while the control sample was collected from Obafemi Awolowo route (untarred and occupied by vegetation due to non-usage). Surface soil samples of 0-10 cm were collected with an auger at an approximate distance of 1, 5 and 10 m from each location. The samples for each sampling position were mixed properly to give a composite sample mixture. Enough soil samples was collected from the composite sample of each location, placed in a cellophane bag (Bamgbose *et al.* 2000), labeled and taken to the laboratory for pre-treatment and analysis of heavy metals and macronutrients. The soil sampling locations were cleared of debris before sampling (Chimuka *et al.* 2005).

Fresh leaves *Pinus carribeae*, *Psidium guajava*, *Gmelina arborea* (FRIN), *Glyricidia sepium*, *Buddleja davidii*, *Icacina trichantha* (NRCRI), *Harungana madascariensis*, *Venonia amydalina*, *Alchornea cordifolia* (ISIALA) and *Lovoa* sp. (control) were randomly harvested with a clean secateur from each sampled location where soil were collected, placed in envelopes, well labeled and taken to the laboratory for pre-treatment and analysis of heavy metals and macronutrients. *Lovoa* sp. was considered as the control because the plant sample was collected from Obafemi Awolowo route (untarred and occupied by vegetation due to non-usage).

Sample preparation for heavy metals

Soil samples from each location were homogenized and air-dried in circulating air in an oven at 30°C to a constant weight and passed through a 2 mm sieve. The procedure according to MAFF (1981) was used for digestion of soil samples. 1 g of soil samples were placed in a 100-ml beaker. 10 ml of HNO_3 acid and 3 ml $HClO_4$ were added and the solution was heated until fuming. The sample solution was obtained by processing the residue with hot E mol/Hec (4 ml), then filtered and diluted with water in a 50 ml standard flask. Triplicate digestion of each sample together with a blank was also carried out. Thereafter, quantitation of the metallic content of digested samples was carried out with a flame atomic absorption spectrophotometer (UNICAM 919 model).

Plant samples were properly rinsed with distilled-deionized water to remove any attached dust and pollen particles and placed in large clean crucibles where they were oven dried at 70°C for 72 h. The dried samples were milled with a Thomas Wiley milling machine (Model ED-5). The digestion of plant samples were carried out according to the method of Allen *et al.* (1976). 0.2 g of sieved leaf samples were weighed into a 100 ml standard flask. A mixture of 1 ml perchloric acid and 5 ml concentrated trioxonitrate (V) acid were added and digested at 80-90°C with hot plate until white fumes evolved. The digest was allowed to cool, filtered into 50 ml standard flask using Watchman No. 1 filter paper. Triplicate digestion of each sample was carried out together with blank digest without the plant sample.

Soil and leaf analysis for macronutrients

Sieved soil samples and milled leaf samples were digested according to the wet digestion method of Novozamsky *et al.* (1983) for multi-element soil and plant analysis. K was determined by flame photometry, P was determined by the Vanodo-molybdate spectrophotometric method while N was determined by the micro Kjeldahl distillation method (Bremner and Mulvancy 1982).

Experimental and data analysis

The experimental design was a simple factorial experiment in randomized complete block design (RCBD). Data generated from this study were subjected to one-way analysis of variance (ANOVA) using Statistical Package for Social Sciences (SPSS) v. 15 and mean separation done according to Steel and Torrie (1980) at $P < 0.05$.

RESULTS AND DISCUSSION

Heavy metal level in soils along highway

The concentration of heavy metal in soils in the various locations along the highway varied significantly ($P < 0.05$) from one sampling position to another (**Table 1**). Pb concentration in soil at sampling position of 1 m (28.80 ± 1.2 mg/kg) in FRIN is significantly ($P < 0.05$) higher than 22.02 ± 1.0 mg/kg and 10.60 ± 0.2 mg/kg found in 5 and 10 m, respectively in the same location as well as the concentrations found in 1, 5 and 10 m in NRCRI and ISIALA. The control with 0.20 ± 0.0 mg/kg had the lowest concentration of Pb. The value of Pb in this study ranged from 0.20 ± 0.0 - 28.80 ± 1.2 mg/kg. The value of Pb is relatively higher than the 25 mg/kg Pb in soil reported in similar study (Canadian Environmental Quality 1992). Also, these values reflected a significant pollution impact when compared with the background concentration of 1.94 ± 0.34 mg/kg reported by Merrington and Alloway (1993). The result shows that there was a marked decrease in the concentration of Pb in soil as the sampling distance increases. Metal contamination of roadside soil by vehicular emission is affected by the distance involved (Turer and Maynard 2003). The source of Pb in the soil, since there were no industries in Umuahia may be attributed to $PbBr_2$ and $PbCl_2$ (lead halides) released into the surroundings through the exhaust pipe of various vehicles plying the highway. Ni concentration in soil was highest ($P < 0.05$) in sampling position of 1 m (4.10 ± 0.2 mg/kg) in FRIN. The value of Ni ranged from 0.20 ± 0.1 - 4.10 ± 0.2 mg/kg. This value is within the range proposed by Alloway and Ayres (1997). The source of Ni is probably from the combustion of gasoline in vehicles. The combustion of fossil fuels contributes the largest amount of Ni to the environment (Asthana and Asthana 2006). Cd concentration in soil was highest ($P < 0.05$) in soil sampled from 1 m (8.90 ± 0.2 mg/kg). The value of Cd in this study ranged from 0.08 ± 0.0 - 8.90 ± 0.2 mg/kg. The level of Cd (8.90 ± 0.2 mg/kg) in 1 m sampling position at FRIN exceeds 0.34-2.12 mg/kg in China (SEPAC 1995; Bai *et al.* 2008) and 0.05-0.30 µg/g in Egypt (Abou-Arab *et al.* 1999). Cd concentration in this study could lead to stunted growth and

Table 1 Heavy metal concentration in soils (mg/kg) at various locations.

	FRIN			**NRCRI**			**ISIALA**			**Control ***
	1 m*	**5 m***	**10 m***	**1 m***	**5 m***	**10 m***	**1 m***	**5 m***	**10 m***	
Pb	28.80 ± 1.2 a	22.02 ± 1.0 b	10.60 ± 0.2 f	15.00 ± 0.2 d	12.01 ± 0.0 ef	7.04 ± 0.0 g	19.36 ± 0.3 c	13.02 ± 0.0 e	6.01 ± 0.1 g	0.20 ± 0.0 h
Ni	4.10 ± 0.2 a	3.03 ± 0.0 b	1.01 ± 0.0 d	2.11 ± 0.0 c	1.90 ± 0.0 c	0.65 ± 0.0 e	0.08 ± 0.0 f	0.06 ± 0.0 f	0.20 ± 0.1 f	ND
Cd	8.90 ± 0.2 a	6.02 ± 0.0 b	1.99 ± 0.0 f	5.01 ± 0.0 c	4.06 ± 0.0 d	1.03 ± 0.0 g	6.04 ± 0.0 b	3.00 ± 0.2 e	1.18 ± 0.0 g	0.08 ± 0.0 h

* = Different letters within a column indicate significant differences ($P < 0.05$)
ND = not detected
FRIN = Forestry Research Institute of Nigeria Umuahia, Nigeria
NRCRI = National Root Crops Research Institute Umudike, Nigeria
ISIALA = Ikwuano Local Government Headquarter, Abia State, Nigeria

Table 2 Heavy metal concentrations (mg/kg) in plant leaves.

Plant species	Pb*	Ni*	Cd*
FRIN			
Pinus carribeae	7.20 ± 0.0 c	0.26 ± 0.0 c	1.50 ± 0.0 c
Gmelina arborea	11.10 ± 0.0 a	0.83 ± 0.0 a	2.70 ± 0.0 a
Psidium guajava	9.00 ± 0.4 b	0.50 ± 0.0 b	1.80 ± 0.0 b
NRCRI			
Glyricidia sepium	3.14 ± 0.0 f	0.08 ± 0.0 d	0.70 ± 0.0 e
Icacina sp.	4.00 ± 0.0 e	0.02 ± 0.0 e	1.30 ± 0.0 d
Masquerade tree	6.04 ± 0.1 d	ND	0.52 ± 0.0 f
ISIALA			
Harungana sp.	1.02 ± 0.0 g	0.02 ± 0.0 e	0.12 ± 0.0 g
Alchornea sp.	4.10 ± 0.0 e	ND	0.15 ± 0.0 g
Venonia sp.	6.13 ± 0.1 d	ND	0.07 ± 0.0 gh
CONTROL			
Lovoa sp.	0.01 ± 0.0 h	ND	ND

* = Different letters within a column indicate significant differences ($P < 0.05$)
ND = not detected
FRIN = Forestry Research Institute of Nigeria Umuahia, Nigeria
NRCRI = National Root Crops Research Institute Umudike, Nigeria
ISIALA = Ikwuano Local Government Headquarter, Abia State, Nigeria

chlorosis (Sereign *et al.* 2004) of the plants. The sources of Cd is probably from the wearing of paints on the body of vehicles (Asthana and Asthana 2006) plying on the road coupled with the attrition of tyres due to rough surfaces of roads. Metals such as Cd, Pb, Ni are included in diesel, tyres, engines, brake wear, lubricating oil and galvanized parts of the vehicles (Falahi-Ardakani 1984; Zechmeister *et al.* 2005). Generally, the concentrations of heavy metals in soils followed an increasing order: Ni < Cd < Pb.

Heavy metal content in plants

The concentrations of heavy metals in leaves of plants that were naturally growing in the study site differed significantly ($P < 0.05$) from one location to another (**Table 2**). The leaves of plants are used as a reflection of the quantitative uptake of metals in plants (Alfani *et al.* 2004). Pb concentration was highest ($P < 0.05$) in leaves of *Gmelina arborea* (11.10 ± 0.0 mg/kg) and this value was significantly ($P < 0.05$) higher than the values obtained in *Psidium guajava* (9.00 ± 0.4 mg/kg), *Pinus carribeae* (7.20 ± 0.0 mg/kg), *Venonia amygdalina* (6.13 ± 0.1 mg/kg), *Buddleja davidii* (6.04 ± 0.1 mg/kg), *Alchornea cordifolia* (4.10 ± 0.0 mg/kg), *Icacina tricantha* (4.00 ± 0.0 mg/kg), *Glyricidia sepium* (3.14 ± 0.0 mg/kg), *Harungana madascariensis* (1.02 ± 0.0 mg/kg) and *Lovoa* sp with 0.01 ± 0.0 mg/kg (**Table 2**). The control sample (*Lovoa* sp.) had the lowest Pb concentration (0.01 ± 0.0 mg/kg). Pb concentration in the leaves of plants ranged from 0.01 ± 0.0 - 11.0 ± 0.0 mg/kg. This value is slightly above the range of 5-10 mg/kg (Alloway and Ayres 1997) but slightly below 1-12 mg/kg (Fleming and Parle 1977). The height of these woody plants (*Gmelina arborea*, *Psidium guajava* and *Pinus carribeae*) which were higher than 5 m probably favoured the exposure of their leaves to contaminated air (vehicular emission) and explains the high lead (Pb) concentrations found in samples from these plants. This agrees with the fact that lead (Pb) in plants is due mainly to aerial deposition (Albertine *et al.* 1997; McLaughlin *et al.* 1999). Pb deposited on the surface of leaves is significantly absorbed inside the plant cells (Issermann 1977; Dalenberg and van Driel 1990) and inhibit a number of cytoplasmic enzymes (Assche and Clijsters 1990). Also, the concentration of Pb may be due to its translocation from root to leaves since Pb concentration in soil (10.60 ± 0.2 - 28.80 ± 1.2 mg/kg) was high. Ni concentration in plants was highest ($P < 0.05$) in the leaves of *Gmelina* (0.83 ± 0.0 mg/kg) followed by *Psidium* (0.50 ± 0.0 mg/kg). Ni concentration in plant leaves ranged from 0.02 ± 0.0 - 0.83 ± 0.0 mg/kg. This value is well below 0.02 - 5 mg/kg (Alloway and Ayres 1997). The high concentration of Ni in the leaves of *Gmelina* and *Psidium* species is presumably from the soil, since the concentration of this element was observed to be high in soils (1.01 ± 0.0 - 4.10 ± 0.2 mg/kg) where the plants are located. Plants growing in metal contaminated soils can take up metals and translocate it to its organs such as the leaves. Cd concentration was highest ($P < 0.05$) in *Gmelina* leaves (2.70 ± 0.0 mg/kg) followed by the leaves of *Psidium* (1.80 ± 0.0 mg/kg). Cd concentration in plant leaves ranged from 0.07 ± 0.0 - 2.70 ± 0.0 mg/kg. This value is relatively higher than 0.10 - 2.40 mg/kg (Alloway and Ayres 1997). The level of Cd in plant leaves can be attributed to the inherent ability of the plants to absorb this metal specie from the vehicular emission deposited in the soil. Plants take up metals that are dissolved in soil solution in either ionic or chelated and complex forms (Moore 1972), and the rate of metal movement in plant tissues varies depending on plant organ, its age and element involved (Kabata-Pendias 2000). From the result, *Gmelina arborea* and *Psidium guajava* sequestrated more metals from the soil than *P. carribeae*, *V. amydalina*, *Buddleja davidii*, A. *cordifolia*, *I. trichantha*, *G. sepium*, *H. madascariensis* and *Lovoa* sp. Indeed, the leaves of *G. arborea* is a good forage material for West African Dwarf (WAD) goats in Nigeria while the leaves of *P. guajava* are boiled and used therapeutically for the treatment of malaria as well as other ailments. Consequently, there is a great need to protect these resources from further degradation by pollutants such as heavy metals so as to safeguard the health and lives of animals including man.

Macronutrient content in soil

The composition of macronutrient in soil at various location studied are not similar (**Table 3**). In the study area, the highest content of N (0.34 ± 0.0 cmol/kg) was obtained at 10 m in NRCRI and this value was significantly ($P < 0.05$) higher than values obtained in FRIN (0.2 ± 0.0 cmol/kg) and ISIALA (0.24 ± 0.0 cmol/kg). The highest content of K (146.0 ± 0.2 cmol/kg) was obtained at 10 m in ISIALA and this value was significantly ($P < 0.05$) higher than values obtained in FRIN (62.0 ± 0.3 cmol/kg) and NRCRI (48.1 ± 0.3 cmol/kg). The value of K in this study ranged from 48.1 ± 0.3 to 146.0 ± 0.2 cmol/kg which is significantly ($P < 0.05$) higher than 0.26 ± 0.0 – 0.39 ± 0.1 reported in a related study (Okoronkwo *et al.* 2006). However, P (71.0 ± 0.2 cmol/kg) was significantly ($P < 0.05$) higher in 10 m sampling positions of NRCRI (71.0 ± 0.1 cmol/kg) and ISIALA (71.0 ± 0.2 cmol/kg) than in FRIN (50.0 ± 0.8 cmol/kg). The mineralization of soil organic phosphorus is brought about by the activities of soil microorganisms. Free enzymes such as phosphates (an enzyme splitting off phosphates from organic molecules) present in soils also hydrolyze organic P from dead organic residue, making it availa-

Table 3 Macronutrient content in soil (cmol/kg) at various locations from the highway.

	FRIN			NRCRI			ISIALA			Control *
	1 m*	**5 m***	**10 m***	**1 m***	**5 m***	**10 m***	**1 m***	**5 m***	**10 m***	
N	0.11 ± 0.0 e	0.16 ± 0.0 de	0.22 ± 0.0 cd	0.20 ± 0.0 d	0.30 ± 0.0 bc	0.34 ± 0.0 b	0.18 ± 0.0 de	0.23 ± 0.0 cd	0.24 ± 0.0 cd	1.17 ± 0.0 a
P	20.83 ± 0.1 i	43.11 ± 0.1 g	50.40 ± 0.8 e	45.80 ± 0.3 f	62.30 ± 0.1 c	71.00 ± 0.1 b	34.10 ± 1.6 h	60.00 ± 1.4 d	71.00 ± 0.2 b	106.00 ± 0.2 a
K	40.14 ± 0.0 h	58.60 ± 1.0 f	62.00 ± 0.3 e	21.30 ± 0.2 i	40.00 ± 1.1 h	48.10 ± 0.3 g	124.00 ± 0.4 d	139.00 ± 0.6 c	146.00 ± 0.2 b	198.40 ± 0.1 a

* = Different letters within a column indicate significant differences ($P < 0.05$)
FRIN = Forestry Research Institute of Nigeria Umuahia, Nigeria
NRCRI = National Root Crops Research Institute Umudike, Nigeria
ISIALA = Ikwuano Local Government Headquarter, Abia State, Nigeria

ble for plant uptake (Agbede 2009). Phosphorus in this study ranged from 50.4 ± 0.8 to 71.0 ± 0.1 cmol/kg which is significantly ($P < 0.05$) higher than 3.23 ± 0.59 – 10.81 ± 0.51 reported by Okoronkwo *et al*. (2006). The result showed that FRIN had significantly ($P < 0.05$) the lowest content of macronutrient (N, P and K) and this may be attributed to the high level of heavy metals in the soil within this location. Heavy metal accumulation in forest soil may affect nutrient cycling by inhibiting litter decomposition (Freedman and Hutchinson 1980; Fritze *et al.* 1989). Generally, the contents of N (1.17 ± 0.0 cmol/kg), P (106 ± 0. 2 cmol/kg) and K (198.4 ± 0.1 cmol/kg) were significantly ($P < 0.05$) higher in control samples than in FRIN, NRCRI and ISIALA. The pattern of the result shows that N < P < K.

Macronutrient content in plants

The contents of N, P and K in plant samples collected from the different locations are presented in **Table 4**. The N contents in plant leaves were statistically equal among the sampled plants. The level of N in the plant leaves is presumably a reflection of its presence in the surface soils in the study area. P content in plant leaves was highest in *Alchornea cordifolia* (42.0 ± 0.1 cmol/kg) while K was highest in leaves of *Harungana madascariensis* (81.0 ± 0.2 cmol/kg) located in ISIALA and these values were significantly ($P < 0.05$) higher than values obtained in *Pinus carribeae* (40.13 ± 0.1 and 10.12 ± 0.0 cmol/kg), *Lovoa* sp. (39.11 ± 0.2 and 46.00 ± 0.3 cmol/kg), *Glyricidia sepium* (31.23 ± 0.0 and 29.10 ± 0.3 cmol/kg), *Gmelina arborea* (30.12 ± 0.0 and 21.30 ± 0.0 cmol/kg), *Icacina trichantha* (29.0 ± 0.4 and 20.36 ± 0.0 cmol/kg), *Venonia amygdalina* (17.14 ± 0.0 and 35.26 ± 0.1 cmol/kg) and *Buddleja davidii* (12.11 ± 0.1 and 21.13 ± 0.0 cmol/kg), respectively. The high content of P and K in leaves of plants in ISIALA probably can be attributed to high content of these elements in soils (160.0 ± 1.4 - 71.0 ± 0.2 and 139.0 ± 0.6 - 146.0 ± 0.2 cmol/kg) where they are located respectively. Also, the high contents of P and K may be due to low level of heavy metals in soils at this location. Accumulation of heavy metals in forest soil may affect nutrient cycling by inhibiting litter decomposition (Freedman and Hutchinson 1980; Fritze *et al.* 1998a), affect negatively roots and mycorrhizas (Colpaert and Van Assche 1992) and plants (Derome and Nieminen 1998). Similarly, metal phytotoxicity leads to inhibition of enzyme activities, disturbed mineral nutrition, water inbalance, change in hormonal status and alteration in membrane permeability (Ernst 1998; Seregin and Ivaniov 2001) which could have affected the macronutrient uptake by plants. Indeed, the low content of K in plants located at FRIN may be associated with Pb toxicity; since concentration of Pb in soil was also high in this location. Malkowski *et al* (2002) asserted that Pb toxicity causes leakage of potassium (K) from root cells of plants. Hitherto, plants exposed to lead ions (Pb^{2+}) show a markedly decrease in rate of photosynthesis, which results from distorted chloroplast ultra structure, disturbed chlorophyll synthesis, obstructed electron transfer (Rebechini and Hanzely 1974) and inhibition of chlorophyll synthesis by Pb is caused by impaired uptake of essential elements like phosphorus (P) and magnesium (Mg) by plants (Burzynski 1987).

Table 4 Macronutrient content in plant leaves (cmol/kg) at various locations from the highway.

Plant species	N*	P*	K*
FRIN			
Pinus carribeae	0.29 ± 0.0 a	40.13 ± 0.1 b	10.12 ± 0.0 i
Gmelina arborea	0.13 ± 0.0 a	30.12 ± 0.0 e	21.30 ± 0.0 f
Psidium guajava	0.70 ± 0.5 a	26.20 ± 0.0 g	18.40 ± 0.0 h
NRCRI			
Masquerade plant	0.22 ± 0.0 a	12.11 ± 0.1 i	21.13 ± 0.0 f
Icacina trichantha	0.27 ± 0.0 a	29.00 ± 0.4 f	20.36 ± 0.0 g
Glyricidia sepium	0.48 ± 0.0 a	31.23 ± 0.0 d	29.10 ± 0.3 e
ISIALA			
Harungana sp.	0.28 ± 0.0 a	26.23 ± 0.0 g	81.00 ± 0.2 a
Venonia amydalina	0.30 ± 0.0 a	17.14 ± 0.0 h	35.26 ± 0.1 d
Alchornea cordifolia	0.64 ± 0.0 a	42.00 ± 0.1 a	53.17 ± 0.1 b
CONTROL			
Lovoa sp.	0.24 ± 0.0 a	39.11 ± 0.2 c	46.00 ± 0.3 c

* = Different letters within a column indicate significant differences ($P < 0.05$)

CONCLUSION

The study on roadside soils and woody plants confirmed transportation *vis-à-vis* vehicular emission as a potential source of environmental pollution. Among the heavy metals, Pb and Cd reflected a significant pollution impact in soil, except for Ni in FRIN. The concentration of Cd in soil was substantially high and this might have affected litter decomposition, mineralization and nutrient flow in the ecosystem. The concentrations of Pb, Ni and Cd in plants were significantly ($P < 0.05$) higher in *Gmelina arborea* followed by *Psidium guajava* and these plants may pose serious health risk to man and other animals that depend on them for food and medicinal purposes. Macronutrient (N, P and K) in soil were significantly ($P < 0.05$) higher at 10 m in both NRCRI and ISIALA than in FRIN which was a reflection of metal impact on the soils. In plants, the highest contents of P and K were obtained in *Alchornea cordifolia* and *Harungana madascariensis* respectively probably due to low concentration of heavy metals in soils where they are located. For the soil and plant samples, the concentrations of heavy metals in this study were found to follow decreasing order: Pb > Cd > Ni from ISIALA – FRIN, and macronutrient content also followed a decreasing order: K > P > N from ISIALA – FRIN. The source of heavy metals is probably from vehicular emission of leaded gasoline, attrition of tyres on rough road surfaces and wearing away of the painted body of the numerous vehicles plying the highway.

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