Effect of Traffic Density on Heavy Metal Content of Soil and Vegetation along Roadsides in Osun State, Nigeria

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Abstract

The study examined the impact of automobile exhaust emissions on heavy metal load of soils and vegetation along two roads with contrasting traffic densities in Osun State, Nigeria. Soils and vegetation along the two roads, one heavy traffic density (HTD) with average daily traffic density (ADTD) of 5,364 vehicles, and the other low traffic density (LTD) of 1,358 vehicles per day, were sampled. The concentrations of lead (Pb), zinc (Zn), cadmium (Cd), nickel (Ni) and vanadium (V) in soils decrease away from the road. There was positive correlation between the level of the metals in soils and vegetation. The concentration of Pb in the plant samples varied from 50.52 µg/g at 1-m distance away from the road-edge to 1.18 µg/g in places 50-m away from the road-edge. At similar locations (i.e. 1-m and 50-m distances away from the road-edge), the plant sample content varied from 41.20 to 1.16 µg/g for Zn, 1.35 to 0.02 µg/g Cd, 3.45 to 0.44 µg/g Ni and 6.60 to 0.58 µg/g V for the HTD road side. The concentrations of these metals in the plant samples along the LTD were significantly lower than for the HTD at similar locations. Furthermore, the metal concentrations in soils and vegetation were related positively to traffic densities, with the soils and vegetation along the HTD having significantly higher ($P > 0.05$) level of the investigated metals than those along the LTD roads. The concentrations of metals in the soils and vegetation within the right of way (ROW) were significantly higher ($P > 0.05$) than those beyond. Appropriate land-use and management strategies that will mitigate the impacts of heavy metals in automobile emission in roadside soils and vegetation were discussed.

Introduction

Pollution in recent years has increased considerably as a result of increasing human activities such as burning of fossil fuels, and industrial and automobile exhaust emissions. Exhaust emission and combustion of fossil fuels were identified as primary sources of atmospheric metallic burden (Aribike, 1996), and it is now well established that a variety of motor vehicles introduce a number of toxic metals into the environment, most of which are released adjacent to roadways (Williamson, 1973; Moore & Moore, 1976). Lagerwerff & Specht (1970) reported the release of lead (Pb), cadmium (Cd), nickel (Ni) and zinc (Zn) into areas adjacent to the roads, while other workers (Cannon & Bowles, 1962; Quinche *et al.*, 1969; Motton *et al.*, 1970) observed that Pb emissions from motor vehicles produce elevated concentrations of the element in roadside vegetation.

In Nigeria, within the cities, atmospheric Zn and Cu concentrations were reported to be a function of traffic density (Fatoki & Ayodele, 1991). Ademoroti (1986) noted that organometallics such as tetraethyl lead [$(C_2H_5)_4Pb$], an additive to gasoline (petrol), is an important source of Pb in automobile exhaust emission. He observed that 58.3-143.5 µg Pb/g plant was obtained in areas of very high traffic volume (greater than 1000 vehicles/h) as against 15.2-15.8 µg Pb/g plant in low traffic volume (< 200 vehicles/h).

Nigerian crude oil is known to have about

0.003–42.31 mg/kg of transition metals (V, Cr, Mn, Fe, Co, Ni and Cu) (Nwachukwu *et al.*, 1995), some of which could not be completely removed during the crude refining processes and can, therefore, readily be emitted during combustion. Man, animals, vegetation and soil act as 'sinks' for atmospheric pollutants (Clyde, 1971; Valkovic *et al.*, 1979; Osibanjo & Ajayi, 1980). Cannon & Bowles (1962) observed that metals in dusts/smoke emitted by vehicles can enter the human food chain through the milk and meat of the animals fed on plants.

Several studies have shown that metals such as Pb, Cd, Ni, amongst others, are responsible for certain diseases that have lethal effects on man and animals (Lawther, 1965; Giddings, 1973; Gustav, 1974). For this reason, various arms of Government are much concerned about the effects of exhaust emission on the environment. However, information on roadside contamination with heavy metals in relation to vehicular emission in Nigeria is limited, and the attempt to bridge this gap forms the thrust of this study. This information is required to put in place appropriate land-use and management strategy that will enhance sustainable development. The objective of this study, therefore, is to investigate the effect of traffic densities on heavy metal pollution of soils and vegetation along roadsides.

Materials and methods

Study site

One major and one minor roads were chosen for the study: Ife-Ibadan (trunk A) and Ife-Ifewara (trunk B) roads, respectively. The road A had average daily traffic density (ADTD) of 5,364 vehicles (FMWH, 1999), hence high traffic density (HTD), while Road B had ADTD of 1,358 vehicles and, therefore, low traffic density (LTD). Road A, located within latitudes 7°21'N and 7°30'N and longitudes 4°7' E and 4°35' E, is both intra and inter state, and the main socio-economic activities along this road are farming, food processing and marketing of farm produce. Road B lies within latitudes 7°28'N and 7°30'N and longitudes 4°33'E and 4°41'N and it is mainly intra state. The main socio-economic activity along this road is farming. It should be noted that no industrial activity is apparent near the vicinity of the sampling locations.

Soil and plant sampling

Soil and plant samples were obtained from the road edge inwards up to 50 m away from the roadsides. Plants growing along the roads were sampled using 1 m^2 quadrant at distances of 1 m, 10 m, 30 m and 50 m away from the edge of the roadside. Vegetations within the quadrant were cut with a stainless steel pen-knife at the ground level. Each vegetation sample was replicated three times along each roadside. The plant samples were kept in labelled polyethylene bags and taken to the laboratory for analysis. Composite soil samples were taken at similar distances (1 m, 10 m, 30 m and 50 m) away from the edge of the road. Ten core soil samples randomly distributed round the observation points were taken with the aid of stainless steel Dutch auger and bulked. Sampling depths were 0-15 cm and 15-30 cm which represent the main feeding zones of the plant roots; the plants are mostly herbaceous. Each composite soil sample was replicated three times along each road and the samples were kept in labelled polyethylene bags.

Chemical analysis

In the laboratory, the plant samples were placed under running tap to wash off soil particles and then dried in an oven maintained at 80 °C for 48 h. Each sample of the dried plant materials was ground to a fine powder using a laboratory stainless steel hammer mill in order to pass through 1-mm aperture screen. Ground plant samples were collected in polyethylene bags and kept in a desiccator. From each ground plant sample, 2 g was accurately weighed into clean platinum crucibles, ashed at 450 °C and then cooled to room temperature in a desiccator. The ash was completely dissolved in 5 ml of 20% HCl which was then made up to volume in a 100-ml volumetric flask (Alloway, 1995). Analysis of the digest for the heavy metal content was carried out using the Atomic Absorption Spectrophotometer (AAS). Replicate analyses were carried out on each sample.

Soil samples were air-dried, crushed and then passed through a 2-mm sieve. One gram of the soil sample (< 2-mm fraction) was digested in 1:1 mixture of concentrated nitric and perchloric acids by heating the mixture plus sample over water bath in a fume cupboard. The solution was heated to dryness while the residue was re-dissolved in 5 ml of 2.0-*M* HCl as in Ure (1990). The mixture was finally filtered (Whatman No. 40). Replicate digestions were run on each sample and the resultant extracts were analysed for Pb, Cd, Ni, V and Zn using AAS (APHA-AWWA-WPCF, 1980). The data obtained were subjected to analysis of variance (ANOVA), and the test of significance of the means was by the Duncan's Multiple Range (DMR) test.

Results and discussion

The total heavy metal (Pb, Cd, Ni, V and Zn) content of the soils with distance away from the roads is presented in Fig. 1 and 2 for topsoil (0–15 cm) and subsoil (15–30 cm), respectively. The concentrations of the metals in the soils are in the order of Pb > Zn > V > Ni > Cd. The average Pb concentration in topsoil along the road with high traffic density (HTD) (Ife–Ibadan) decreased from 264.94 ±56.4 mg Pb/kg at a distance of 1 m from the road-edge to 4.79 mg Pb/kg soil at a distance of 50 m (Fig. 1).

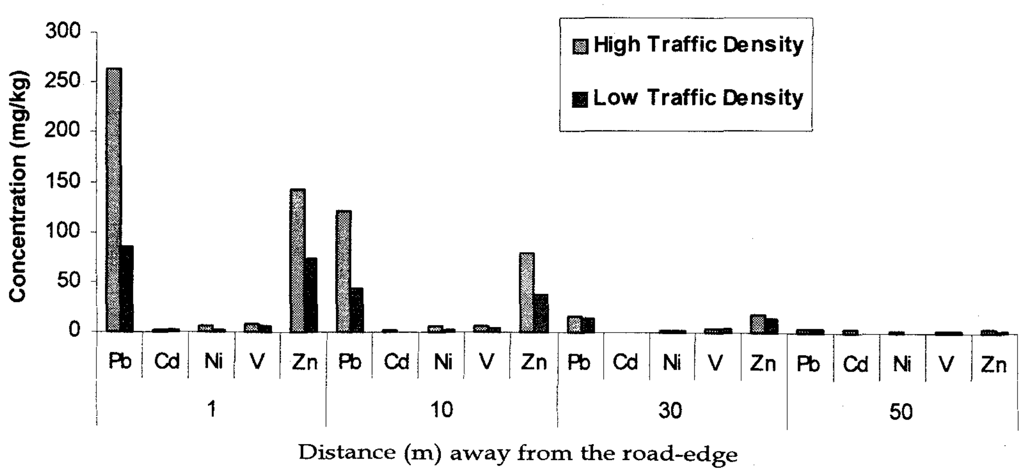

Fig. 1. Total heavy metal content of topsoil

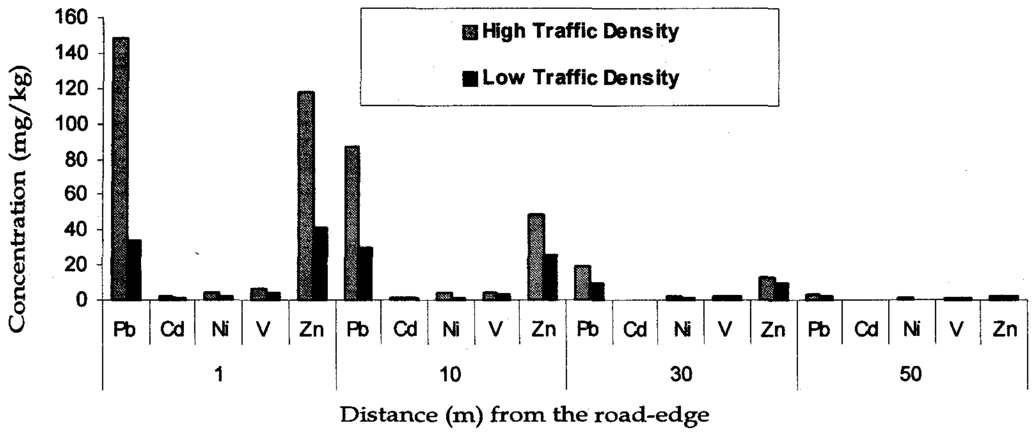

Fig. 2. Total heavy metal content of subsoil

Within the same range of distance, values obtained for Cd in the topsoil were 2.05±0.23 - 0.05 ± 0.02 mg/kg; 5.93 ± 0.45-1.45 ± 0.18 mg/kg for Ni; 8.82 ± 1.01-2.41 ± 0.56 mg/kg for V and 143.94 ± 49.49-4.18 ± 0.82 mg/kg for Zn, 1-50 m from the road-edge, respectively (Fig. 1).

The metal concentrations were significantly lower ($P < 0.05$) in the subsoil than the topsoil. For instance, along the same HTD road, average total metal contents of the subsoil were for Pb, 148.29 ± 22.37 mg/kg at 1m to 2.99 ± 0.88 mg/kg at 50 m; 1.59 ± 0.22 to 0.02 ± 0.01 mg Cd/kg soil; 4.47 ± 0.58 to 1.04 ± 0.32 mg Ni/kg soil; 6.61 ± 0.94 to 1.54 ± 0.20 mg V/kg soil, and 117.79 ± 20.5 to 2.40 ± 0.60 mg Zn/kg soil at 1 m and 50 m distances, respectively (Fig. 2). The road with HTD has significantly higher ($P > 0.05$) concentration of these metals than the LTD road (Ife-Ifewara) (Fig. 1 and 2).

Furthermore, the topsoil (0-15 cm) has significantly higher metal concentration than the subsoil (15-30 cm). This observation is consistent with that of Nyangababo & Hamya (1986), in which they attributed high heavy metal concentration of the topsoil to high organic matter status responsible for fixation of metals in soils. The concentrations of the metals in soils decrease with distance from the road. Decreasing metal concentrations with increasing distance from the road might be due to heavy metals emitted from vehicle exhausts in particulate forms which are forced to settle under gravity closer to the road edge (Haygarth & Jones, 1992).

The metal concentrations in the vegetation along the roadsides are shown in Table 1. The vegetation along the HTD road had higher concentrations of metals than the vegetation along the LTD road. This suggests that with increasing concentrations of metals in soils, the uptake of the metals by the vegetation may also increase (Alloway & Davies, 1971; Grant & Dobbs, 1977). Also, the metal content of the plant tissue decreases with distance from the roadside.

From Fig. 1 and Table 1, it is observed that the metal contents of the topsoils and vegetation are significantly higher for HTD than LTD. This is an indication of an enhanced level in the HTD surrounding atmosphere. Moore & Moore (1976) similarly noted that motor vehicles introduce

TABLE 1

Average metal concentration of plant (mg/kg dry weight) along the roadsides

Distance (m)	Pb		Cd		Ni		V		Zn	
	HTD	LTD	HTD	LTD	HTD	LTD	HTD	LTD	HTD	LTD
1	50.52a	17.83a	1.35a	0.81a	3.45a	1.61a	6.60a	2.82a	41.20a	14.53a
10	20.88b	11.89b	1.29a	0.63a	2.89a	1.31a	3.89a	2.35a	13.33b	8.04b
30	7.96c	4.57c	0.29b	0.05b	1.54a	0.59b	1.21b	0.77b	5.11c	3.81c
50	1.18d	0.50d	0.02bc	0.01b	0.44b	0.13b	0.58bc	0.18bc	1.16d	0.39d

Means in the same column followed by the same alphabet are not statistically different ($P > 0.05$).

a number of toxic metals into the atmosphere adjacent to roadways. Studies by Smith (1976) and Ho (1979) indicate that elevated metal concentration in street soil of industrialized and/or densely populated cities resulted from increased automobile circulation. As in this study, elevated concentrations of Pb and Zn in roadside vegetation were reported by cannon & Bowels (1962) and Fatoki (1987) as cited in Fatoki & Ayodele (1991). Ademoroti (1986) also observed that the levels of heavy metals in bark and fruit of trees along roads in Nigeria vary according to traffic volume. The metals are considered to arise from motor vehicle tyre wear and motor vehicle emissions (Lagerwerff & Specht, 1970), both of which can account for up to 80% of the air pollution problems in urban areas of south-western Nigeria (Osibanjo & Ajayi, 1980). This study suggests that plants growing on soils having enhanced heavy metal concentration will have increased metal concentration in accordance with earlier reports by Alloway & Davies (1971) and Grant & Dobbs (1977).

Tables 2 and 3 show the level of the metals in the topsoil and associated plants along the various segments of each road, respectively. Taking Ife as the starting point, soils and vegetation in the uphill segment have the highest concentrations of the metals, followed by the flat surface, road bend and downhill. The high metal concentration obtained in soils and vegetation along the uphill segment of the road may have resulted from increased rate of vehicular emission. When descending, low level of emission is released because of less power requirement to move the vehicles. The mean metal contents in soils along the uphill and downhill seemed to indicate similar amounts of emissions occurred for both the uphill/ downhill and the flat surface. However, it is obvious that the more energy consumed by vehicles, the higher the level of emissions, most of which are deposited closest to the roadside.

To reduce metal concentration of food chain and ecosystem from vehicular emissions, an appropriate land use policy which prohibits the use of roadside lands, especially within 30 m either side of the road, for farming, grazing or as source of pastures to feed livestock is required. Although some states in Nigeria, including Osun, already have statutory edict banning the sun-drying of foodstuff such as pepper, onions, okro and fermented cassava flour, amongst others, along roadsides, the enforcement of its compliance needs to be vigorously pursued and, indeed, be made a

TABLE 2

Average metal concentration (mg/kg) of the topsoil at different road segments

Metal	*Sampling distance (m)*	*Road segment* *Up/Down hill* *HTD*	*LTD*	*Flat* *HTD*	*LTD*	*Bend* *HTD*	*LTD*
Pb	1	272.17±92.6	86.47 ±40.7	274.70±77.2	91.07±36.8	240.73±65.2	81.97±28.6
	10	127.10±33	44.70 ±13.9	123.50±35.1	45.50±09.0	104.30±19.6	43.33±08.9
	30	17.27±06.5	13.95 ±03.4	15.90±03.8	13.00±02.1	16.50±02.9	12.87±02.4
	50	4.67±01.2	3.24 ±00.6	5.20±01.8	3.40±00.9	4.63±01.6	3.27±00.9
Cd	1	2.09±00.4	1.20 ±00.4	2.11±00.4	1.09±00.2	1.93±00.3	0.85±00.3
	10	1.67±00.4	0.94 ±00.4	1.64±00.3	1.02±00.2	1.54±00.3	0.93±00.3
	30	0.60±00.2	0.10 ±00.03	0.61±00.2	0.10±00.03	0.55±00.1	0.05±00.03
	50	0.05±00.02	0.02 ±00.01	0.05±00.03	0.02±00.01	0.04±00.02	0.00±00.00
Ni	1	5.05±00.7	2.27 ±00.3	6.17±00.9	2.33±00.2	5.64±00.9	2.20±00.5
	10	5.24±01.5	1.85 ±00.4	5.29±00.8	1.93±00.3	4.92±00.5	1.60±00.3
	30	2.07±00.2	1.17 ±00.3	2.23±00.4	1.17 ±0.05	2.19±00.2	0.93±00.3
	50	1.43±00.2	0.70 ±00.2	1.50±00.3	0.73±00.2	1.45±00.2	0.63±00.2
V	1	8.72±02.3	1.77 ±01.7	9.56±01.2	6.43±01.1	8.27±01.7	6.07±01.47
	10	6.32±02.1	1.06 ±01.3	4.68±01.3	4.73±00.5	6.10±01.2	4.47±00.5
	30	4.18±01.1	0.59 ±01.1	3.62±01.1	3.37±00.7	3.47±00.6	3.00±00.5
	50	2.55±00.9	0.95 ±00.3	2.36±00.6	1.60±00.4	2.17±00.3	1.40±00.3
Zn	1	165.04±46.1	13.36 ±02.1	174.07±21.7	77.00±19.7	171.60±22.7	72.77±17.7
	10	73.20±17	8.65 ±03.5	88.13±19.9	40.40±07.2	84.30±17.6	33.57±08.4
	30	17.79±05.0	2.86 ±02.4	18.83±03.2	14.30±02.9	17.77±03.1	13.40±01.8
	50	4.15±01.4	0.73 ±00.7	4.40±01.3	2.43±00.5	4.00±01.1	2.37±00.4

HTD: High traffic density
LTD: Low traffic density

national policy. Further step should include the legislation against the use of smoking vehicles to prevent severe environmental pollution. In addition, regular maintenance (weeding) of the right of ways (ROW) by the appropriate organ of government could reduce foliar absorption of the metals that may be contained in the emission.

Conclusion

The concentration of heavy metals decreases with increasing soil depth and horizontal distance away from the road-edge, while the extent of metal contamination was positively related to traffic volume. The metal content of soils and associated vegetation along the HTD road was significantly higher ($P > 0.05$) than that of the LTD. Road segments also affected the level of the metals in soils and vegetation surrounding the roads. Regulations proscribing the use of ROW for cultivation, grazing, marketing or related activities are desirable, and public compliance with such laws needs to be enforced.

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TABLE 3

Average metal concentration of the plant (mg/kg) at different segments of the roads

Metal	Sampling distance (m)	Road segment					
		Up/Down hill		Flat		Bend	
		HTD	LTD	HTD	LTD	HTD	LTD
Pb	1	51.35±3.4	18.09±2.6	51.13±3.2	18.03±2.6	48.23±1.9	17.10±1.2
	10	20.85±3.2	12.22±3.6	21.77±3.2	12.00±3.5	20.03±4.1	11.13±3.1
	30	8.55±1.6	4.52±1.0	7.50±0.5	4.73±1.0	7.23±0.6	4.50±0.7
	50	1.35±0.1	0.52±0.1	1.07±0.1	0.53±0.1	0.97±0.5	0.43±0.1
Cd	1	1.35±0.1	0.82±0.1	1.37±0.1	0.84±0.1	1.33±0.6	0.76±0.1
	10	1.26±0.1	0.60±0.1	1.34±0.2	0.71±0.1	1.29±0.2	0.62±0.1
	30	0.26±0.1	0.05±0.01	0.33±0.1	0.05±0.01	0.30±0.1	0.04±0.01
	50	0.02±0.01	0.02±0.01	0.02±0.01	0.01±0.00	0.02±0.01	0.00±0.00
Ni	1	3.63±0.3	1.64±0.1	3.43±0.4	1.67±0.1	3.13±0.1	1.50±0.1
	10	2.95±0.1	1.29±0.1	2.83±0.1	1.47±0.1	2.81±0.3	1.20±0.1
	30	1.47±0.2	0.54±0.1	1.67±0.2	0.70±0.1	1.55±0.1	0.57±0.2
	50	0.52±0.1	0.14±0.1	0.43±0.2	0.13±0.05	0.30±0.2	0.13±0.1
V	1	6.80±1.6	2.85±0.3	6.67±1.6	2.87±0.3	6.13±0.5	2.70±0.2
	10	3.93±0.3	2.32±0.2	4.17±0.3	2.47±0.3	3.53±0.4	2.27±0.4
	30	1.30±0.2	0.80±0.1	1.30±0.2	0.80±0.2	0.93±0.3	0.67±0.2
	50	0.58±0.1	0.24±0.1	0.63±0.2	0.03±0.1	0.53±0.2	0.20±0.1
Zn	1	40.72±1.6	14.27±2.0	42.43±3.2	15.17±0.3	40.93±1.3	14.40±0.6
	10	13.00±3.4	8.37±2.0	13.90±1.5	8.33±0.6	13.43±1.2	7.10±0.7
	30	5.30±1.6	3.75±0.6	5.27±0.5	4.07±0.3	4.57±0.2	3.67±0.5
	50	1.14±0.1	0.37±0.1	1.20±0.2	0.47±0.1	1.17±0.2	0.37±0.1

HTD: High traffic density
LTD: Low traffic density

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