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Full Length Research Paper

Evaluating the impact of traffic activities on the heavy metals concentrations along a major highway in Delta State, Nigeria

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ABSTRACT: Traffic emissions are one of the biggest drivers of heavy metals contamination in ecosystem; therefore vehicular traffic has become a major source of worry. The purpose of this study was to determine the influence of automobile emissions on roadside soil. Soil specimens were taken from two significant locations in Delta State, Nigeria, along a major highway. Soil samples were collected at four different distances from the roadside (1 m, 10 m, 20 m, and 30 m) at each location. The amounts of heavy metals (copper, zinc, lead, and cadmium) in soil samples were determined using established techniques. The chemical analysis results revealed that heavy metal concentrations in roadside soil samples were substantially ($p \leq 0.05$) higher than in the control soil sample. This revealed that the quantities of heavy metals in the soil samples were related to road traffic activity. The results also revealed that the amounts of heavy metals in roadside soil reduced as the distance between the test point and the highway increased. According to the findings, the copper, zinc, and lead contents in the soil samples were lower than the World Health Organization's maximum tolerated values (WHO). However, the results revealed that the cadmium concentration was frequently higher than the WHO's maximum tolerated limit. The findings also found that heavy metal pollution in roadside soils along the route ranged from minor to significant (degree). Furthermore, the concentration and pollution level at sampling position A were higher than those at sampling location B, which can be attributable to the fluctuation in the volume and concentration of traffic emissions received at each sampling point. To avoid the excessive accumulation of dangerous heavy metals in the ecosystem, our findings highlight the necessity to decongest vehicular traffic along major highways throughout the country.

Keywords: Contamination factor, heavy metals, highway, roadside soil, traffic emission

INTRODUCTION

With the rising globalization of industrialization and urbanization, heavy metal poisoning of the environment is becoming a severe concern. Heavy metals such as cadmium "Cd," zinc "Zn," lead "Pb," nickel "Ni," arsenic "As," copper "Cu," mercury "Hg," and chromium "Cr" can be hazardous to the human body if the body absorbs them in excess of the maximum allowable amount. The body absorbs these heavy metals by direct touch (dirt and dust), ingestion, or breathing (Abrahams, 2002; Akpokodje and Uguru, 2019). According to Liu (2007), natural flora growing in the environment ingested heavy metals, which had a substantial impact in human exposure to these heavy metals. Heavy metal concentrations in the environment, even at low levels (as in the case of Pb, Hg, Ni, and Cd), have been scientifically proven to cause adverse health effects such as nervous, cardiovascular, renal, and reproductive system disorders, cancer, reduced intelligence, and behavioral abnormalities (Jarup, 2003; Willers et al., 2005). Due to their irreversible immobilization within various soil environments, heavy metals are persistent in the environments (Akpomrere and Uguru 2020; Gülser and Erdoan, 2008). Due to the long-term accumulation of traffic emissions, vehicular traffic activities are one of the primary sources of heavy metal contamination along the roadside environment. Due to the collapse of the railway system, the number of vehicular traffic on Nigerian highways is gradually increasing; as a result, the cumulative pollution of the environment is increasing daily. According to Winther and Slentø (2010), automobile emissions are responsible for the majority of heavy metal pollution in the environment. When particulate materials from bitumen and other materials used in road construction are released into the environment, they create Cu, Zn, Cd, and Pb pollution, while motor engine oil causes Cd pollution, unleaded petrol causes Pb contamination, and tire and brake wear cause Zn and Cu pollution, respectively (Turer et al., 2001). According to Chen et al. (2010), vehicular traffic is one of the major sources of environmental pollution, and roadside vegetation and soil are the transmission agents, as people who live near the roadsides are constantly in contact with these agents (soil and vegetation) that are contaminated with heavy metals. According to Nabuloa et al. (2006), heavy metals can enter the environment via precipitation, surface runoff, or air movement (wind). Several researches on the impact of automotive traffic emissions on the ecosystem have been done. Chen et al. (2010) evaluated the impact of urban traffic on Beijing's roadside soils. The concentrations of Cd, Cu, Pb, and Zn were highest at the roadside and dropped linearly as distance from the roadside increased from 1 m to 30 m. In a similar vein, Kadi (2009) investigated the impact of automotive traffic on roadside soil in Jeddah, Saudi Arabia, and discovered elevated lead and zinc concentrations in soil samples, which she attributed to traffic emissions. Nabulo et al. (2006) looked at the connection between traffic emissions and heavy metal concentrations in roadside soils and vegetation. They reported that heavy metal concentrations (Pb, Zn, and Cd) in soil and vegetation samples were highest near the road and decreased rapidly as distance from the road increased from 1 m to 30 m. Zhang et al. (2015) discovered that Cr, Cu, Zn, As, Cd, and Pb concentrations were higher in soil samples collected along major highways than in soil samples collected 200 meters away from the roadway. Despite various studies on the environmental impact of vehicular traffic emissions, there is a paucity of data on the influence of vehicular traffic emissions on certain important highways in Southern Nigeria. The Asaba-Onitsha highway is a significant thoroughfare that connects southern and eastern Nigeria. Due to the major markets in Eastern Nigeria, this highway usually experienced daily gridlock mostly at the “River Niger Bridge”. Most of the area along the Asaba-Onitsha highway is occupied with cultivated vegetation and outside influences, such as artisans’ workshops, filling stations, local markets, etc. As a result, the study area was chosen to be the Asaba-Onitsha highway. The goal of this study is to characterize the concentrations of heavy metals (Cu, Zn, Pb, and Cd) in soil samples collected along the Asaba-Onitsha roadside, as well as to assess the level of pollution these heavy metals pose to the environment.

MATERIALS AND METHODS

Site description

This study was conducted along Asaba-Onitsha highway, around the River Niger bridge area. The area falls within the geographical co-ordinate of Lat. 6.152 N, Long. 6.748 E and elevation 23 m; experiencing annual rainfall of about 2100 mm. The study area experiences two major climatic seasons, which are the rainy and dry seasons; the area is generally flooded during the rainy season. This highway transverses across a hydromorphic soil type. Natural and cultivated vegetation are common within the area; some of the commonly cultivated crops are plantain, vegetables and yam. Dominant natural vegetation includes; guinea grass (*Megathyrsus maximus*), elephant grass (*Pennisetum purpureum*), etc. The Asaba-Onitsha highway experiences high traffic volumes daily, with congestion at the of the River Niger bridge, which usually lasts for about 8 hours daily. Vehicles that ply the road consist mainly of cars, busses and articulated vehicles. Excluding the agricultural activities in the area, the study area has interference from other anthropogenic activities.

Soil sampling

Soil samples were taken from two locations, at a distance of 1000 m apart. At each selected location (A or B), four sampling sites were chosen at distances of 1 m, 10 m, 20 m and 30 m respectively, perpendicular to the roadside. Location (Spot) A is situated at about 400 m from the entrance of the bridge (at the Asaba end), while Location B is located at about 1.4 km from the entrance of the bridge (at the Asaba end). At each spot, the soil sample was collected at a depth of 0-15 cm, poured into a black nylon bag, coded accordingly and taken immediately to the laboratory for chemical analyses. Additionally, another location, about 30 km from the study area, was taken as the control (background). This location has no recorded history of anthropogenic activities or automobile activities for the past five years.

Chemical analysis of the soil samples

The soil samples were air dried in the laboratory under ambient temperature, crushed in a porcelain mortar and sieved with a 2 mm gauge nylon sieve. 10 g of the sieved soil sample was poured into a digestion tube, and mixed with 15 ml of three concentrated acids (HNO_3, HCl, and H_2SO_4) added in the ratio of 5:1:1 respectively. The mixture was heated on an electric hot plate until a clear solution was obtained. The solution was then cooled at ambient temperature, filtered into a volumetric flask with a whatman No1 filter paper, and diluted with distilled water up to the 100 ml mark (Akpomrere and Uguru, 2020b; Zhang *et al.,* 2012). Subsequently, the heavy metals (Cu, Zn, Pb and Cd) concentrations in the digested solution were determined using an atomic absorption spectrophotometer.

Contamination factors

Contamination factor (CF) is used to evaluate the enrichment and pollution level of a heavy metal in the soils (Ogbaran and Uguru, 2021). The contamination factor is an expressed in the formula given in Equation 1.

$$Cf = \frac{C_1}{C_2} \quad (1)$$

Where:
C_1 = concentration at the sampled point
C_2 = concentration at the reference point

The contamination factor is evaluated in the following ranking order/degree.
CF < 1 = no or minimal pollution;
1 ≤ CF ≤ 3 = moderate pollution;
3 ≤ CF ≤ 6 = considerable pollution;
6 > CF = very high pollution (Hakanson, 1980).

Statistical analysis

Results obtained from the research were statistically analyzed, by using Statistical Package for Social Sciences (SPSS version 22.0). Duncan's Multiple Range Test (DMRT) was used to separate and compare the mean at 5% significance level. Charts were plotted from the data obtained in this study, by using the Microsoft Excel for Windows.

RESULTS AND DISCUSSION

The effect of sampling location and sampling distance are revealed by the analysis of variance (ANOVA) results presented in (Table 1). As shown in (Table 1), sampling location and sampling distance had significant ($p \leq 0.05$) effect on all the four heavy metals evaluated in this study. Furthermore, it was observed from the ANOVA table that the interaction of sampling location and distance had significant ($p \leq 0.05$) effect on all the four heavy metals evaluated in this study. This indicated that the two independent variables and their two-way interactions were discursively associated, with the concentrations of copper, zinc, lead and cadmium in the roadside soils. Similar results were obtained by Zhang et al. (2012b) which stated that altitude, terrain, vegetation and distance had significant ($p \leq 0.05$) effect on the heavy metals concentrations in roadside soils situated along a major highway in Kathmandu, Nepal.

Heavy metals concentration and distribution pattern

Detailed information of the heavy metals concentration in the roadside soil samples are presented in (Table 2). As presented in (Table 2), the mean copper concentration values ranged between 14.73 mg/kg and 35.07 mg/kg, zinc concentration ranged between 32.13 mg/kg and 95.33 mg/kg, lead concentration ranged between 21.97 mg/kg and 45.60 mg/kg, while cadmium concentration ranged between 0.45 mg/kg and 1.03 mg/kg. The results showed that the heavy metals content in the soil samples were generally higher along the roadside, compared to the results obtained from the control soil sample (Table 2).This signified that anthropogenic source(s), probably traffic emissions, was liable for the high heavy metals concentrations in the soil samples situated along the roadside. According to Winther and Slentø (2010), emissions from vehicle brake wear and oil combustion are responsible for high accumulation of copper and cadmium metals in roadside soils and plants. Likewise, Dolan *et al.* (2006) stated that lead, zinc, and copper are some of the major contaminants (heavy metals) found along highway environments, in which concentrations are influenced by the volume of the traffic emissions. Although the heavy metals concentrations were lower than the recommended World Health Organization (WHO) maximum allowable limits; however, the cadmium concentration at most of the sampling points are close to or higher than the WHO maximum allowable limits. Furthermore, observations made from the results revealed that the concentrations of the heavy metals in the soil samples declined significantly, with the increment in distance of the sampling point from the roadside. At location A, the copper concentration declined from 35.07 mg/kg to 20.73 mg/kg as the distance increased from 1 m to 20 m, but increased to 24.53 mg/kg as point 30 m from the roadside. Whereas, at Location B, the copper concentration declined continually from 22.53 mg/kg to 14.73 mg/kg as the distance increased from 1 m to 30 m. With respect to the zinc concentration, at location A, the concentration decreased significantly ($p \leq 0.05$) from 95.33 mg/kg to 42.77 mg/kg as the distance from the road side increased from 1 m to 30 m .Whereas, at location B, the concentration decreased from 74.93 mg/kg to 45.73 mg/kg; as the concentration (45.73 mg/kg) recorded at 30 m from the roadside, was higher

Table 1: ANOVA result for the heavy metal concentrations.

Source of variation	Metal	df	F. Stat	p-value
Location	Cu	1	3493.38	3.67E-20*
	Zn	1	7776.86	6.21E-23*
	Pb	1	1164.81	2.24E-16*
	Cd	1	312.89	6.29E-12*
Distance	Cu	3	1086.78	1.08E-18*
	Zn	3	16112.23	4.79E-28*
	Pb	3	2533.90	1.26E-21*
	Cd	3	175.92	1.85E-12*
Location x Distance	Cu	3	122.34	3.04E-11*
	Zn	3	1262.44	3.26E-19*
	Pb	3	1502.950	8.15E-20*
	Cd	3	113.714	5.31E-11*

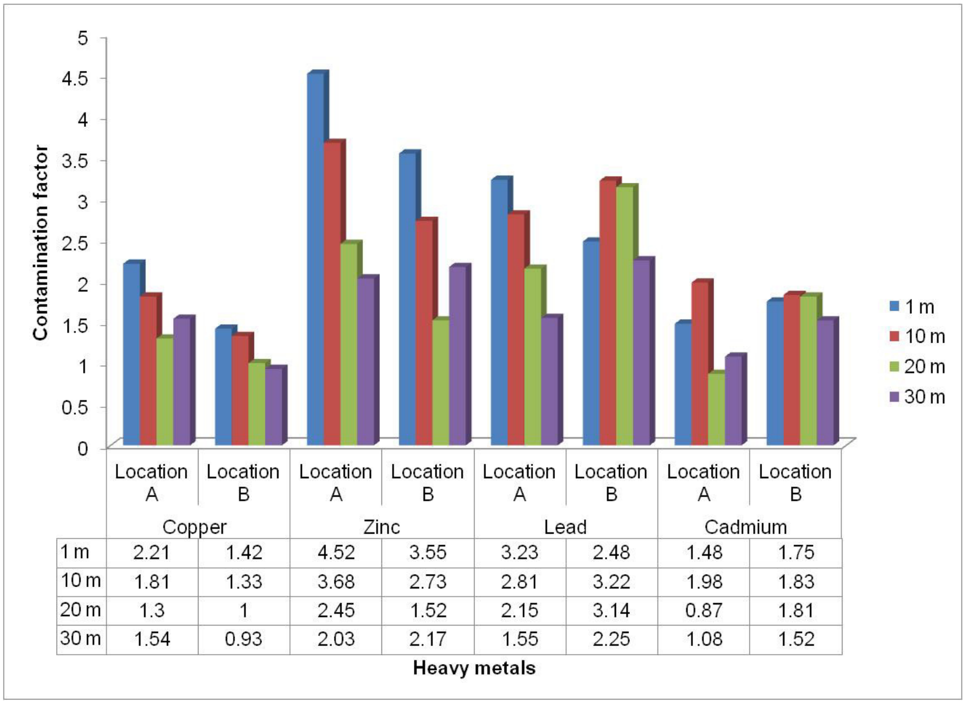
*Significant at the 0.05 significant levels according to Duncan's Multiple Range Test

Table 2: Concentration of the heavy metals

Distance	Location	Heavy metals			
		Copper (mg/kg)	Zinc (mg/kg)	Lead (mg/kg)	Cadmium (mg/kg)
1 m	Spot A	35.07^{h}±0.3	95.33^{h}±0.5	45.60^{h}±0.44	0.77^{e}±0.02
	Spot B	22.53^{e}±0.3	74.93^{f}±0.4	35.03^{d}±0.21	0.91^{f}±0.02
10	Spot A	28.70^{g}±0.5	77.47^{g}±0.4	39.77^{e}±0.52	1.03^{g}±0.05
	Spot B	21.10^{d}±0.3	57.47e±0.4	45.50^{g}±0.40	0.95^{c}±0.04
20	Spot A	20.73^{c}±0.7	51.70^{d}±0.6	30.37^{b}±0.15	0.45^{a}±0.03
	Spot B	15.87^{b}±0.1	32.13^{a}±0.3	44.33^{f}±0.15	0.94^{c}±0.01
30	Spot A	24.53^{f}±0.3	42.77^{b}±0.4	21.97^{a}±0.29	0.56^{b}±0.02
	Spot B	14.73^{a}±0.2	45.73^{c}±0.2	31.73^{c}±0.50	0.79^{d}±0.02
Control		15.89±0.5	21.08±0.4	14.13±0.4	0.52±0.03
WHO*		36	50	85	0.8

*WHO (1996); Mean± standard deviation.

than the concentration (32.13 mg/kg) recorded at 20 m from the roadside. Regarding the cadmium concentration across the study area, the results revealed that at Location A, the cadmium concentration behaved irregularly but generally declined from 0.77 mg/kg to 0.56 mg/kg, as the distance from the road side increased from 1 m to 30 m. As shown in (Table 1), although the cadmium concentration decreased generally (at location A), the concentration at 1 m (0.77 mg/kg) from the road side was significantly ($p \leq 0.05$) lower than the cadmium concentration as 10 m (1.03 mg/kg) from the roadside. Similarly, the results showed that at location A, lead concentration declined relatively linearly from 45.60 mg/kg at a distance of 1 m from the roadside to 21.97 mg/kg at a distance of 30 m from the roadside. Whereas, at location B, the lead concentration decreased irregularly and non-linearly as the distance from the roadside increased from 1 m to 30 m. It was observed from the results that the lead concentration at 1 m from the roadside was significantly lower than the concentration recorded at a distance of 10 m and 20 m from the roadside. These results are in similarity with previous results obtained by Zhang et al. (2015) where there was a negative correlation between distance and copper, zinc, lead and cadmium concentrations in the soil samples. Similarly, Werkenthin *et al*. (2014) reported that concentration of heavy metals, in the topsoil was inversely proportional to the decrease from the roadside. These previous authors' observations couple with this study's results revealed that the copper, zinc, lead and cadmium concentrations in the soil were generally highly influenced by the traffic emissions. In terms of the sampling location, the results indicated that, concentration of the heavy metals (copper and zinc) at Location A was generally higher, than the concentration of the heavy metals at Location B. Apart from 30 m from the roadside for zinc, the concentration of the heavy metals (copper and zinc) recorded at location A, was significantly ($p \leq 0.05$) higher than the concentration of the heavy metals recorded at location B. The high concentration of heavy metals recorded at Location A could be attributed to the volume and concentration of traffic emissions the area received. Field observations generally indicated that area close to the entrance of the River Niger bridge head experienced daily gridlock (longer idle times), and larger volume of emissions emitted by vehicles (mostly the articulated vehicles), into the environment due to constriction of the roadway



	Copper		Zinc		Lead		Cadmium	
	Location A	Location B	Location A	Location B	Location A	Location B	Location A	Location B
1 m	2.21	1.42	4.52	3.55	3.23	2.48	1.48	1.75
10 m	1.81	1.33	3.68	2.73	2.81	3.22	1.98	1.83
20 m	1.3	1	2.45	1.52	2.15	3.14	0.87	1.81
30 m	1.54	0.93	2.03	2.17	1.55	2.25	1.08	1.52

Figure 1: Contamination factor of the heavy metals.

towards this point, as a results of inpatient drivers. According to Wiseman et al. (2013) vehicular traffic movement and road conditions affect the distribution of heavy metals across the roadside soils and vegetation. Vehicular traffic emissions had being earlier reported by Ogundele *et al.* (2015) and Onder *et al.* (2007), as one of the major influence of lead, nickel and copper contamination of the roadside soil and vegetation. The relatively higher heavy metal (zinc) concentration observed at 30 m from the road side at Location B, over sampling Location A could be attributed seepage of leachates from other anthropogenic sources along the roadside into the sampling area. According to Pierzynski *et al*. (2000), leachates from anthropogenic sources, such as: agricultural operations, indiscriminate discharge of solid waste, etc., can significantly increase heavy metals concentrations of the soil samples. A similar conclusion can also be made for the irregular variations of the lead and cadmium concentration, with respect to distance at Location b, and any other such irregularities generally witnessed.

Contamination factor

The results of the pollution level of the traffic emissions on the roadside soil are presented in (Figure 1). As shown in (Figure 1), the contamination of most of the metals was above minimal level. The copper contamination level in the soil was of a moderate degree at 1 m, 10 m and 20 m from the roadside, regardless of the sampling location; while at 30 m from the roadside, it was at moderate degree at sampling location A, and minimal degree at sampling location B. Irrespective of the sampling location, the zinc contamination levels in the soil at 1 m was considerable in degree; while at 20 m and 30 m from the roadside, the contamination level was moderate in degree. It was also observed that at 10 m from the roadside, the zinc contamination of the soil was at considerable degree at sampling location A, and moderate degree at sampling location B. furthermore, the results revealed that lead concentration in the soil varied between minimal and moderate levels. In terms of cadmium contamination of the roadside soil, the results revealed that apart from 20 m from the roadside, cadmium contamination was within moderate level in the soil. As shown by the results, at 20 m from the roadside, the cadmium contamination was at minimal level at sampling location A, and moderate level at sampling location B. It was observed from the results that, none of the sampling locations registered very high pollution level of the heavy metals. The high concentration and contamination levels of zinc and lead within the roadside soil are of great concern, as these elements are extremely poisonous in human beings.

Conclusion

This study was carried out to evaluate the impact of vehicular traffic emissions, from a major highway in Southern Nigeria on the environment. Soil samples were collected from two locations along the highway, at four distances (1 m, 10 m, 20 m and 30 m) from the roadside at each location. The heavy metals (zinc, copper, lead and cadmium) concentrations in all the soil samples collected, were tested in accordance with standard procedures. Results obtained from the chemical analysis revealed that the heavy metals concentrations of the soil samples collected from the highway environment were higher than in the control soil sample. Compared with the WHO standards, the zinc, copper and lead concentrations in the soil samples were lower than the maximum tolerable levels, recommended by the World Health Organization; while the cadmium concentration from most of the sampling points was above the maximum tolerable levels, recommended by the World Health Organization. This indicated that more attention must be given to cadmium contamination in roadside soils. Regardless of the sampling distance, the findings of this study revealed that, the heavy metals concentration at Location A were generally higher than the heavy metals concentration at Location B. Likewise, the study findings revealed that irrespective of the sampling location, the concentration of the metals generally decreased, as the sampling distance increases. In terms of the contamination level within the study area, the results showed that lead and zinc pollution in the soil, were mainly at the considerable degree; while the copper and cadmium pollution in the soil, were mainly at the moderate degree. Regardless of the sampling distance, the heavy metals pollution level at Location A, was generally considered to be higher than location B. This study's results call for the need of the government to make policies and device means that will decongest the traffic volume at along this region of the highway, to the prevent accumulation of these hazardous heavy metal contaminants, which are poisonous to human beings and the environment.

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