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Quantifying vehicular heavy metal deposits on roadside soil and vegetation along Akure-Ilesa express road, South-Western Nigeria

Ekundayo Taiwo Olajumoke [1,*] and Fatoba Paul Ojo [2]

[1]*Department of Plant Science and Biotechnology, Faculty of Science, Adekunle Ajasin University Akungba Akoko P.M.B. 001, Akungba Ondo State, Nigeria.*

[2] *Department of Plant Biology, Faculty of Life Sciences, University of Ilorin P.M.B. 1515, Ilorin, Kwara State, Nigeria.*

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Abstract

Vehicular emission is one of the major sources of heavy metal deposition on roadside vegetation and soil. This is influence by the degree of traffic congestions on the road. The heavy metals can affect plants negatively with health hazards to humans and animals in the food chain. This study investigated the quantity of vehicular heavy metal deposits on vegetation and soil along Akure-Ilesa road. Plant and soil samples were collected at 10 km intervals along Akure-Ilesa road, digested using Aqua regia methods and metals; Cd, Pb, Cr, Zn and Cu contents determined with Atomic Absorption Spectrophotometer (AAS). Data were analysed with ANOVA and t-test and differences tested at $p \leq 0.05$. The study revealed that; 0.021 – 0.320, 0.110 – 0.301, 0.092 – 0.170, 0.055 – 0.113 and 0.061 – 1.280 mg/kg; and 0.068 – 0.421, 0.110 – 0.410, 0.100 – 0.181, 0.008 – 0.141, and 0.267 – 0.411 mg/kg of Pb, Cr, Cd, Cu, and Zn were found in plants and soils respectively. It was concluded that vehicular emissions contributed to the heavy metal load of the roadside vegetation and soil.

Keywords: Vehicular emission; Roadside; Heavy metal; Vegetation; Soil

1. Introduction

Heavy metals are naturally present in soil; contamination comes from local sources, mostly industry, agriculture, waste incineration, combustion of fossil fuels and road traffic. Long-range transport of atmospheric pollutants adds to the metal load and is the main source of heavy metals in natural areas. Plants interact with environment and thus, changes in the environment, like impaired air quality; can be mirrored in the physiological status of plants, for example, in the plant element concentrations. In severe cases, pollutants can cause visible plant injuries and, in some extreme cases, even plant death. Environmental pollution has unpleasant changes on physical, chemical and biological characters of natural resources such as water, air and soil which has dangerous effect on health and survival of human and other living organs or limit their activities.

Environmental pollution is always on the increase due to human activities such as agricultural operations, sewage discharge, energy production, smelting, refining, disposal of waste, industrial and vehicular emissions. Emissions of pollutants into the air amounted to the greatest source of heavy metal pollution [1]. Heavy metal pollution of soil enhance plant uptake causing accumulation in plant tissues and eventual phytotoxicity and change in plant community [2, 3]. Heavy metals such as Pb, Cd, Cu, and Zn have been reported to be released into the atmosphere during different operations of the road transport [4, 5]. [4] reported engine oil consumption as the largest emission for Cd, tyres wear for Zn, and brake wear for Cu and Pb. Cadmium was reported to biomagnify in *Chromolaena odorata* along the road [6],[7] noted that organometalics such as tetraethyl lead, an additive to gasoline (petrol), is an important source of lead in automobile exhaust emission. Soil, vegetation and animals including man act as ‘sinks’ for atmospheric pollutants [8].

* Corresponding author: Ekundayo Taiwo Olajumoke

Among the heavy metals, lead (Pb) has long been known as potential hazard to health [9, 10, 11]. Fossil fuels combustion and exhaust emission have been identified as primary sources of atmospheric metallic nuisance [12, 13].

Plant leaf is the most sensitive part to air pollutants as major physiological processes are concentrated in the leaf [14]. Plants near road ways have relative increase of Pb deposition due to vehicles using leaded petrol [15, 16]. The high sensitivity of plants towards some pollutants means that a great variety of plants can be used as bioindicators of heavy metal pollution in soil. [17] and [18] worked on the basic criteria for selection of species as a bioindicator. The major criteria are species should be represented in large numbers all over the monitoring area, have a wide geographical range, be possible to differentiate between air-borne and soil-borne heavy metals, be easy to sample and there should be no identification problems. Therefore this research was carried out to quantify the heavy metal content of soil and vegetation along Akure-Ilesa road during 2012 rainy season and 2013 dry season.

2. Material and methods

2.1. Study Site

The study was carried out along Akure-Ilesa road, covering a distance of about 50 km South Western Nigeria. The road was chosen based on the fact that it is the major road linking the South-West to the Northern part of Nigeria, hence heavy traffic congestion.

2.2. Traffic Density

A 3-day 18 hour traffic count conducted from 7am to 9am, 12pm to 2pm and 5pm to 7pm at locations along the route indicated the following trend in traffic volume. The point chosen for the survey included Erin Ijesa junction, Igbara Oke junction and Futa Gate. The traffic condition of the road was heavy consisting of 73% (494) cars, 5% (39) trucks, 17% (112) short buses while luxury buses and pick-up van had 5% (36) totaling 681 vehicles per hour.

2.3. Collection of Samples

Plant and soil samples were collected during the rainy season (October, 2012) and dry season (March 2013). The collection was done at every 5 km interval along the roadside, the co-ordinate of each sampling location was recorded by the use of a hand-held Global Positioning System (GPS) devise. The plant samples were collected with the aid of knife, and put in separate polyethylene bags after collection. The soil samples were collected with soil auger and also put in separate polyethylene bags. Plant and soil samples were collected at a distance of 15 km inward from the roadside and these serves as a control sample for the study. All samples were labeled appropriately.

2.4. Analysis of samples

2.4.1. Soil Digestion

Soil samples were digested after drying in the oven and ground into fine powder. 5 g of soil sample was weighed into digestion flask. 2 ml of perchloric acid and 5 ml of HCl was added to the sample and digestion carried out on hot plate inside fume cupboard. 50 ml of distilled water was added to avoid splattering throughout the process. The digestion was continued until the entire volume was reduced to about 15ml and clear solution. The flask was allowed to cool to room temperature. The digest was then filtered into 50 ml volumetric flask and made up to the mark with distilled water.

2.4.2. Plant Digestion

Plant samples were digested by weighing 2.5 g of the plant. Aqua-regia method of digestion was used. 4 ml of HNO_3 plus 1 ml of HCl was added to the sample. The digestion was carried out on hot plate inside fume cupboard. The digest was allowed to cool to room temperature, then filtered and made up to 25 ml of solution. The samples were then subject to Atomic Absorption Spectrophotometer (AAS) using GBC A Vanta PM Version 2.02 for metal analysis.

2.5. Data Analysis

The data generated from this study were analyzed statistically by using the Statistical Package for Social Sciences (SPSS version 24.0). Analysis of Variance was used to test for differences in the concentrations of the heavy metals and the means separated with Ducan Multiple Range Test (DMRT).

3. Results

Table 1 shows the mean concentration of heavy metals in road side higher plants along Akure-Ilesa road during 2012 rainy season. The mean concentration of Pb, Cr, Cd, Cu and Zn were 0.112 mg/kg, 0.188 mg/kg, Cd 0.119 mg/kg, 0.085 mg/kg, 0.757 mg/kg respectively. The mean concentrations of all the heavy metals in higher plants were compared with the values obtained in the control sample of higher plant, it was discovered that Pb and Zn concentrations (0.112 mg/kg and 0.757 mg/kg respectively) in the higher plants were lower than the Pb and Zn (0.241 mg/kg and 0.910 mg/kg respectively) of the control sample. On the other hand, the Cr, Cd and Cu (0.118 mg/kg, 0.119 mg/kg, and 0.085 mg/kg respectively) of sampled higher plants were found to be higher than the Cr, Cd and Cu (0.161 mg/kg, 0.068 mg/kg and 0.065 mg/kg respectively) of the control sample.

Table 1 Heavy metal concentrations (mg/kg) in road side higher plants along Akure – Ilesa during 2012 rainy Season

Sample Locations	Pb	Cr	Cd	Cu	Zn
Long 5°1' Lat71°28'12"	0.021	0.111	0.110	0.085	0.791
Long 5°6'24" Lat 7°20'16"	0.112	0.301	0.130	0.064	0.086
Long 4°54' Lat 7°28'02"	0.211	0.114	0.092	0.058	1.280
Long 4°53'34" Lat 7°30'42"	0.310	0.212	0.142	0.113	1.001
Long 4°52'98" Lat 7°33'	0.044	0.163	0.121	0.100	0.641
Long 4°51'54" Lat 7°36'42"	0.038	0.214	0.111	0.101	0.820
Long 4°48'9" Lat 7°37'14"	0.046	0.201	0.123	0.072	0.680
Mean ± S.D	0.112 ± 0.109^b	0.188 ± 0.066^b	0.119 ± 0.016^b	0.085 ± 0.021^b	0.757 ± 0.367^a
Control (n = 5)	0.241 ± 0.283	0.161 ± 0.144	0.068 ± 0.065	0.065 ± 0.011	0.910 ± 0.520

Values with same superscript along the column are statistically same at p≤0.05.

Table 2 Heavy metal concentrations (mg/kg) in road side soil along Akure – Ilesa during 2012 rainy season

Sample Locations	Pb	Cr	Cd	Cu	Zn
Long 5°1' Lat 7°18'12"	0.388	0.299	0.181	0.078	0.401
Long 5°6'24" Lat 7°20'16"	0.356	0.303	0.100	0.092	0.280
Long 5°3'78" Lat 7°23'82"	0.420	0.294	0.118	0.112	0.321
Long 5°1'02" Lat 7°24'36"	0.216	0.311	0.172	0.046	0.411
Long 4°58'32" Lat 7°24'66"	0.258	0.313	0.164	0.141	0.311
Long 4°54'42" Lat 7°28'02"	0.282	0.302	0.142	0.008	0.294
Long 4°53'34" Lat 7°30'42"	0.431	0.410	0.171	0.070	0.340
Long 4°52'98" Lat 7°33'	0.324	0.328	0.183	0.081	0.281
Long 4°51'54" Lat 7°36'42"	0.330	0.298	0.177	0.076	0.311
Long 4°48'9" Lat 7°37'14"	0.312	0.402	0.180	0.078	0.296
Mean ± S.D	0.332 ± 0.069^a	0.326 ± 0.043^a	0.159 ± 0.029^b	0.078 ± 0.035^c	0.325 ± 0.047^a
Control (n = 5)	0.297 ± 0.022	0.300 ± 0.027	0.153 ± 0.023	0.162 ± 0.120	0.301 ± 0.023

Values with same superscript along the column are statistically same at p≤0.05.

Analysis of Variance showed that the heavy metals were statistically different (F=18.73) at P<0.05, while DMRT showed Pb, Cr, Cd and Cu were statistically the same but significantly lower than Zn. Table 2 shows the mean concentrations of heavy metals in road side soil along Akure – Ilesa road during 2012 rainy season. The Pb concentrations ranged from 0.216 – 0.431 mg/kg, Cr, 0.294 – 0.410 mg/kg, Cd, 0.100 – 0.181 mg/kg, Cu 0.008 – 0.141 mg/kg and Zn 0.280 – 0.411 mg/kg. Concentrations of Pb, Cr, Cd and Zn were higher than those of the control sample. Pb was found to be statistically the same with Cr and Zn, they were also found to be statistically higher than Cd and Cu, while Cd was found to be statistically higher than Cu.

Table 3 Heavy metal concentrations (mg/kg) in roadside higher plants along Akure – Ilesa during 2013 dry Season

Sample Location	Pb	Cr	Cd	Cu	Zn
5º9ˈ06"7º18ˈ18"	0.342	0.211	0.162	0.062	0.409
5º6ˈ3"7º20ˈ22"	0.421	0.301	0.131	0.056	0.084
5º3ˈ84"7º23ˈ82"	0.156	0.142	0.170	0.055	0.411
5º1ˈ08"7º24ˈ42"	0.073	0.218	0.141	0.112	0.490
4º58ˈ38"7º24ˈ72"	0.136	0.201	0.112	0.059	0.415
4º54ˈ48"7º28ˈ08"	0.146	0.151	0.114	0.100	0.625
4º53ˈ4"7º30ˈ48"	0.440	0.216	0.140	0.044	0.532
4º53ˈ04"7º33ˈ06"	0.082	0.118	0.154	0.071	0.061
4º51ˈ6"7º36ˈ48"	0.068	0.110	0.092	0.082	0.831
4º48ˈ96"7º37ˈ2"	0.320	0.112	0.101	0.105	1.200
Mean ± S.D	0.218 ± 0.147^{b}	0.178 ± 0.062^{b}	0.132 ± 0.026^{b}	0.075 ± 0.024^{b}	0.506 ± 0.334^{a}
Control (n = 5)	0.226± 0.155	0.106± 0.011	0.102± 0.004	0.082± 0.031	0.722± 0.550

Values with same superscript along the column are statistically same at p≤0.05.

Table 3 shows the mean concentrations of heavy metals in roadside higher plants along Akure – Ilesa road during 2013 dry season. The mean concentrations of Pb, Cr, Cd, Cu and Zn were 0.218 mg/kg, 0.178 mg/kg, 0.132 mg/kg, 0.075 mg/kg and 0.506 mg/kg respectively. Concentrations of Pb, Cu and Zn in the experimented higher plants (0.218 mg/kg, 0.075 mg/kg and 0.506 mg/kg respectively) were lower than that of the control (0.226 mg/kg, 0.082 mg/kg and 0.722 mg/kg respectively) while that of Cr and Cd (0.178 mg/kg and 0.132 mg/kg respectively) in the higher plants were higher than that of the control (0.106 mg/kg and 0.102 mg/kg respectively) Pb did not statistically differ from Cr, Cd and Cu but were found to be statistically lower than Zn ($p<0.05$). No significant differences were obtained among Pb, Cr and Zn, but a significant difference existed between Cd and Cu at $p<0.05$ ($t = 4.400$ and -11.132 respectively) for experimented higher plant and the control sample.

Table 4 Heavy metal concentrations (mg/kg) in roadside soil along Akure – Ilesa during 2013 dry season

Sample Location	Pb	Cr	Cd	Cu	Zn
5º9ˈ06"7º18ˈ18"	0.312	0.142	0.162	0.111	0.267
5º6ˈ3"7º20ˈ22"	0.326	0.106	0.141	0.106	0.274
5º3ˈ84"7º23ˈ82"	0.340	0.069	0.120	0.101	0.281
5º1ˈ08"7º24ˈ42"	0.420	0.372	0.142	0.046	0.315
4º58ˈ38"7º24ˈ72"	0.284	0.247	0.140	0.120	0.261
4º54ˈ48"7º28ˈ08"	0.410	0.361	0.178	0.082	0.374
4º53ˈ4"7º30ˈ48"	0.226	0.330	0.160	0.096	0.341
4º53ˈ04"7º33ˈ06"	0.276	0.212	0.101	0.084	0.436
4º51ˈ6"7º36ˈ48"	0.382	0.312	0.162	0.068	0.411
4º48ˈ96"7º37ˈ2"	0.391	0.440	0.146	0.052	0.386
Mean ± S.D	0.337 ± 0.064^{a}	0.259 ± 0.124^{b}	0.145 ± 0.022^{c}	0.087 ± 0.025^{c}	0.335 ± 0.064^{a}
Control (n = 5)	0.321± 0.048	0.341± 0.206	0.160± 0.037	0.016± 0.046	0.246± 0.025

Values with same superscript along the column are statistically same at p≤0.05.

The mean concentrations of the soil heavy metals during 2013 dry season varied from one location to another (Table 4). Their mean concentrations were Pb (0.337 mg/kg), Cr (0.259 mg/kg), Cd (0.145 mg/kg), Cu (0.087 mg/kg) and Zn (0.335 mg/kg). Pb, Cu and Zn concentrations of the roadside soils were higher than that of d control while Cr and Cd were lower than that of the control. Cr, Cu and Zn concentrations were significantly different from the control (t= -11.167, 31.177 and 6.928, respectively) Pb content did not statistically differ from Zn, but significantly higher than Cr, Cd, and Cu. Cr was found to be statistically higher than Cd and Cu which were in-turn without statistical difference ($p<0.05$). The order of increment in heavy metal concentrations was Cd = Cu < Cr < Pb = Zn

4. Discussion

The rapid increase in mobility of human beings has led to exceptional rise in vehicular traffic on the major roads. The vehicles release substantial quantity of exhaust emission which consists of poisonous gases like carbon monoxide, sulphurdioxide, oxides of nitrogen etc., with a report that 75% of air pollution takes place through exhaust gases from automobiles [19]. Emissions from vehicles usually results in adverse effects on plants, animals, soil and other environmental components. The tremendous increase in the use of vehicles for day to day mobility in most developing countries, together with lack of emission standards in these countries, has contributed a great deal of concern over vehicular pollution [20, 21].

Except for vehicle emissions, the concentrations of heavy metals in soil can be influenced by other local factors, like the use of agricultural fertilizers and pesticides, other anthropogenic activities and climate change. Results of this study showed that concentrations of the heavy metals were higher in the soil than the plants. [22] and [23] reported undesirable and abnormal concentration of lead (Pb) in air, water, soil and vegetation particularly close to heavily plied automobile free-ways. The heavy metals determined in this study are among the wide range of heavy metals found in fossil fuel which are either emitted into the environment as particles during burning or may be transported in air and contaminate soil [24]. This is in line with the report of [25] that asserted that combustion and traffic are among the sources of heavy metals into the environment.

Result of this study also revealed higher concentration of Zn in the plants than the soil. This is an evidence of bioaccumulation or biomagnification of the heavy metals in plants. When soil is polluted with heavy metals, the metals are taken up by plants and as a result accumulate in their tissues [26]. This is in line with the work of [27] that reported increase in metal concentrations in plants than soil along three major roads in Eleme.

The results obtained in this study also indicated high heavy metal pollutants of the soil and vegetations along high traffic road. This result could be corroborated by that of [28] who reported decreased metal concentrations with increasing distance from the road. He observed that this might be as a result of heavy metals emitted from vehicle exhausts in particulate forms which are forced to settle under gravity closer to the edge of the road. The top soil used in this research contained high metal content, this is in line with the results of several authors who did related research [20, 29]. [29] attributed high heavy metal concentration of roadside topsoil to high organic matter status responsible for fixation of metals in soils.

Zn was found to have the highest concentration in the higher plants in the study area, followed by Pb, while Cu had the least concentration. This is comprehensible since tyre wears released zinc in addition to exhaust emission [30]. In addition, Zn is used in brake linings owing to their heat conducting properties and as such released during mechanical abrasion of vehicles and from engine oil combustion [31, 32, 33]. The high concentration of Zn in this study might also be due to lubricant oil used by vehicles that passed through the road. [34] also reported that lubricant oil added Zn to soils closest to major roads in metropolitan areas. Natural occurrences such as volcanic eruption, forest fires, dust storms and sea spray also add to the continuous cycling of Zn through nature. It is predictable that these natural discharges of Zn quantify to 5.9 million metric tonnes every year [35]. Anthropogenic releases of Zn into the environment are estimated to be a portion of the total emissions from the natural cycling of Zn from erosion, sea spray, volcanic eruption etc [35].

The higher level of Pb might be from the deposition from automobile exhaust since most petroleum fuel is made up of tetraethyl lead as antiknock agent [36]. Large amount of fertilizers are frequently added to soils in intensive farming systems to supply adequate NPK for crop development, and the compounds used to produce them contain trace quantities of heavy metals (e.g Cd and Pb) as impurities, which after persistent fertilizer application may extensively increase their content in the soil [37]. The use of certain phosphate fertilizers ineffectually adds Cd and other potentially toxic elements to the soil such as F, Hg and Pb [38], these may also contribute to the high level of Pb in the study area. Moreover, some pesticides that might have been used in agriculture in that area contain considerable concentrations of metals. Lead arsenate was applied in fruit orchards for many years to control some parasitic insects [39].

These findings can be reasonably explained by vehicular heavy metal emission processes. Almost 100% of Cu emission comes from brake wear while 83% of Cd emission comes from engine oil consumption [40]. However, Pb and Zn emissions are quite evenly distributed in the mechanisms of fuel utilization, engine oil application, brake wear, or tire wear [40].

5. Conclusion

Heavy metal accumulation by plant tissues, its presence in the soil persistently or its presence in ground waters is not a healthy sign for the environment. Controlling air pollution from motor vehicle is essential if the adverse effects will be nip in the bud. The reason for different concentrations of heavy metals in plant and soil in urban roadsides in this study may be due to the density of the traffic. The level of contamination was more pronounced in the soil than in the plant. Nonetheless, results of this study have shown different concentrations of the heavy metals in both plants and soils along the roadside.

6. Recommendations

- Proper maintenance of vehicles and regulation of truck emission control systems should be adopted; this will not only limit harmful emissions but will also improve fuel use efficiency and extend the life of vehicles.
- Appropriate legislation to enhance the performance of regulatory agencies should be provided and a technical committee should also be established in order to develop emission standards for Nigeria and provide a means for its implementation.
- Several antipollution measures should be adopted by the government to stop the pollution or contamination of agricultural land and food; part of this is discouraging the production of vegetables along road sides, because of the potentials of vegetables to accumulate heavy metals up to toxic levels.
- Drying of edible food on tarred roads in rural and urban community should be discouraged.
- Educating the people on the danger involved in the consumption of vegetables grown naturally on non-agricultural land should be done regularly.
- Enhancement of fuel quality and the placement of emission standards to mitigate the impact of vehicle emissions on human health should be adopted.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that there are no conflicts of interest.

References

[1] Adelasoye KA and Alamu LO. (2016). Accumulation of heavy metal pollutants in soil and vegetation and their effects on soil microbial population on roadsides of Ogbomoso, Nigeria. *Journal of Environmental Science and Water Resources,* 5(1), 001 – 007.

[2] Zeyed A, Lytle CM, Qian JH and Terry N. (1998). Chromium accumulation, translocation and chemical Speciation in vegetable crops. *Planta,* 206, 293-299.

[3] Gimmler H, Carandang J, Boots A, Reisberg E and Woitke M. (2002). Heavy metal content and distribution within a woody plant during and after seven years continuous growth on municipal solid waste (MSW) bottom slag rich in heavy metals. *J. Appl. Bot,* 76, 203-217.

[4] Zhang F, Yan X, Zeng C, Zhang M, Shrestha S, Devkota LP and Yao T. (2012). Influence of Traffic Activity on Heavy Metal Concentrations of Roadside Farmland Soil in Mountainous Areas. *Int. J. Environ. Res. Public Health,* 9(5), 1715-1731.

[5] Sharma S and Prasade FM. (2010). Accumulation of Lead and Cadmium in Soil and Vegetable Crops along Major Highways in Agra (India). *J. Chem,* 7(4), 1174-1183.

[6] Emmanuel OF and Edward OO. (2010). Evaluation of the status of heavy metal pollution of soil and plants (*Chromolaena odorata*) of Agbabu Bitumen Deposit Area, Nigeria. *American-Eurasian J. Sci. Res,* 5 (4), 241-248.

[7] Ademoroti CMA. (1986). Levels of heavy metals on bark and fruit of trees in Benin-city, Nigeria. *Int. J. Environ. Pollut,* 11, 241-253.

[8] Osibanjo O and Ajayi SO. (1980). Trace metal levels in tree barks as indicators of atmospheric pollution. *Envir. Int*, 4, 239-244.

[9] Rowchowdhury A and Gautum AK. (1995). Alteration of human sperms and other seminal constituents after lead exposure. *Ind. J. Physiol. Allied Sci,* 49(2), 68.

[10] Kim R, Rotnitzky A and Sparrow D. (1996). A longitudinal study of lowleveled exposure and impairment of renal function: A normative aging study. J. Am. Med. Assoc, 275(15), 1177.

[11] Shannon M and Graef JW. (1996). Lead intoxication in children with pervasive developmental disorders. *J. Toxicol. Clin. Toxicol*, 34(2), 177.

[12] Onianwa PC and Adoghe JO. (1997). "Heavy metal content of roadside dust gutter sediments in Ibadan, Nigeria", *Environ. Int*, 23, 873-877.

[13] Aribike DS. (1996). "Environmental impacts of industrialization in Nigeria": A treatise paper presented at the conference of Nigerian society of chemical Engineers, 14-16.

[14] Rejini MBJ and Janardhanan K. (1989). "Effect of heavy metals on seed germination and early seedling growth of groundnut, sunflower and ginger". *Geobios,* 16, 164-170.

[15] Prodgers RA and Inskeep WP. (1981). "Heavy metals tolerance of inland salt grass Distichlis spicata." *Great Basin Nat*, 51, 271-278.

[16] Bu-Olayan AH and Thomas BU. (2002). "Biomonitoring studies on the Lead levels in Mesquite (*Prosopis juliflora* L.) in the arid ecosystem of Kuwait, *Kuwait J. Sci. Eng,* 29(1), 65-73.

[17] Wittig R. (1993). General Aspects of Biomonitoring Heavy Metals by Plants. In: *Plants as biomonitors - Indicators for heavy metals in the terrestrial environment,* B. Markert, (Ed)3-27, VHC, ISBN 3527300015, Weinheim

[18] Markert B. (1993). Instrumental Analysis of Plants, In: *Plants as biomonitors, indicators for heavy metals in terrestrial environment*, B. Markert, (Ed), VCH, ISBN1560812729, Weinheim, 65 – 103.

[19] Chandan B and Kumar A. (2004). Studies on air pollution due to automobile exhaust in tribal dominated area of Jharkhand, India. *Journal Curr. Science,*5(1), 307–310.

[20] Amusan AA, Bada SB and Salami AT. (2003). Effect of Traffic Density on Heavy Metal Content of Soil and Vegetation along Roadsides in Osun State, *West African Journal of Applied Ecology*, 4, 6-8.

[21] Ibrahim BG. (2009). Strategic approach to reducing vehicle emissions in Nigeria, role of fleet operators, Safety managers training programme, FRSC academy, Jos.

[22] Habashi F. (1992). Environmental Issues in the Metallurgical Industry: Progress and Problems. In: *Environmental Issues and Management of Waste in Energy and Mineral Production,* Singhal, R.K. and A.K. Mehrotra (Eds.). A.A. Balkema Publisher, Rotterdam, Netherlands, 2, 1143-1153.

[23] Fuller EC. (1974). Chemistry and Man's Environment. Houghton Mifflin School, Boston, ISBN: 9780395170861, 502.

[24] Yahaya MI, Ezeh GC, Musa YF and Mohammad SY. (2010). Analysis of heavy metals concentration in roadsides soil in Yauri, Nigeria. Afr. J. Pure Applied Chem., 4, 22-30.

[25] UNEP/GPA. (2004). Why the marine environment needs protection from heavy metals. UNEP/GPA Coordination Office.

[26] Trusby P. (2003). Impact of heavy metals on forest trees from mining areas. Proceedings of the International Conference on Mining and the Environment III, October 24, 2005, Sudbury, Ontario, Canada.

[27] Tanee FGB and Albert E. (2013). Heavy metals contamination of roadside soils and plants along three major roads in Eleme, Rivers State of Nigeria. *Journal of Biological Sciences, 13, 264-270.*

[28] Haygerth PM and Jones KC. (1992). Atmospheric deposition of metals to Agricultural surfaces. In: *Biogeochemistry of trace metals.* Eds. D.C. Adviano. CRC Press, Boca Raton, 249 – 276.

[29] Nyangababo JT and Hamya JW. (1986). The deposition of lead, cadmium, zinc and copper from motor traffic on *Brachiaria enimi* and soil along a major Bombo road to Kampala City. *Int. Envir. Stud.,* 27, 115-119.

[30] Kabata-pendias A and Pendias H. (1994). *Trace element in soil and plants.* Second edition. Boca Raton, Florida: CRC, 365.

[31] Dolan LMJ, Van Bohemen H, Whelan P, Akbar KF and Omalley V. (2006). Towards The Sustainable Development of Modern Road Ecosystem. *The Ecology of Transportation:* Managing Mobility for the Environment, 10, 275-331.

[32] El-Gamal IM. (2000). Distribution pattern of some heavy metals in the soil and plants along EL-Moukattam highway, Egypt. *ICEHM,* 518-524.

[33] Hjortenkrans DST, Bergback BG and Haggerud AV. (2007). "Metal Emissions from Brake Linings and Tires: Case Studies of Stockholm, Sweden 1995/1998 and 2005, *Environmental Science and Technology,* 41(15), 5224 – 5230.

[34] USEPA. (1996). *A citizens guide to bioremediation – technology fact sheet.* Office of Solid Waste and Emergency Response, EPA 542-F-96-007.

[35] International Zinc Association. (IZA). (2017). International Zinc Association Conference February 26 – March 1 2017, Omni Rancho Las Palmas, Rancho Mirage, California.

[36] Lenntech Water Treatment and Air Purification. (2004).*Water Treatment.* Lenntech Publishers, Rotterdamseweg, Netherland.

[37] Jones LHP and Jarvis SC. (1981). "The fate of heavy metals," in The Chemistry of Soil Processes, Green, D.J. and Hayes, M.H.B. Eds., p.593, John Wiley & Sons, New York, NY, USA.

[38] Raven JA, Griffiths H, Smith EC and Vaughn KC. (1998). New perspectives in the biophysics and physiology of bryophytes. In: Bates, J.W., Asthon, N.W. and Duckett, J.G. (eds). *Bryology in the twenty-first century.* Maney publishing and the British Bryological Society, UK, 261-275.

[39] McLaughlin MJ, Parker DR and Clarke JM. (2000). Metals and micronutrients – food safety issues. *Field Crops Research,* 60(1–2), 143–163.

[40] Winther M and Slento E. (2010). Heavy Metal Emissions for Danish Road Transport; NERI Technical Report No. 780. Aarhus Universitet; Roskilde, Denmark.

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