Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print), 2222-3045 (Online)
http://www.innspub.net
Vol. 6, No. 2, p. 1-7, 2015

INNSPUB

RESEARCH PAPER OPEN ACCESS

Assessment of heavy metals (Pb, Cd, Zn and Cu) concentrations in soils along a major highway in Wukari, North-Eastern Nigeria

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Key words: Heavy metals, Soil pollution, Highway, Wukari.

Article published on February 01, 2015

Abstract

Heavy metal pollution is a major environmental problem, especially around highways with high traffic density. This study investigates the levels of Pb, Cd, Zn and Cu in roadside soils of Wukari section of the Wukari-Jalingo highway, Taraba state, Nigeria. Samples were randomly collected and analyzed using standard methods. The mean concentrations (µg/g) of Pb, Cd, Zn and Cu from all sample sites ranged: 89.6-247.0, 0.15-5.3, 26.8-163.0 and 7.1-61.2 respectively. The extent of the heavy metals contamination was assessed, as analytical data were subjected to pollution calculation methods. The contamination factors (CF) reveal extreme contamination of the sites and an increasing trend in the heavy metals concentrations was observed in sites with more human activities. The pollution load index (PLI) showed that the sites are severely polluted as the PLI of the metals from each sample site exceeded the PLI of the background (control) sample (0.7). Spearman's rank correlation analysis showed clear correlations ($p<0.001$) amongst the metals suggesting a common source. It can be concluded that the study sites pollution is mostly due to automobile emissions. This study provides awareness for residents to avoid activities such as farming, trading etc very close to the highway due to exposures to these toxic metals.

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Introduction

Emissions from heavy duty and commuter vehicles on the roads contain lead (Pb), cadmium (Cd), zinc (Zn), and nickel (Ni), Copper (Cu) which are present in fuel as anti-knock agents and this leads to contamination of air and soils on which vegetables are planted (Ikeda *Et al.*, 2000). Accumulation of heavy metal in agricultural land through traffic emission may result in soil contamination and elevated heavy metal uptake by crops, and thus affect food quality and safety (Ho and Tai, 1988; Garcia and Millan, 1998). Food chain contamination is one of the important pathways for the entry of these toxic pollutants into the human body (Ma *Et al*, 2006). Apart from lead, very little concern has been given to the likelihood of pollution by other heavy metals which can originate from automobiles, tyre wear and motor oils. Lagerwerff and Speeht (1970) reported that the Cd content of three lubricating oils range from 0.20 to 0.26 ppm and that of three diesel oils from 0.07 to 0.10 ppm. The lead content of four tyres of different brands was also found to range from 20 to 90 ppm (Ward *Et al*, 1975). Certain components of automotive engines, chasis and piping contain copper and manganese, while nickel and chromium are usually used in chrome plating (Word *Et al*, 1977). Some of the metals presumably derive from the wear of metallic automobile parts containing these metals (Voegborlo and Chirgawi, 2007). Moreover, release of Pb through vehicle emission, leading to Pb pollution of the atmosphere, soil and crops (Pei and Chaolin, 2004).

With the rapid increase in number of motor vehicles on Nigerian highways recently, and as a consequence of a boost in commercial and industrial activities, considerable amounts of some heavy metals are likely to be emitted regularly as long as the nearby sources remain active. Very limited information is available in Wukari, Taraba state, Nigeria on the levels of heavy metals accumulation in roadside soils due to highway traffic. This article contains information of heavy metal contents in soils collected at various points from the Wukari section of the major highway (Wukari-Jalingo highway) in Taraba State, North-Eastern Nigeria.

Materials and methods

Study area

The study was conducted along Wukari section of Wukari-Jalingo highway, Taraba state, Nigeria. This highway connects the South-south (Cross River) and North-central region of Benue (Gboko, Makurdi etc.) to the north-eastern region (Wukari, Jalingo, Yola etc.) of Nigeria. The highway contains sections of adjacent farmlands, markets, malls, automobile workshops etc.

Sample collection and preparation

Surface soils of up to 10 cm deep were collected using hand driven stainless steel corers, following a simple random and judgmental sampling technique. The soils were sampled both from the west and east sides of the road section. Topsoil samples of 0-30cm depth from five (5) different sampling locations along the highway were taken and designated as S1, S2, S3, S4 and S5 respectively. The collected samples were placed in a clean polyethylene bags to avoid contamination and were well labelled. The soil samples were sun dried, sieved with a 2µm sieve, ground and stored in plastic vials. Exact locations for all sampled sites were determined using global positioning system and entered into a geographical information system for data processing.

Chemical analysis of sample

In the laboratory, from the prepared samples, 0.50 g were digested in 20 ml freshly prepared aqua regia (1:3 HNO_3: HCl) on a hot plate for 3 hours, then evaporated and analyzed for metal concentration. Standard reference materials prepared using stock solutions as obtained from BATO chemical Laboratory (Lagos, Nigeria) were used to have a check on the accuracy of the results. The total concentrations of Cd, Cu, Pb and Zn in filtrates were then determined using a Flame Atomic Absorption Spectrometer (Varian SpectrAA 220 FS) equipped with deuterium background correction devise using air-acetylene flame. All reagents used in the analysis were of analytical grade. Quality control was measured by the use of triplicate and standard reference materials and procedural blanks. Soil pH was determined using a soil-water ratio 1: 2.5 (w/v) with a properly calibrated Hanna bench top pH meter (UK).

Assessment of metal contamination

In order to assess heavy metal enrichment and degree of contamination in soils, analytical data were subjected to pollution calculation methods expressed in (1-2) (Sutherland, 2010), with the aim of deriving realistic estimates for the amount of contamination that has impacted soils along the Wukari section of the highway.

Contamination factor (CF)

The level of contamination of soil by metal is expressed in terms of a contamination factor (CF) calculated as:

$$CF = \frac{C_m\ Sample}{C_m\ Background} \qquad (1)$$

Where the contamination factor CF < 1 refers to low contamination; 1 ≤ CF < 3 means moderate contamination; 3 ≤ CF ≤ 6 indicates considerable contamination and CF > 6 indicates very high contamination.

Pollution Load Index (PLI)

Each site was evaluated for the extent of metal pollution by employing the method based on the pollution load index (PLI) developed by Thomilson *Et al.* (1980), as follows:

$$PLI = (CF_1\ X\ CF_2\ X\ CF_3\ X \ldots CF_n)^{\frac{1}{n}} \qquad (2)$$

Where n is the number of metals studied (4 in this study) and *CF* is the contamination factor calculated as described in Equation 1. The PLI provides simple but comparative means for assessing a site quality, where a value of PLI < 1 denote perfection; PLI = 1 present that only baseline levels of pollutants are present and PLI > 1 would indicate deterioration of site quality (Thomilson *Et al.*, 1980).

Data Analysis

In order to study the characteristics of roadside soils, the concentrations of heavy metals content in surface soils were subjected to correlation analysis to determine association as well as the differences in the concentration between different sampled locations.

Results and discussion

The results of the levels of Pb, Cd, Zn and Cu and pH of the soils from the different sampled sites along the highway are presented in Table 1. The mean heavy metal concentration (µg/g) along roadside soils ranged from (89.6-247) Pb; (0.15-5.3) Cd; (26.8-163) Zn and (7.1-61.2) Cu. Their concentrations in all the sample sites were found in the following order: Pb>Zn>Cu>Cd.

Table 1. Heavy metals levels (µg/g) and pH of soils in sampled sites.

Sample ID	Pb	Cd	Zn	Cu	pH
S1	89.6	0.15	26.5	7.1	5.63
S2	129.8	0.54	65.3	15.2	5.02
S3	236.1	1.75	94.2	30.7	5.12
S4	233.5	4.15	119.7	44.6	5.80
S5	247.1	5.3	163.7	61.2	5.55
Background (0.5km)	7.5	0.03	2.5	1.5	6.90

Since this study is the first of its kind for Wukari section of the Wukari-Jalingo highway roadside soils, there is no local information in literature available for comparison. Data reported here were therefore used to examine the extent of contamination by Pb, Cd, Zn and Cu using comparable pristine samples obtained at least 0.5km from the roadside sampled sites. Concentrations of individual heavy metal elements and their background data are given in the Table 1.

Heavy metals release into the environment is from divergent sources. The heavy metals levels from roadside soil were generally higher than the background levels. These observations indicate some level of contamination from point and non-point sources which amongst others, could be vehicular emissions, road pavement materials, climate and anthropogenic activities.

The Pb levels in the study ranged within 89.6-247 µg/g. Roadside soils have been reported to have Pb level within the range obtained in this study. 25.0 to 1198.0 µg/g have been reported on roadside soil in England, 0.00 to 50.10 µg/g in India, 78.4 to 832 µg/g in Tanzania, 9.27 ± 0.23 to 45.92± 22.06 µg/g and 47 to 151 µg/g on major highways in Lagos, Nigeria (Akbar *Et al.*, 2006; Atayese *Et al.*, 2008; Luilo and Othman, 2006; Sharma and Prasade, 2010; Othman *Et al.*, 1997). Pb content of leaded gasoline in Nigeria ranges from 0.60 to 0.80 g/L (Kakulu, 2003). Consequently the most probable source of such contamination is the lead particulate matter emitted from gasoline vehicles which settles not far from the highway (Harrison *Et al*, 1981). In addition, wearing down of automobile tyres can lead to the deposition of Pb to the roadside soils (Sharma and Prasade, 2010; Zhang *Et al.*, 2012).

Cadmium levels (0.15- 5.3 µg/g) in this study was found to be consistent with the reported results of 5.2 µg/g roadside soils in Lancaster(Harrison *Et al*, 1981), 4.2 µg/g of Cd was reported on a highway roadside soil in London (Culbard *Et al*, 1988). The results obtained in this study was within the range of reported results obtained in Hongkong (1.1 µg/g), Lagos, Nigeria (0.3-1.33 µg/g) (Ho and Tai, 1988; Ndiokwere, 1984). In the absence of any major industry in the sampling sites, the levels of Cd could be due to engine oil consumption and the wearing of tyres. Such findings have been reported previously (Sharma and Prasade, 2010; Atayese *Et al.*, 2008; Zhang *Et al.*, 2012).

Zinc levels in the highway side soils exhibited elevated levels within the range 26.8-163.0 µg/g, compared with the background level of 2.5 µg/g which indicates deposition from extraneous sources. The observed level is lower than Zn 56.7- 480.0 µg/g, reported in roadside soil of England (Akbar *Et al,* 2006), Zn 300-530 µg/g reported in Lancaster (Harrison *Et al*, 1981). 163 µg/g was reported in a study in Nigeria which is consistent with the observed level in this study (Ndiokwere, 1984). Zn is used in brake linings because of their heat conducting properties and as such released during mechanical abrasion of vehicles, and from engine oil combustion and tyres of motor vehicle (Manno *Et al.*, 2006 and El-Gamal, 2000). Hence, the probable sources of Zn on this highway could be due to deposits from automobiles and other anthropogenic activities.

Cu concentration (µg/g) in the roadside soils of the highway was within the range 7.1- 61.2 with a mean concentration (µg/g) of 31.76±21.881. Higher levels of Cu have been found in roadside soils in Hongkong (120 µg/g) (Ho and Tai, 1988), In England, 15.5-240.0 µg/g concentration of Cu was reported in roadside soils (Akbar *Et al*, 2006). Jos city roadside Cu level ranges from 1.01 – 2.19 µg/g which is much less than what is observed in our study (Abechi *Et al*, 2010). Various levels have been reported in the literature, Cu (µg/g): 29.70 (Jordan)(Jaradat and Momani, 1999), 61.0 (Nigeria)(Ndiokwere, 1984) and 2.78 (China)(Bai *Et al*, 2008). Cu deposits derived from engine wear, brake linings (Manno *Et al*, 2006) could find its way into the roadside soils from the heavy trucks and other automobiles frequently on this very busy highway.

Contamination factor (CF)

Contamination factors of various metals in the roadside soils in sampled sites are presented in Table 2 and Fig 2. Using the contamination factor categories previously described, all samples suffered very high contamination by all metals except S1 with considerable contamination by Cd. It was also observed that Sample site S5 showed very extreme contamination by Pb, Cd, Zn and Cu. The trend in the contamination factor as determined was S1<S2<S3<S4<S5.

Table 2. Contamination factor for heavy metals in roadside soils samples.

	Pb	Cd	Zn	CU
S1	11.94	5	10.72	14.2
S2	17.31	18	26	30.4
S3	31.48	58.3	37.68	61.4
S4	31.13	138.3	47.88	89.3
S5	32.93	176.7	65.2	122.4

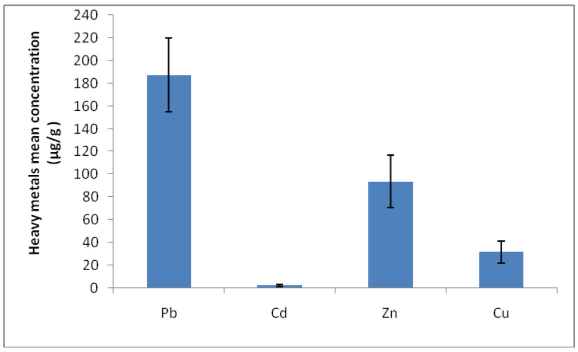

Fig. 1. Heavy metals mean±S.E in soils adjacent to the highway.

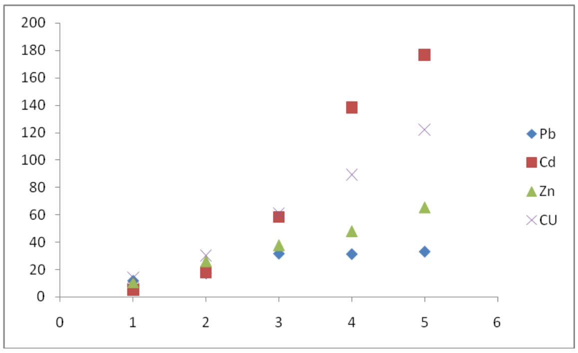

Fig. 2. Contamination factor of heavy metals in soil.

Pollution load index (PLI)

To effectively compare whether the five (5) sample sites suffer contamination or not, the pollution load index, PLI, described in Equation 2, was used. The PLI is aimed at providing a measure of the degree of overall contamination at a sampling site. Fig. 3 shows results of the PLI for the four (4) metals studied at these sites. Based on the results presented (Fig. 3), the overall degree of contamination by the four (4) metals is of the order S5>S4>S3>S2>S1.

All sites show strong signs of pollution or deterioration of site quality, since the background (control) sample's PLI was calculated to be 0.7 and a baseline value of ≤ 1.0 indicates well (good) to moderate site quality. Relatively high PLI values at S5, S4 and, to some degree, S3 suggest input from anthropogenic sources attributed to increased human activities and/or vehicular emissions. These sites are along a major highway were there are high human activities ranging from automobile workshops, restaurants and auto parts dealers. This highway also connects a number of townships and villages. Furthermore, S5 and S4 sites is along the highway which is frequently used (as stop over parks) by commercial trucks for transportation of goods and petroleum products to and from the north-eastern and north central regions of Nigeria.

Statistical Analysis

Inter-elemental association was also evaluated by Spearman's rank correlation coefficient, ρ and the results are presented in Table 3. Result (Table 3) indicates that some elemental pairs, for example Pb/Zn ($r = 0.901$, $P < 0.001$), Zn/Cu ($r = 0.989$, $P < 0.0001$), and Cd/Zn ($r = 0.958$, $P < 0.0001$) and Cd/Cu ($r = 0.985$, $P < 0.001$) have very strong correlations with each other. Strong correlations signify that each paired elements have common contamination sources. Physico-chemical properties (except pH) and metal associations were however not performed in the present study, to help in ascertaining these results.

Table 3. Spearman's rank correlation for heavy metals.

	Pb	Cd	Zn	Cu
Pb	1.00			
Cd	0.84	1.00		
Zn	0.901	0.958	1.00	
Cu	0.894	0.985	0.989	1.00

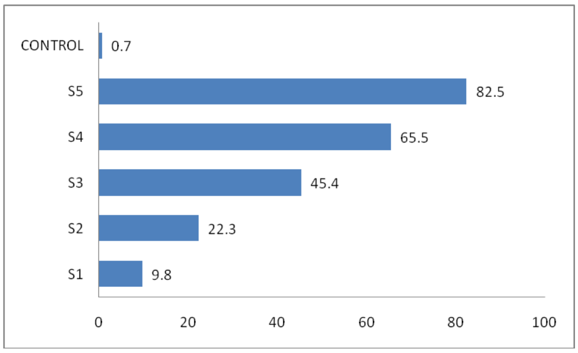

Fig. 2. Pollution Index of heavy metals in soil.

Conclusion

The levels of Pb, Cd, Zn and Cu in roadside soils were found to be higher than the background (control) levels for the heavy metals. Pollution assessment methods employed showed that the sites were extremely polluted. These concentrations, however, were below the critical maximum levels above which toxicity is possible. Nonetheless, the level of contamination could lead to the leaching of these metals to adjacent farmlands and potable water sources, which would eventually find their way into the food chain. Also, constant exposures to the vehicular emissions could lead to the bioaccumulation of these metals in plants and humans until it reaches the critical maximum level of toxicity. This study provides ample information and assessment of the current status of soils adjacent to the highway and brings to the awareness of the residents imminent dangers from roadside activities.

Reference

Abechi ES, Okunola OJ, Zubairu SMJ, Usman AA , Apene, E. 2010. Evaluation of heavy metals in roadside soils of major streets in Jos metropolis, Nigeria. Journal of environmental chemistry and ecotoxicology **2(6),** 98-102.

Akbar KF, Hale WHG, Headley AD, Athar M. 2006. Heavy Metal Contamination of Roadside Soils of Northern England. Soil and Water Resources **1(4),** 158-163.

Atayese MO, Eigbadon AI, Oluwa KA, Adesoduni JK. 2008. Heavy Metal Contamination of Amaratus grown along major highways in Lagos, Nigeria. African Crop Science Journal **16(4),** 225-235.

Culbard EB, Thornton I, Watt J, Weatley M, Moorcraft S, Thompson M. 1988. Metal contamination in British suburban dusts and soils. Journal of Environmental Quality **17,** 226–234.

El-Gamal IM. 2000. Distribution pattern of some heavy metals in soil and plants along EL-Moukattam highway, Egypt. ICEHM, 518-524.

Garcia R, Millan E. 1998. Assessment of Cd, Pb and Zn contamination in roadside soils and grasses from Gipuzkoa (Spain). Chemosphere **37,** 1615-1625.

Harrison RM, Laxen DPH, Wilson SJ. 1981. Chemical Association of Lead, Cadmium, Copper, and Zinc in Street Dusts and roadside soils. Environmental Science Technology **15,** 1378-1383.

Hjortenkrans D. 2003. Diffuse metal emissions to air from road traffic. A case study of Kalmar, Sweden. Environmental Science Sect. Bullet, 1-55.

Ho IB, Tai KM. 1988. Elevated levels of Lead and other Metals in Roadside Soil and Grass and their use to monitor Aerial metal Depositions in Hong Kong. Environmental Pollution **49,** 37-51.

Ikeda M, Zhang ZW, Shimbo S, Watanabe T, Nakatsuka H, Moon CS, Matsuda-Inoguchi N, Higashikawa K. 2000. Urban population exposure to lead and cadmium in east and south-east Asia. Science of the Total Environment **249,** 373-384.

Kakulu SE. 2003. Trace metals concentration in roadside surface soils and tree bark: A measurement of local atmosphere pollution in Abuja, Nigeria Journal environmental monitoring and assessment **89,** 233-242.

Lagerwerff JV, Specht AW. 1970. Contamination of roadside soil and vegetation with Cd, Ni, Pb and Zn. Environmental Science Technology **4,** 583-586.

Luilo GB, Othman OC. 2006. Lead Pollution in urban roadside environments of Dares Salaam city. Tanzania Journal of Science **32(2),** 61-67.

Ma HW, Hung ML, Chen PC. 2006. A systemic health risk assessment for the chromium cycle in Taiwan. Environment International **10,** 1016-1023.

Manno E, Varrica D, Dongarra G. 2006. Metal distribution in road dust samples collected in an urban area close to a petrochemical plant at Gela, Sicily. Atmosphere and Environment **40,** 5929-5941.

Ndiokwere CL. 1984. A study of heavy metal pollution from motor Vehicle emission and its effect on vegetation and crops in Nigeria. Environmental Pollution Journal **7,** 35-42.

Othman I, Al-Oudat M, Al-Masri MS. 1997. Lead levels in roadside soils and vegetation of Damascus city. Science and Total Environment **207(1),** 43-48.

Pei XU, Chaolin L. 2004. Lead Contamination of soil along road and its remediation. Chinese Journal of Geochemistry **23(4),** 329-332.

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

Sutherland RA, Tolosa CA, Tack FMG, Verloo MG. 2000. Characterization of selected element concentration and enrichment ratios in background and anthropogenically impacted roadside areas. Archives of Environmental Toxicology **38,** 428–438.

Thomilson DC, Wilson DJ, Harris CR, Jeffrey DW. 1980. Problems of heavy metals in estuaries and the formation of pollution index. Helgol. Wiss. Meeresunlter **33(4),** 566–575.

Voegborlo RB, Chirgawi MB. 2007. Heavy metals accumulation in roadside soil and vegetation along major highway in Libiya. Journal of Science and Technology **27(3),** 1-12.

Ward NI, Reeves, RD, Brooks RR. 1975. Lead in soil and vegetation along a New Zealand State highway with low traffic volume. Environmental Pollution **9,** 243-251.

Word NI, Brooks RR, Roberts E. 1977. Heavy-metal pollution from automotive emissions and its effect on roadside soils and pasture species in New Zealand. Environmental Science Technology **11,** 917-920.

Zhang F, Yan X, Zeng C, Zhang M, Shrestha S, Devkota LP, Yao T. 2012. Influence of Traffic Activity on Heavy Metal Concentrations of Roadside Farmland Soil in Mountainous Areas. International Journal of Environmental Resources and Public Health **9(5),** 1715-1731.