JASEM ISSN 1119-8362

Full-text Available Online at www.ajol.info and www.bioline.org.br/ja

J. Appl. Sci. Environ. Manage. *December 2013*
Vol. 17 (4) 509-514

Assessment of Traffic Related Heavy Metals Pollution of Roadside Soils in Emerging Urban Centres in Ijebu-North Area of Ogun State, Nigeria

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Key words: Heavy metal; pollution; roadside soils; transportation; monitoring; vehicular emission; Ogun State; Nigeria.

ABSTRACT: This study investigated the concentration of eight critical heavy metals in the roadside soils of selected urban centres in Ijebu-North Local Government Area of Ogun State, SW, Nigeria. Thirty-six composite soil samples were collected along the roadside based on distances to the roads. Physiochemical properties and concentrations of heavy metals (Cd, Cr, Cu, Fe, Mn, Pb, and Zn) in roadside soils in some selected locations were determined using atomic absorption spectroscopy. Accumulation of heavy metals in top soils is greately influenced by traffic volume and all the heavy metals exhibited a significant reduction in the roadside soils with increasing distance from the road. Metal concentrations in the roadside soils followed order of Zn>Pb>Fe>Cu>Mn>Cd>Cr. Concentration of Zn was 156.09 mg/Kg in roadside soils of Ijebu-Igbo/Oru/Ago-Iwoye which is experiencing high volume of traffic , while it ranged from 10 – 47 mg/Kg for Ijebu-Igbo/Bajowa/Akanran road with low traffic volume. Pb concentration of 26.7 mg/Kg was observed in : Ijebu-Igbo/Oru/Ago-Iwoye road especially in centre of the city. Concentration of all heavy metals examined were below the EU guideline, however, the paper suggested a regular monitoring and assessment to ensure sustainable management of the urban environment and reduction of traffic-related contamination of soil, plants and water. ©JASEM

http://dx.doi.org/10.4314/jasem.v17i4.8

Roadside soils in urban areas all over the world are pointers of heavy metal contamination from a variety of sources mostly of anthropogenic influences. Major metal pollutants of the roadside environments and are released from fuel burning, wear out of tyres, leakage of oils, and corrosion of batteries and metallic parts such as radiators etc. (Xia et al., 2010). Although many heavy metals are naturally occurring, some however, have shown potential health hazards especially in high concentrations in human and plant cells. Heavy metals such as cadmium, lead, and others like copper and zinc are potentially toxic and pose great threat to food safety and human health even in minute concentrations (Abduljaleel et al., 2012).

In recent times, research has focused on heavy metals in urban soil, including those contributed by automobiles along transport routes (Lu et al., 2012; Świetlik et al., 2013). Environmental management problems of transport related discharge of heavy metal into the environment varies across time, location, the intensity of human activities and traffic volume, mobility and bioavailability of the metals (Zheng et al., 2002). Poisonous metals such as Cd, Cr, Cu, Fe, Mn, Pb, and Zn have been shown to be associated with ambient particles released by roadside dust and can cause the production and release of inflammatory mediators by the respiratory tract epithelium (Duan et al., 2012). These emphasized the need to respond to the continuous deposition of heavy metals on urban soils in order to achieve sustainable environmental management. This study aim at assessing traffic related heavy metals pollution on roadside soils in urban centres in Ijebu-North Local Government Area, Ogun State, Nigeria.

MATERIALS AND METHODS

Study Area : The study was conducted on major roads in Ijebu-North Local Government Area of Ogun State, SW Nigeria. Major towns such as Ijebu-Igbo, Ago-Iwoye and Oru in the area have witnessed rapid increase in population and urban expansion, increased vehicular activities and other socio-economic activities that have brought about attendant problems of traffic

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congestions and environmental pollution by heavy metals. Roadside soil samples were collected in March 2011 during the dry season to avoid rain washing out the heavy metals. The study area was divided into three based on volume of traffic: Ijebu-Igbo/Oru/Ago-Iwoye (>2000 vehicle per day), Oru/Mamu/Ibadan (~1000 vehicle per day) and Ijebu-Igbo/Bajowa/Akanran roads (> 1000 vehicle per day) and were referred to as IOA, OMI and IBA respectively.

Sampling: Prior to sampling, the locations were cleared of debris and roadside soil samples were collected at depths of 0-10 cm (A) and 10-20 cm (B) using hand driven stainless steel augers. A total of thirty-six (36) samples were collected at varied distances of 0, 5, 10 and 15 metres from the side of the selected roads. Background or control samples were collected at least 500 m away from the direction of sampling locations. The geographical coordinates of these locations were determined using a Garmin global positioning system (GPS) and entered into a geographical information system (GIS) for data processing. Soil samples for each sampling location were thoroughly mixed after the removal of all debris and extraneous materials to give composite samples for each location.

Sample Treatment : Soil samples were air - dried in a circulating air in the oven at 30°C to a constant weight and then passed through a 2 mm sieve and stored in dry labelled plastic and taken to the laboratory for pre-treatment and analyses under frozen condition (4°C) to prevent any microbial activity.

Soil pH was determined using pH meter, while electrical conductivity was determined by the method described by Chopra and Kanzar (1988). Total organic carbon was determined by Walkey-Black digestion method as described by Anderson and Ingram (1989). Organic matter content in the soils were determined by multiplying the organic carbon content by 1.742 using the assumption that organic matter content is approximately 58 % of carbon. Soil samples for metal analysis were digested according to the procedure described by Sharidah (1999) digested samples were analysed for the following heavy metals Cd, Cr, Cu, Fe, Mn, Pb, and Zn using flame atomic absorption spectroscopy (model AA 650). Standard solutions prepared by appropriate dilution of the stock solution 1000 µg/mL were used to calibrate the device by means of the standard curve method. The detection limit for all analyzed heavy metals was 0.005 $mg.L^{-1}$. The accuracy of the results obtained in this study was assessed by preparing blank solutions the same manner as employed for the digested soil samples. The blank solutions were checked and found to be uncontaminated. Data were subjected to Pearson Correlation Analysis to examine the relationship between the analyzed heavy metals. The analysis was done using the SPSS Package (Version 17.0).

RESULTS AND DISCUSSION

The soils contain high percentage of sand which ranged from 70.02 to 89.7 percent, while percent silt and clay ranged from 7.05 to 11.10 and 9.95 to 20.2 percent respectively. Soil pH ranged from 6.62 to 7.10 indicating that the soils are slightly acidic. Electrical conductivity ranged from 1.10 to 1.26 µS/cm, while organic matter content ranged from 0.98 to 3.03 percent which is typical of tropical soils.

Heavy metal concentration in roadsides soils : In the high traffic volume areas (IOA), the mean concentration of heavy metals like Cd ranged from 0.05 to 0.13 mg/kg while Pb, Mn, Cu, Fe, and Zn ranged from 18.03 to 122.03 mg/kg, 7.03 to 30.14 mg/kg, 20.62 to 82.12 mg/kg, 16.20 to 120.89 mg/kg, and 30.78 to 160.99 mg/kg respectively (Table 1). Concentration of these metals differ significantly according to traffic density as the values obtained for the medium and low traffic volume areas were lower than those of the high traffic volume areas. In the medium traffic volume area (OMI), Cd ranged from 0.02 to 0.07 mg/kg, while Pb, Mn, Cu, Fe, and Zn ranged from 3.02 to 30.08 mg/kg, 0.08 to 6.71 mg/kg, 2.02 to 11.03 mg/kg, 1.30 to 23.09 mg/kg, and 6.32 to 31.28 mg/kg respectively (Table 1). For the low traffic volume area (IBA), Cd and Cr were not detected in most cases, while the concentrations of Mn, Fe, Cu, Pb and Zn were lowest compared to the two other areas. Concentrations of Mn, Fe, Cu, Pb and Zn ranged from 1.02 to 2.02 mg/kg, 1.10 to 20.16 mg/kg, 0.92 to 10.08 mg/kg, 0.06 to 9.65 mg/kg, and 1.04 to 12.03 mg/kg respectively.

However those areas with less concentrations of metal may be attributed not only to less traffic but it might be due to strong leaching from the topsoil favoured by sandy textured soils predominant in the soil. Generally, Cr has significantly lower concentrations in the roadside soils than other heavy metals. Cr ranged from not detected (ND) to 0.11 mg/kg in the roadside soils. Roadside soils consistently had greater metal content for all metals than those farther away as corroborated by Joshi et al. (2010). The order of concentration of the heavy metals in the roadside soils is as follows: Zn>Pb>Fe>Cu>Mn>Cd>Cr. The concentrations of zinc are significantly higher in relation to other elements with the maximum value of 160.99mg/kg. Since no major industry exists in the study areas such as smelting operations, we may assume that the primary sources of Zn are probably the attrition of motor vehicle tire rubber exacerbated by poor road surfaces, and the lubricating oils in which Zn is found as part of many additives such as zinc dithiophosphates (Bai et al., 2008). Concentrations of Pb found in the study area were consistent with studies such as that of 90–210 mg/kg for Michigan (Francek, 1997); and 9.8–136.1 mg/kg for Oshogbo, Nigeria (Fakayode and Olu-Owolabi 2003). Concentration of Fe is also very high in the study area probably due to occurrence of Fe at high concentrations in Nigerian soils (Adefemi et al., 2007). None of the samples fell within or exceeded the stipulated range for zinc and lead as recommended European Union Standard (2002). To quantify the degree of metal contamination in the roadside soils, the geo-accumulation index (I_{geo}) (Doung and Lee, 2011) was calculated based on the equation:

$$I_{geo} = \log 2 \left[\frac{C_n}{1.5B_n}\right]$$

where n-metal concentration in the roadside soil was used as Cn, and n-metal concentration in unpolluted soils was used as Bn. Due to the non-availability values of the studied heavy metals in background soils, I_{geo} was calculated using the global average shale data (Doung and Lee, 2011). The 1.5 is a factor used because of possible variations of the background data due to lithological variations. The result shows that Zn, Pb and Fe pollution in the roadside soil in the study area did not exceed the moderately polluted level.

The geo-accumulation index (I_{geo}) was 0.418, 0.417 and 0.763 respectively. The soil can be classified as uncontaminated or moderately contaminated because the geo-accumulation index (I_{geo}) were with the range of $0 < Igeo < 1$. Cu with I_{geo} of 3.29 reached moderately to strongly polluted ($2< I_{geo} \leq 3$) level. Based on the calculated I_{geo} it can be said that the roadside soils in the study area are exposed to pollution from vehicular traffic but the concentration level is still minimal. Heavy metals such as Zn, Pb and Cu exhibited high level of concentration on the roads witnessing high traffic volume. Significant positive correlations were found among most metals (Table 3). Positive correlations may suggest that the heavy metals are from the same sources.

Conclusion: Roadside soils from different locations in Ijebu-North Local Government Area of Ogun State, Nigeria were examined for Cd, Cr, Cu, Fe, Mn, Pb, and Zn. Results from the study showed that Zn, Pb, Cu, Mn, and Fe were the most abundant element especially in the topsoil. Generally, the concentration of these metals in roadside environment increases with increasing traffic volumes and also in urban areas. The pattern of total metal concentrations in the roadside soils followed Zn>Pb>Fe>Cu>Mn> Cd>Cr. The mean concentration of heavy metals like Cd ranged from 0.05 to 0.13 mg/kg while Pb, Mn, Cu, Fe, and Zn ranged from 18.03 to 122.03 mg/kg, 7.03 to 30.14 mg/kg, 20.62 to 82.12 mg/kg, 16.20 to 120.89 mg/kg, and 30.78 to 160.99 mg/kg respectively. These values are however below permissible limits set by the EU, but care must be taken to maintain a low level of heavy metal concentration on roadside soils as these soils are often cultivated to produce food crops such as vegetables, maize and cassava. It is necessary to have continuous studies on the accumulation of heavy metals and the potential ecological risk assessment to ensure effective protection and management of urban soil and other environmental media.

Acknowledgements: We wish to appreciate the anonymous persons that help to proof read the manuscript and also for technical information.

Table 1: Descriptive statistics of heavy metal concentrations in topsoil (mg/kg) along major Roads in INLG, Ogun State, Nigeria

,**High Traffic Volume**							
IOA	**Cd**	**Cr**	**Cu**	**Fe**	**Mn**	**Pb**	**Zn**
Mean	0.10	0.10	49.30	64.33	13.78	61.02	76.74
SD	0.02	0.02	21.97	32.10	7.29	37.05	39.62
MAX	0.13	0.11	92.02	120.89	30.14	122.03	160.99
MIN	0.08	0.08	20.62	16.20	5.90	18.03	30.78
Range	0.08	0.08	71.40	104.69	24.24	104.0	130.21
Medium Traffic Volume							
Mean	0.03	0.04	3.68	7.27	2.72	8.42	7.71
SD	0.01	2.54	0.02	6.05	1.70	8.67	7.69
MAX	0.07	0.11	11.03	23.09	8.62	30.08	31.28
MIN	0.01	0.01	1.78	1.30	0.08	3.02	6.32
Range	0.07	0.11	9.25	21.79	8.54	27.06	24.96
Low Traffic Volume							
Mean	0.00	0.001	1.41	1.54	1.23	1.37	1.67
SD	0.00	0.004	0.43	1.10	1.43	0.80	0.51
MAX	0.00	0.01	2.01	3.29	3.22	2.12	2.26
MIN	0.00	0.00	0.92	0.10	0.00	0.06	1.04
Range	0.00	0.01	1.09	3.19	3.22	2.06	1.22

Table 2: Pearson Correlations between the heavy metal examined in the roadside soils

	Cd	**Cr**	**Cu**	**Mn**	**Fe**	**Pb**	**Zn**
Cd	1	.834**	.760**	.711**	.695**	.723**	.799**
Cr		1	.720**	.724**	.702**	.757**	.765**
Cu			1	.745**	.776**	.701**	.838**
Mn				1	.702**	.815**	.784**
Fe					1	.828**	.818**
Pb						1	.882**
Zn							1

**. Correlation is significant at the 0.01 level (2-tailed).

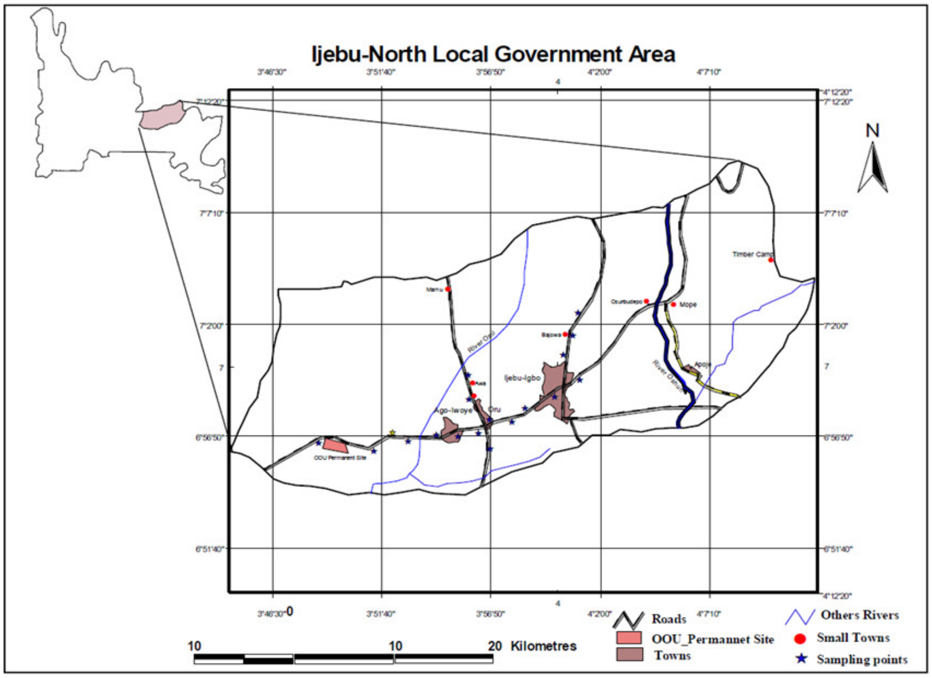

Fig:: 1 Map of Ijebu North Local Government Area in Ogun state showing sampling points

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