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Metal Inter-relationship and its Mobility in Samples Collected along Roadside Corridors of Kano Metropolis, Nigeria

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ABSTRACT

The aim of the study was to assess the impact of traffic volume on metal (Cd and Pb) concentration and to evaluate the mobility of the metals using sequential extraction. Particulate dust fall-out and roadside surface soil samples were collected from ten locations along major roads in the Kano metropolis, Nigeria in four seasons: Cool and dry, hot and dry, warm and wet and warm and dry. The samples collected were digested using standard methods and analysed using flame atomic absorption spectrophotometer. The results of metal inter-relation analysis on both samples revealed positive correlations for Cd and traffic volume and the metals for the studied seasons while positive correlation was found for Pb during warm and wet and warm and dry seasons. Positive correlation between the metals (Cd and Pb) and traffic confirmed the fact that automobiles are major source of the presence of these metals in the roadside environment. Also, the results showed that the concentrations in the mobile phase (water soluble, exchangeable and carbonate bound fractions) were generally high for Cd (29.49-92.7%) and Pb (26-76.4%) with the highest obtained during warm and wet and warm and dry seasons. This suggests potential toxicity to residential and food vendors adjacent to major roads in Kano metropolis. These could be direct or indirect pathways of metal in humans.

Key words: Particulate dust fallout, roadside soils, kano, metal inter-relationship, correlation and roadside environment

INTRODUCTION

Globally, roads have been identified as a source of social and economic development (Bai *et al*., 2008). According to Adefolalu (1980) and Mabogunje (1980), in developing countries like Nigeria, improved road accessibility creates variety of socio-economic activities which range from mobile shops, cafes, vehicle repairs, vulcanizers and dealers in other facilitators of motor transportation. These activities send metals into the air in particulate form and the metals subsequently are deposited into nearby soils which are absorbed by plants on soils (Okunola *et al*., 2008). Among the sources of metals in road environment, traffic emissions from vehicles, lorries and motorcycles have been identified to introduce a number of toxic metals into the atmosphere which are later deposited on roadsides (Ogunfowokan *et al*., 2004, 2009; Okunola *et al*., 2011a).

Kano metropolis may not be an exception to the foregoing heavy metal concentration problem especially with its steady progress of industrialization and increasing population and traffic density (Ministry of Information, Kano Satate, 2005). The routes of exposure to particulate dust and soil metals includes inhalation of contaminated particles, direct soil ingestion (usually by children) and

ingestion of food produced along the roads (Finzgar *et al*., 2007). Quantifying the exposure of these pathways requires information on the bioavailability and mobility of these metals regarding their availability levels and hence potential mobility to food and water sources, sequential extraction analysis remains a widely used procedure (Maiz *et al*., 2000; Onianwa, 2001), such that their chemical reactivity can be elucidated (Olajire *et al*., 2003; Okunola *et al*., 2011b).

Based on the information above earlier studies in Kano metropolis have reported impact of traffic density on the total metal content in different grain sizes of roadside soils (Okunola *et al*., 2011a). In furtherance of this study, this article is aimed at evaluating the relationship between Pb and Cd in roadside soils and particulate dust fallouts along major roads in Kano metropolis and also to evaluate the mobility of the metals in road environment. Pb and Cd were chosen among the previous metals (Cu, Cr, Cd, Ni, Pb and Zn) studied because of their known potential toxicity (Lee *et al*., 2005).

MATERIALS AND METHODS

The study area: Kano metropolis is located at the central western part of Kano State between latitude 11°59′59.57-12°02′39.57°N of the equator and between longitudes 8°33′19.69-8°31′59.69°E. It lies in the northern central boundary of Nigeria and is located 840 km away from the edge of the Sahara desert and 1,140 km from the Atlantic Ocean (Oseiki, 2009). Its metropolis population is the second largest in Nigeria after Lagos. The Kano urban area covers 137 square kilometres and comprises six Local Government Areas (LGAs)-Kano Municipal, Fagge, Dala, Gwale, Tarauni and Nassarawa.

Sample collection and pre-treatment: Sampling of roadside surface soils for this study was conducted from December 2009 to September 2010, i.e., across the four main seasons: December: Cold and dry; March: Hot and dry; June: Warm and wet; September; Warm and dry.

The criteria for selection of roads for the study were based on previous knowledge of the relative traffic density on each road and the intent to have each category of traffic density in different sections of the metropolis. Soil sample were collected from 10 roadside locations (1-10) 3 m from the roadway and a Control site (C) all over the metropolis as shown in Fig. 1. These sites were mainly located in residential and commercial areas. Control samples (only for soil) were obtained from a small garden within a residential buildup area of farm center which is not close to any secondary or main road. Average temperature across the seasons are; 31.5-36.6°C for Cool and Dry Season, 30.0-39.1°C for Hot and Dry Season, 30.5-33.9°C for Warm and Wet Season and 30.1-39.5°C for warm and dry season.

For the soil sampling, approximately 20 g of surface (0-5 cm) roadside soils were collected from five sites at a distance of 10 m from each side of the road within a given site with a stainless steel spoon, the samples were pooled together and homogenized to form a representative sample for a given road (Onianwa, 2001). Samples were placed in polythene bags and air-dried in the laboratory for 3 days. They were then passed through 150 μm mesh standard sieve (Rupson Industires 9238/6 Multani Dhanda, Pahargany New Delhi-110055).

Also, along the 10 roadside locations where soil samples were collected, atmospherically deposited particulate dust from window glass were sampled as an indirect method of air sampling according to Nabuloa (2004), Window glass was used as an inert collector of airborne contaminants because it has the ability to accumulate pollutants from the atmosphere. Glass windows were placed on the roof of houses by the roadside. Three houses were selected at each site for sampling. The

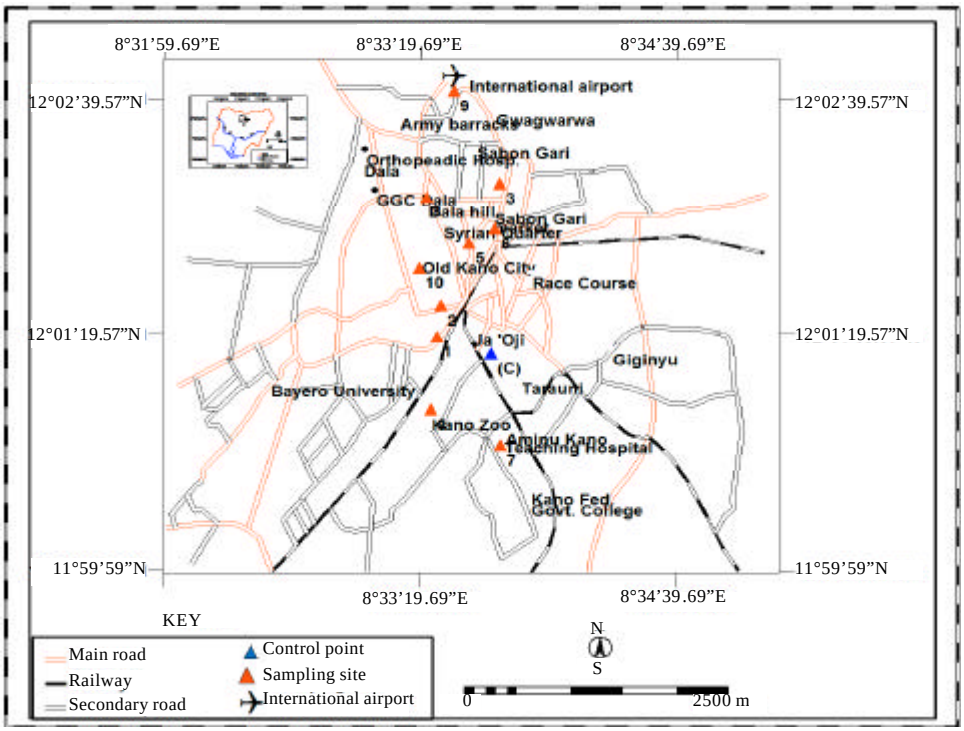

Fig. 1: Kano metropolis showing the sampling sites. Source: Adapted and modified from google map data, 2010

windows were first washed using a detergent and tap water then rinsed with distilled-deionized water. The windows were then left for 1 month without washing to accumulate pollutants and ensure that all windows had uniform exposure period. Sampling was done by cleaning the effective window area using a plastic brush into a dried plastic pan. Dust from each sites were made into composite representative samples and stored in a polythene bags prior before analysis.

Traffic density: Traffic density was determined by directly observing and counting the traffic during the usual peak traffic periods 8:00-10:00, 12:00-14:00 and 16:00-18:00 h each day for three days. The average number of motor vehicles at each site per hour was calculated as shown in Table 1.

Quality assurance: All glassware, polythene tubes and Teflon beakers used in the analyses were pre-cleaned by washing with liquid detergent, rinsed with water and distilled-deionized water and then soaked in 10% HNO_3 (Sigma-Aldrich, 70% (v/v)) for 24 h at a temperature of 80°C. All reagents used were of analytical grade and the instrument working calibrations were made by diluting the commercial stock solution of a metal (1000 ppm) standard (Scharlau, Kojima, Japan) with distilled-deionized water.

Quality assurance tests such as spiking experiments are usually conducted to ascertain the accuracy of the analytical procedure in absence of reference standard materials. The percentage recoveries and standard deviations obtained for the metals under investigations were as follows:

Table 1: Average traffic volume per hour on high traffic roads in kano metropolis

		Average traffic vol. hr^{-1}			
Sampling site code	Sampling site	Number of motorcycles	No. of vehicles	No. of trucks/lorries	Total
1	Aminu Kano	1902±12	2634±10	196±2	4732
2	Zoo	2011±20	1504±8	121±5	3636
3	Dan Agundi	1206±15	1935±12	216±2	2831
4	Kofar Nassarawa	1323±13	1801±19	46±2	3170
5	Rimi Market	3005±10	2008±14	25±2	5038
6	Sani Abacha	6857±23	1292±13	207±2	8357
7	Ibo Road	2464±19	1845±19	35±5	4344
8	Court/France	2651±18	1041±90	16±2	3708
9	Kofar Mazugal	1995±21	2836±12	149±2	4180
10	Zungeru/Airport	1443±11	2366±17	198±3	4007
C	Farm Center	Nil	Nil	Nil	Nil

Cd (90.4±0.5) and Pb (93.2±0.6). High percentage recoveries obtained in these samples validate the experimental protocol. The detection limits for metal analysis was 0.01 mg L^{-1} for Cd and Pb.

Determination of total metal concentration: Samples were digested for metal analysis using the method of Ogunfowokan *et al.* (2009). For each sample, 1 g was digested in a Teflon beaker with 30 mL aqua-regia ($HCl:HNO_3$, 3:1) on a hotplate thermostated to 150°C. After 2 h of digestion, the Teflon beaker with its content was brought down from the hot-plate, 5 mL HF was added and the sample was digested for another 30 min. The Teflon beaker was allowed to cool down to room temperature before the content was quantitatively transferred into a 50 mL volumetric flask and the volume was made up to the mark with distilled-deionized water. A blank determination was carried out using the procedure described above without the sample. The concentrations of Cd and Pb were determined using a flame atomic absorption spectrophotometer (FAAS, Shimadzu AA-6800).

Statistical data analyses were done using SPSS version 17 (SPSS Inc. Chicago, IL, USA).

Sequential extraction of heavy metals from dust and soils: Chemical fractionation of heavy metal was done on dust and soils using Finzgar *et al.* (2007) method. This method modified the conventional method developed by Tessier *et al.* (1979). The modified method determines fractionation of heavy metals into six geochemical fractions as follows:

FI (Fraction soluble in soil solution): One gram of air-dried sample was mix with 10 mL of deionized water with continuous agitation for 1 h, centrifuge and supernant decanted and made up to 50 mL with deionized water prior to analysis.

FII (Exchangeable fraction): The residue from FI was leached at room temperature with 10 mL of 1 M $MgNO_3$ at pH 7.0 with continuous agitation for 1 h, centrifuge and supernatant decanted and made up to 50 mL with deionized water prior to analysis. $MgNO_3$ displace ions electrostatically bound in the soil matrix.

FIII (Acid extractable-carbonate bound fraction): Residue from FII was leached at room temperature with 10 mL of 1M NaOAc (pH 5 adjust with HOAc) with continuous agitation for 5 h and centrifuge. The supernatant was decanted and made up to 50 mL with deionized water prior to analysis. NaOAc solubilises carbonates (calcites, dolomite) and releases entrapped metals.

FIV (Reducible-Fe-Mn oxides and hydroxide fraction): Residue from FIII was leached with 20 mL of 0.1 M $NH_2OH.HCl$ (pH adjusted with 25%v/v HOAc) at 96°C for 6 h with occasional agitation and centrifuge. The supernatant decanted and made up to 50 mL with deionized water prior to analysis. $NH_2OH.HCl$ reduces Fe and Mn oxides to soluble forms.

FV (Oxidizable-organic matter bound fraction): To the residue from FIV, 3 mL of 0.02 M HNO_3 and 30% v/v H_2O_2 was added. The mixture was heated to 85°C in a water bath for 3 h. After cooling, 5 mL of 1M NaOAc will then be use to extract with occasional agitation for 3 h at 85°C. Mixture was centrifuge and supernatant made up to 50 mL with deionized water prior to analysis. HNO_3 and H_2O_2 oxidize organic matter and solubilise sulphides. Oxidized organic matter releases complexed, adsorbed and chelated metals.

FVI (Residual and inert fraction): Residual from FV was digested with a mixture of 8 mL of 5:1 mixture of HF and $HClO_4$ in acid digestion Teflon cup. Then mixture was dried ashed for 2 h and evapourated to dryness. The residue was diluted to 50 mL with deionized water prior to analysis.

After successive extraction, the sample was centrifuge at 3000 rpm for 15 min. The supernatants was removed with pipette and filtered with Whatmann No 42 filter paper. The residue was washed with deionized water followed by vigorous hand-shaking and then follows 15 min of centrifugation before next extraction. The volume of rinse water use was left at minimum to avoid excessive solubilization of solid materials. The process was carried out in triplicate for a particular sample. Appropriate reagent blanks were prepared and analyzed for each extraction type. All extracts were analyzed for the metals (Pb and Cd) by atomic absorption spectrophotometry.

RESULTS AND DISCUSSION

Total metal concentration: The total contents of metals namely Cd and Pb in particulate dust and roadside soil samples of the various studied sites and control site are shown in Table 2. Analysis of mean difference of the sites across the seasons revealed significant difference ($p<0.05$). An indication of seasonal effect on concentration levels of Cd and Pb in both samples with lower concentrations in Warm and Wet Season. Also, from the results, the mean total concentrations of Cd and Pb in the particulate dust samples are much higher than those in soil samples with exceptions in Warm and Dry Season with higher concentration in soils compared to particulate dust samples. This likely reflects an anthropogenic source of these metals at these sites. Similar assertion was made by Mashal *et al.* (2009). Similarly, the concentrations of Cd and Pb in samples from studied sites were found to be high compared to control sites. This also supports the facts that activities on the roads and roadsides are potential sources of heavy metal deposition to the roadside environment (Yongming *et al.*, 2006).

Table 2: Concentration of metals (mg kg^{-1}) in dust and roadside soils from Kano metropolis

	Cd							
	Cool and dry		Hot and dry		Warm and wet		Warm and dry	
Location	Dust	Soil	Dust	Soil	Dust	Soil	Dust	Soil
1	4.80	3.7	9.40	4.80	12.0	2.9	2.7	3.2
2	5.70	4.5	10.8	5.50	13.5	3.6	3.3	3.5
3	2.80	2.1	5.20	2.80	7.00	1.6	1.5	2.0
4	10.8	8.9	20.3	10.6	24.8	7.1	7.5	6.7
5	10.4	7.8	18.8	10.5	25.1	6.4	6.8	7.5
6	8.90	7.2	15.3	8.80	19.5	6.0	6.4	5.7
7	6.60	5.3	11.8	6.40	14.9	4.4	5.3	4.07
8	13.9	11.0	26.0	13.9	32.9	9.1	8.8	9.2
9	8.70	6.6	15.2	8.50	20.7	5.3	5.5	5.9
10	12.8	9.8	19.7	12.8	25.8	8.1	8.6	9.0
C		0.20		0.2		0.9		1.5
	Pb							
1	133.7	93.4	90.3	133.4	127.5	76.2	61.5	98.7
2	167.4	121.4	135.2	166.9	182.7	94.9	80.8	122.4
3	189.0	143.2	151.2	188.0	196.2	112.9	95.1	130.0
4	129.1	176.7	218.5	233.5	291.1	141.6	121.7	166.5
5	188.8	896.1	1068.0	1174.2	1408.5	711.1	640.6	866.0
6	156.7	108.6	118.9	156.5	178.7	86.1	75.8	121.2
7	215.3	117.6	137.6	214.7	253.6	90.2	78.1	197.5
8	213.7	115.0	135.0	213.5	247.8	90.5	78.6	199.0
9	161.2	116.1	143.2	160.4	197.2	96.8	86.5	119.2
10	219.5	145.0	164.0	219.0	254.9	117.1	101.9	174.7
C		32.5		30.5		5.5		32.2

Values are mean of triplicate determinations of a sample mixed from three simultaneous soil collections at each site

However, the highest Cd concentration (32.9, 13.9 mg kg^{-1}) in the particulate dust and soil samples, respectively has been found at Site 8, a low elevation region and comparatively low traffic volume (3708 h^{-1}) compared to Site 6 (8357 h^{-1}). High Cd concentration in Site 8 can be closely related to the fact that, this road is flagged by electronic, stationary, paints dealers and other road ancillary work such as vulcanizers to synergize with effect of traffic jam. This is also supported with non-significant correlations between traffic and Cd concentrations except in cool and dry season were significant positive correlation was observed. Compare to literature studies, Aksoy (1996) found mean Cd concentrations for urban roadside soils and rural roadside soils as 2.44 and 1.04 mg kg^{-1}, respectively which is lower than higher concentration reported in this study.

Cd in this study especially at Site 8 is higher than Cd levels in Kavala's region, Greece-0.2 and 1.4 mg kg^{-1} in dust and soil sample, respectively (Christoforidis and Stamatis, 2009) and 1.7 mg kg^{-1} in dust (Al-Khashman, 2007) and 0.24-0.94 mg kg^{-1} in soils (Lagerwerff and Specht, 1970). However the range of Cd is within the range; 0.1-14.6 mg kg^{-1} reported in a similar study in Turkey (Tokalioglu *et al*., 2003). Existence of Cd in roadside soils could be derived from attrition of automobile tires (Akhter and Madany, 1993). Surface area could be an implication for high Cd concentration in this study, since particle size used for roadside soils are usually of 2 mm in related

studies. This could explain reasons for high concentration in this study compared to the literature. Pb is of most concern in environmental heavy metal pollution. Results on Pb contents in soils Kano Metropolis (study and control area) indicate the presence of Pb. The reason is that Pb is emitted from different sources such as glass, waste cans, paints, batteries, PVC-products and cables (Paola, 2005). Similar to other metals, Pb level is highest in sample from Site 5 (1068 and 1174.2 mg kg^{-1} in particulate dust and soil, respectively) during Hot and Dry Season. The main source of Pb contamination is traffic, usually the highest concentration of this metal is found close to roads with high traffic density (Shaikh *et al*., 2005; Saeedi *et al*., 2009). This is due to the fact that Pb is too heavy for being transported by the air. In the case of this study, the highest concentration was found in the samples from Site 5, as mentioned before not in the samples taken from Site 6, the road with the highest traffic density in Kano Metropolis. This can be explained by the fact that Site 5 is the last bus-stop for most intra-city buses or taxes, located along this road is local market specialized in plates and local foodstuff. As common feature along market roads, the traffic in this part of the city has always been quite intense coupled with the fact that automobile flow would be slower and hence, lengthier time is spent by automobile which subsequently leads to more emissions of particle especially from the exhaust compared to other roads. Since Pb is known to be use as antiknock in petrol (Jaradat and Momani, 1999), it is clear from the results that Pb in this Site is due to automobile emissions. This is also supported with strong positive correlation between traffic volume and Pb in soils. However, according to Christoforidis and Stamatis (2009) it is generally agreed that automobile exhaust emission accounted for the elevated Pb levels as all samples were collected at major roads. Also, other researchers in Nigeria (Onianwa, 2001; Awofolu, 2005; Okunola *et al*., 2007; Abechi *et al*., 2010) have reported that metal disposal and ancillary work such as metal working and motor repairs could have a stronger influence on the accumulation of the metal in roadside soils.

Inter-relationship between metals in roadside soil and particulate dust: Correlation coefficients between the levels of heavy metals in roadside soil and in particulate dust are presented in Table 3. Correlations between metals indicate whether there is any common source of pollution. From the Table 3, positive correlations were observed between $Cd_{particulate\ dust}$ Vs Cd_{soil} and traffic volume Vs Cd and Pb across the seasons while positive correlation was found between $Pb_{particulate\ dust}$ and Pb_{soil} in warm and wet and warm and dry seasons. The positive relationships between roadside soils and particulate dust indicate that contaminations by these metals originated from a common anthropogenic source, with automobiles as a major common source. Since particulate contaminants emitted from traffic mostly tend to disperse into nearby roadside soils (Saeedi *et al*., 2009).

Mobility of metal in particulate dust and roadside soils: Mobility of metals in soil may be assessed on the basis of absolute and relative content of fractions weakly bound to dust or soil components which may equilibrate with the aqueous phase and thus become more rapidly bioavailable (Pardo *et al*., 1993). Since some of the metal fractions (FIV-FVI) are strongly bound to the dust and soil components (relatively less mobile) than those extracted in FI, FII and FIII, hence, the relative index of metal mobility was calculated as a Mobility Factor (MF) according Yusuf (2007) and Kabala and Singh (2001) on the basis of the following equation:

$$MF = (FI + FII + FIII) \times 100 \Big/ (FI + FII + FIII + FIV + FV + FVI)$$

Table 3: Relationships between heavy metals in particulate dust and roadside soils

Parameters	Cd_{soil}	Pb_{soil}	Cd_P	Pb_P	Traffic
Cool and dry season Cd_{soil}	1.000				
Pb_{soil}	0.161	1.000			
Cd_P	0.990**	0.198	1.000		
Pb_P	0.178	1.000**	0.208	1.000	
Traffic	0.464*	0.935**	0.156	0.104	1.000
Hot and dry season					
Cd_{soil}	1.000				
Pb_{soil}	0.254	1.000			
Cd_P	0.993**	0.288	1.000		
Pb_P	0.359	0.229	0.323	1.000	
Traffic	0.359	0.905**	0.097	-0.177	1.000
Warm and wet season					
Cd_{soil}	1.000				
Pb_{soil}	0.169	1.000			
Cd_P	0.980**	0.217	1.000		
Pb_P	0.180	1.000**	0.238	1.000	
Traffic	0.420	0.922**	0.053	0.092	1.000
Warm and dry season					
Cd_{soil}	1.000				
Pb_{soil}	0.336	1.000			
Cd_P	0.984**	0.301	1.000		
Pb_P	0.274	0.999**	0.322	1.000	
Traffic	0.388	0.904**	0.054	0.097	1.000

Mp: air particulate dust metal ion. *Correlation is significant at the 0.05 level (2-tailed). **Correlation is significant at the 0.01 level (2-tailed)

The Fig. 2 and 3 show the percentage Mobility Factor (MF) of as evaluated for Cd and Pb per site for particulate dust and roadside soils across the four study seasons. Evidently from the Fig. 2 the dust and soil samples from Sites 4, 5, 6, 7 and 9 have the highest vulnerability to Cd with the highest MF 87.35 and 92.75% recorded during warm and wet season and warm and dry Season for soils and particulate dust, respectively. However, the MF of Cd in the soil and particulate dust samples across the seasons decreased in the following order, respectively:

Soils:

- Cool and dry season: 7>9>5>6>4>10>8>2>1>3
- Hot and dry season: 7>6>5>9>10>4>8>3>2>1
- Warm and wet season: 7>6>5>9>4>10>8>2>1>3
- Warm and dry season: 7>5>9>6>4>8>10>2>1>3

7>5>9>6>4>10>8>3>1>2

- Cool and dry season:
- Hot and dry season: 7>9>5>6>4>10>8>2>1>3
- Warm and wet season: 7>5>9>6>4>10>8>3>2>1
- Warm and dry season: 7>5>9>6>4>8>10>2>1>3

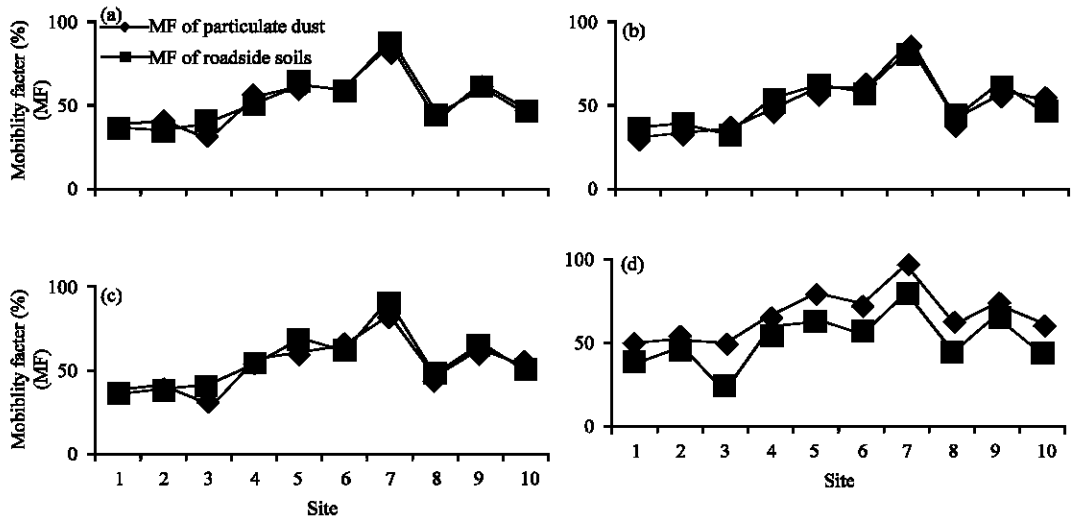

Fig. 2(a-d): Percentage mobility factor of Cd in particulate dust and roadside soil (a) cool and dry, (b) hot and dry, (c) warm and wet and (d) warm and dry season

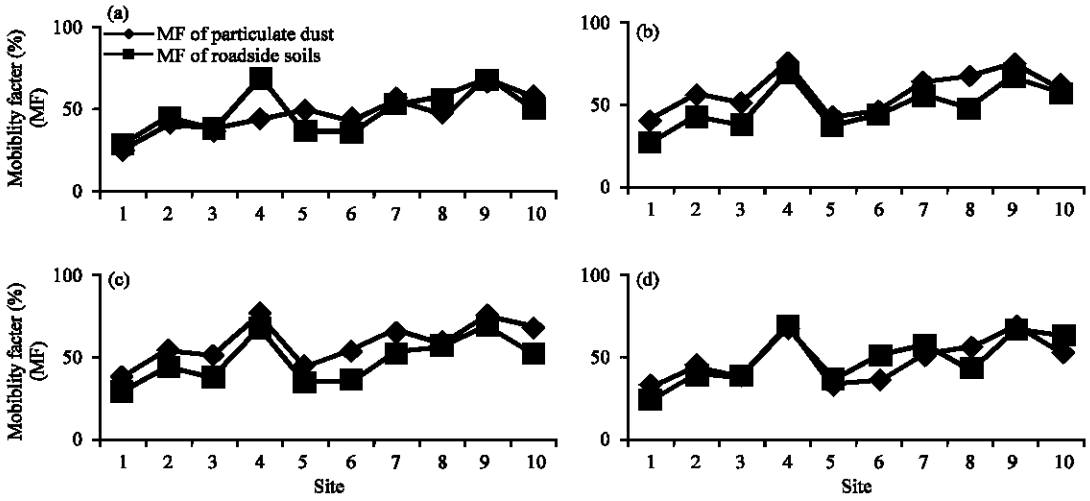

Fig. 3(a-d): Percentage mobility factor of Pb in particulate dust and roadside soil (a) cool and dry, (b)hot and dry, (c)warm and wet and (d) warm and dry season

The values of mobility factor (MF) for Pb (Fig. 3) revealed highest MF at Sites 4 and 9 for particulate dust and soils across the seasons. This implies that across the seasons, population living or working around Sites 4 and 9 showed highest vulnerability to Pb exposure compared to Site 1. Furthermore, MF value of Pb in samples of roadside soils and particulate dust across the seasons decreased in the following order, respectively:

Soils

Cool and dry season: 4>9>8>7>10>2>3>5>6>1

Hot and dry season: 4>9>10>7>8>6>2>3>5>1

Warm and wet season: 9>4>8>10>7>2>3>6>5>1
Warm and dry season: 4>9>10>7>6>8>2>3>5>1

Particulate dust:
Cool and dry season: 9>10>7>5>8>6>4>2>3>1
Hot and dry season: 4>9>8>7>10>2>3>6>5>1
Warm and wet season: 4>9>10>7>8>6>2>3>5>1
Warm and dry season: 9>4>8>10>7>2>3>6>5>1

From the trends above, it is confirmed that Site 7 for Cd and Site 4 and 9 for Pb have the highest MF across the seasons. This is an indication that the level of water soluble, exchangeable and carbonate bound fractions Cd and Pb in this study is relatively high, though less than 1 (minimum threshold for MF) compared to other sites. Also as evident from the trends, Site 1 and 3 (Cd) and Site 1 (Pb) have the least MF value across the seasons, the low value could be an index of high stability of these metals in the samples (Ogunfowokan *et al*., 2009). Also, apart from reflecting levels of water soluble, exchangeable and carbonate bound of these metals, high MF values, an indication of lability and biological availability of heavy metals (Ahumada *et al*., 1999; Kabala and Singh (2001) and Yusuf (2007), showed the extent of the vulnerability of living things generally to heavy metals (Ogunfowokan *et al*., 2009). Similarly, as observed in the Fig. 2. Cd was generally at the highest in Warm and Wet and Warm and Dry Season for roadside soils and particulate dust in Sample 7, respectively while Pb was generally at its highest in both samples in Warm and Dry Season. This indicates that during the aforementioned seasons there was an increased mobility of these metals, representing the highest potential risk for the surrounding environment. Generall,y the mobility factors in all the study seasons were less than 100 (<1), indicating low pollution due to the metal. Hence, from this study, the inhabitants of Sites 4, 5, 6, 7, 8, 9 and 10 have the highest vulnerability to Cd and Pb exposure while those living around sites 1, 2 and 3 have low vulnerability compared to others.

CONCLUSION

Generally, the results of the present study, confirmed the contamination of the particulate dust fallout and roadside soils of Kano Metropolis by Cd and Pb with automobile emissions as possible sources of these metals in the samples as shown in inter-relation between the metals and traffic volume. The mobility of these metals as depicted by sequential extraction showed that majority of the samples used for the study have Cd and Pb in the mobile phases. Also, the amount of Cd determined as sum of water soluble, exchangeable and carbonate fractions was often more than 50% of the total in Sites 4, 5, 6, 7 and 9 with few less than 50%. Similar trends were observed for Pb at Sites 4, 7, 9 and 10. This represents the potential mobility of Cd and Pb to the immediate environment at these sites. Therefore, Cd and Pb represent the highest potential risk for the surrounding environment.

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