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Contamination of heavy metals in road dust at Northern Highway in Abidjan, Côte d'Ivoire

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--**ABSTRACT**--
The objective of this study was to investigate the concentration offour heavy metal elements (Cd, Cu, Pb and Zn) in road dust at the Northern Highway in Abidjan. The concentrations of the heavy metals weredetermined using atomic absorption spectrometer.The results show that the average concentrations of Cu, Zn, Pb and Cd in the dust samples are 409.34, 125.42, 452.84 and 2.2 mg/kg, respectively were higher than their value in the continental crust data.Contaminationlevels were evaluated using contamination factor and the enrichment factor.Results showed that the dust contained significantly elevated heavy metal elements concentrations compared with the background soil.

Keywords -*Heavy Metals, Road dusts, contamination assessment, Abidjan, Côte d'Ivoire*

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I. INTRODUCTION

Road dust is comprised of solid particles which accumulate on impervious, hard road surfaces, such as cement and sidewalks in urban areas (Liu et al., 2014). It was observed that the particles and associated metals, particularly with fine dust, remain suspended in air longer under certain meteorological conditions. Road dust, an important environmental indicator of metal contamination from atmospheric deposition, receives varying inputs of anthropogenic metals from various stationary and mobile sources such as vehicular traffic, industrial activities, power plants, residential fossil fuel burning, waste incineration, construction and demolition activities, and resuspension of contaminated soil (Bilos et al., 2001; Charlesworth et al., 2003; Bhanarkar et al., 2005, 2008; Gupta et al., 2012). Long-term exposure to the polluted dust environment would cause chronic damage through ways of inhalation, ingestion, anddermal contact. Heavy metals are dangerous because they tend to be bioaccumulated, meaning that over a long time the concentrations of heavy metal within a biological organism can be higher than that in the environment.Chronic problems associated with long-term heavy metal exposures are metal lapse caused by Pb exposure; Cd has effects on the kidney, liver and gastrointestinal tract (LuX etal, 2010). Metals can accumulate in fatty tissues,affecting the functions of organs and disrupting the nervous system or the endocrinal system (Waisberg et al., 2003; Duzgoren-Aydin, 2007) and some metals could cause mutagenic, teratogenic and carcinogenic effects in living beings (Lienesch et al., 2000; Cook et al., 2005).Many studies have been performed on heavy metal contamination of soil around the world (Odewande A A, et al, 2008). At the same time, more and more studies have focused on the concentration; distribution and source identification of heavy metals in roadside dusts (Yongming Han et al, 2006; Pekey H et al. 2004; Sezgin N et al., 2007).However, there are little studies about heavy metals of dusts in road dusts, especially for Abidjan.

The objectives of this study were to 1) investigate the mass concentration of four heavy metals (Pb, Cu, Zn and Cd)collected at the Northern Highway and 2) evaluate the contamination levels of these metals using contamination factor (CF) and enrichment factor (EF).

II.MATERIALS AND METHODS

2.1 Site description

Abidjan, the capital city, is situated in the southeast of Côte d'Ivoire (5° 20' 11" north, 4° 01' 36" west).The study area chosen for the road dust sampling were the Northern Highway (Figure 1). These sampling sites wereselected based purely on traffic density. The site has an average traffic density of 5000 vehicles/day. Thevehicles use either gasoline or diesel fuel. A large number of people frequenting these sites daily are subjected tothe dusty environment created by vehicular emissions. Abidjan has a tropical climate with the rainy season fromMay to October; and a long dry season, with virtually no rainfall, from October to April. Temperatures rangebetween a maximum of 45 degrees in March / April and a minimum of 12°C in December.

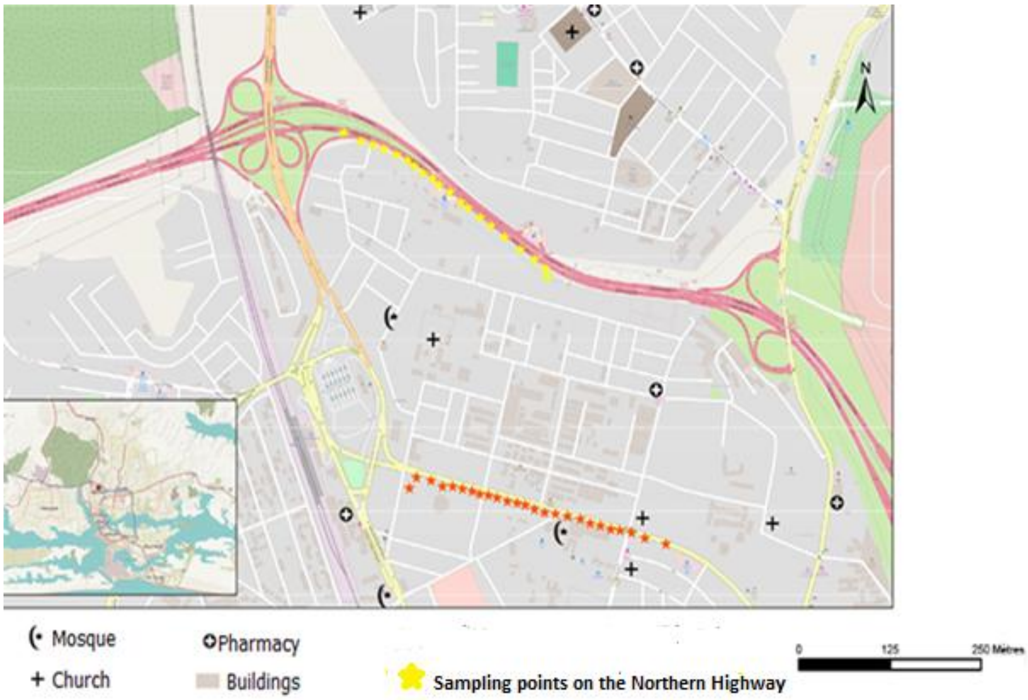

Figure 1: Study area (Northern Highway)

2.2 Sample collection

Samples were collected during the dry season from each selected location at 6 days intervals fromDecember 2014 to February 2015. At each sampling site, about 500 g of road dust composite sample wascollected by sweeping using a soft touch brush and plastic dust pan from points of road pavement. A minimumof 19 samples were collected from each site for the period of sampling. In order to avoid cross contamination, Different brushes and dust pans were used for each sampling day.Sampling was not done on rainy days. The samples were collected between 16.30 am and 18.30 am oneach sampling day because of heavy traffic. All the samples collected were stored in self sealed polyethylenebags, carefully labelled and transported to the laboratories of the National Nuclear Research Institute of theGhana Atomic Energy Commission for elemental analysis.

2.3 Sample processing

Samples collected from each spot (on each sampling day) were homogenously mixed to form acomposite sample and carefully air-dried in the laboratory for 1 week. The samples were sieved using a mesh(metric sieve test Bs 410, WS Tyler) with a geometric diameter of 250 µm and 112 µm. As a measure ofavoiding cross contamination, the sieves were cleaned with acetone between samples. The size fraction between250 µm and 112 µm was labelled as +112 µm and those less than 112 µm were labelled as "-112 µm". Theanalyses were restricted to the size fractions below 112 µm because particles of such sizes are easilyresuspended. The samples were then pulverized for 15 minutes into fine powder using the Fritsch Pulverisette-2to ensure homogeneity and also to avoid particle size effect. 1.5 g of the sample was weighed into a 100 mLpolytetraflouroethylene PTEF Teflon bombs. Aqua regia solution (1HCl: $2HNO_3$) was added followed by 0.25mL of H_2O_2. The samples were digested for 21 min using a milestone microwave labstation (Ethos 900). Afterthe digestion, the resulting solution was made up to 20 mL with double distilled H_2O. The concentration of trace metals (Pb, Cd, Zn and Cu) in the filtrate was determined using Varian AA240FS AtomicAbsorption Spectrophotometer in an acetylene-air flame (Ozaki et al., 2004). The quality controls for the strongacid digestion method included reagent blanks, duplicate samples, and standard reference materials. TheStandard Reference Material (SRM) IAEA Soil 7 was used for the validation to verify the accuracy of theresults.

2.4 Contamination assessment methodology

2.4.1 Enrichment factor:

The enrichment factor (EF) is aconvenient measure of geochemical trends; it is usedfor making comparisons in metal contaminationbetween different soil locations (Sinx and Helz, 1981).Enrichment factor can be used to differentiate betweenmetals originating from human activities and those ofnatural sources, and also to assess the degree ofanthropogenic influence. The following equation can beused to determine enrichment factors of metals in soilsamples.

$$EF_X = \lfloor C_S / C_{S(ref)} \rfloor / \lfloor B_C / B_{C(ref)} \rfloor \qquad (1)$$

Where EF_X is the enrichment factor for the element X;
C_S is the concentration of element of interest in the sample; $C_{S(ref)}$ is the concentration of the referenceelement used for normalization in the sample; B_C is theconcentration of the element in the crust; $B_{C(REF)}$ is theconcentration of the reference element in the crustwhich is used for normalization.A reference element is a conservative element;commonly used reference elements include aluminum(Al), silicon (Si), iron (Fe), manganese (Mn), scandium(SC), titanium (Ti), etc. (Manoli et. al., 2002; Yongming et. al., 2006). In this study, Silicon was usedas a reference element with reference elementalconcentrations taken from the chemical composition ofthe average continental crust data (Taylor andMcLennan, 1985). Five categories of contaminationsare recognized on the basis of the enrichment factor: EF<2 shows 'deficiency', EF = 2-5 indicates 'moderateenrichment', EF = 5-20 indicates 'significantenrichment', EF = 20-40 indicates 'very high enrichment' and EF > 40 indicates 'extremely highenrichment' (Bai et. al., 2008).

2.4.2 Contamination factor

To assess the extent of contamination of heavy metalsin road dust and also provide a measure of the degree ofoverall contamination at a particular sampling site,contamination factor and pollution load index havebeen applied. The contamination factor (CF) parameteris expressed as:

$$CF = C_{metal} / C_{background} \quad (2)$$

Where CF is the contamination factor, C_{metal} is theconcentration of pollutant in sediment $C_{background}$ is thebackground value for the metal. The geochemicalbackground values in continental crust averages of thetrace metals under consideration reported by Taylor andMcLennan was used as background values for the metal(Taylor and McLennan, 1985). Contamination FactorCF < 1 refers to 'low contamination'; 1≤ CF < 3 means'moderate contamination'; 3 ≤ CF ≤6 indicates'considerable contamination' and CF > 6 indicates'very high contamination'.

III.RESULT AND DISCUSSION

3.1 Heavy metals contents in road dust

The results of the heavy metal concentrations investigated in the samples are presented in Table 1. The background value of the metals is the average continental crust data (H. J. M. Bowen et al, 1979; S. R. Taylor et al, 1985) are also shown in Table 1.The concentration of Cu, Zn, Pb and Cd in road dust ranged from 105.50 to 516.50, 58.50 to 440.00, 144.00 to 475.50 and 1.5 to 5 mg/kg, with means of 409.34, 125.42, 452.84 and 2.0 mg/kg, respectively.The mean metal concentration values are arranged in the following order: Pb> Cu>Zn>Cd for the Northern Highway.The results showshigh concentrations of heavy metals in road dust compare to their background value at the northern highway indicating the pollution from the anthropogenic activities.This road is characterized by both light and heavy-duty vehicular traffic during morning and evening rush hours. Pb comes mainly from automobile exhaust and vehicle emissions, for example tire wear, bearing wear, wear of brake linings (Paggio et. al., 2009). Cu is a common element in automobile thrust bearing, brake lining and other parts of the engine. Cu replaced asbestos and has been used as a friction brake material since the 1930's (Hopke et. al., 1980). Zn mean concentration was also obtained at Northern Highway site (125.42 mg/kg). The presence of this amount of Zn in the samples may be explained by the fact that Zn compounds are used extensively as anti-oxidants and as detergent/depressants improving agents for motor oil. The use of old and weak engines with low combustion efficiency could contribute significantly to Zn in the road dust. Vehicle brake linings and tyre wear have been identified as possible sources of Zn (Bai et. al., 2008).

Table 1: Heavy metal concentrations (mg/kg) in road dust at Northern Highway and the background values for comparison

Element	NorthernHighway				Background Value
	Min	Mean	Max	SD	
Cu	105.50	409.34	516.50	141.50	55
Zn	58.50	125.42	440.00	100.76	70
Pb	144.00	452.84	4757.50	1043.35	12.5
Cd	1.5	2.2	5	1.25	0.2

3.2 Contamination assessment results

Contamination factor (CF): The Contamination Factor values for the sampling site are shown in Table 2. Moderate contamination was obtained for Zn, a considerable contamination for Cd, while Cu and Pb values were higher than 6 signifying very high contamination.

Table 2: Results of contamination factor (CF) for the sampling site

Contamination Factor (NorthernHighway)	
Elements	Value
Cu	7.44
Zn	1.79
Pb	36.23
Cd	5.8

Enrichment Factor (EF):

The Enrichment factor values obtained for the metals measured at the Northern Highway dust are presented in table 3. Silicon was used as a reference element because there is no indication of any human activity that can produce silicon in and around the sampling sites.

The results show that the mean EFs were in the following order: Pb > Cd> Cu> Zn. An increase in EF values indicates an increase in the contributions from anthropogenic origins (Surthland et. al., 2000). Zn generally showed moderate enrichment at the sampling sites. Cu and Cd were significantly enriched at Northern Highway. The mean EF value of Pb showed extremely high enrichment at Northern Highway, indicating anthropogenic influx, which is largely coming from vehicular activities. In general, Northern Highway showed relatively higher EFs. This could be expected as speeding and breaking on the highways can cause break and tyre to wear at higher rates. The elements Cu, Zn, Pb and Cd are present in break, tyre and exhaust emissions.

Table 3: Results of the Enrichment Factor

Enrichment factor	
Element	NorthernHighway
Cu	8.77
Zn	2.12
Pb	43.74
Cd	12,98

NB: Silicon used as reference element

IV. CONCLUSION

The heavy metal concentrations and human health risk due to exposure to road dust at the Northern Highway in Abidjan was investigated in this present study. Contamination indexes and enrichment factor (EF) were used in the assessment of level of metal contamination in the study area.

The average concentration of Cu, Zn, Pb and Cd were compared with the background value of the average continental crust data. The results showed that these metals concentrations were higher than their background values indicating that the pollution may come from anthropogenic sources.

The sampling site considered in this study were found to be moderately contaminated with respect to Zn, and highly contaminated in Pb and Cu.

The EFof heavy metals obtained in this work ranked as follows: Pb > Cu> Ni> Zn. These EFs indicated that there was considerable Pb and Cu pollution, which mainly originate from vehicular traffic.

The observed levels call for more attention to befocused on heavy metal contamination in road dust inAbidjan. With the rapid population growth, an expectedincreased vehicular fleet in Abidjan could aggravate thesituation. There is therefore the need for the necessarymitigation methods to be applied

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CONFLICT OF INTEREST

The author(s) have not declared any conflict of interests.

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