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Health risk assessment of heavy metals in road dusts at Attinguie tollbooth in Abidjan, Côte d'ivoire

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--***ABSTRACT***--
The study of anthropogenic contamination by heavy metals in road traffic is very necessary for planning and also for environmental monitoring in urban areas. In this study, 19 road dust samples were collected at Attinguie tollbooth in Abidjan. The concentrations of metals Cu, Zn, Pb, Cd, Cr and Ni were determined using atomic absorption spectrometer. The human health risks associated with exposure to the road dust were assessed. The results show that the average concentrations of Cu, Zn, Pb, Cd, Cr and Ni in the dust samples were 432.58, 85.39, 191.71, 3.10, 105.82 and 151.24 mg/kg, respectively which are higher than their corresponding average value in the crust. The assessment of health risk indicated that there were mainly three exposure pathways for people which are: ingestion, inhalation and dermal contact. The main exposure pathway of heavy metals to both children and adults is ingestion. The values of HQ and HI are lower than the safe level (=1), indicating no significant health risk.

KEYWORDS *- Road dusts, Human Health Risk assessment, Hazard Index, Heavy Metals, Abidjan*

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I. INTRODUCTION

Dust is the most pervasive and important factor affecting human health and well-being (Yongming et al., 2006). Of the contaminants in the urban area, heavy metals have caused serious concern of both researchers and governments for their characteristics of accumulation and degradation-resistant (Bi et al., 2006; Christoforidis and Stamatis, 2009; Wei and Yang, 2010). Heavy metals may come from many different sources in urbanized areas, including vehicle emissions, industrial discharges and other activities (Harrison et al., 1981).

Road dust can be generated from the following processes: exhaust emissions, tyre wear, break wear, clutch wear, road surface wear, corrosion of vehicle components and corrosion of street furniture, signs, crash barriers and fencing (O.A.Al-Khashman, 2004). The use of leaded gasoline is primarily responsible for the Pb exposure (Chen et. al., 2005), while tyre wear and corrosion of roadside safety fences contribute to Zn pollution (Blok, 2005). Cu is mainly released from the wear of brake linings, which is also an important source of Pb and Zn. The source of Ni and Cr in street dust is believed to be due to corrosion of vehicular parts (Read et. al., 2009).Components and quantity of road dust are environmental pollution indicators (Yongming et al., 2006). All these metals are deposited in the form of dust and can form aerosols when re-suspended (Han et. al., 2007).

Moreover, heavy metal elements in road dust are known to easily enter the human body through ingestion, inhalation, and dermal contact. Elderly people whose immune system is compromised by age; Children through the unintentional ingestion of large amounts of dust from their mouths and whose immune systems are underdeveloped are the most vulnerable to toxicity (Rasmussen, Subramanian and Jessiman, 2001).

The adverse effects on human health from exposure to heavy metal elements have been well-documented (Sun et al., 2010). Study shows that lead toxicity is associated with deficits in central nervous system functioning that can persist into young adulthood. Hair lead and cadmium are correlated with both reduced intelligence scores and lowered school achievement scores (Oskarson, Hallen, & Sundberg, 1995). The toxicity of Cu, Cd, and Zn is acknowledged, these elements can change the function of the human central nervous system and respiratory system, and disrupt the endocrine system. A thorough determination of the risks to human health, heavy metals contained in the dust of the road proves necessary. The conceptual process of contact, then input and absorption, can be used to calculate the exposure and dose equations for all exposure pathways.

Abidjan, the capital city of Cote d'Ivoire, has experienced rapid growth in population and urbanization over the last few decades. Between the years 2002 and 2016 huge numbers of vehicles were registered in

Abidjan. Majority of these vehicles are second-hand and are still in circulation. The rapid growth of industry, population and vehicles exert a heavy pressure on its environmental resources.

The purposes of this research are to investigate concentration of six heavy metals (Cr, Ni, Cu, Zn, Cd and Pb) in road dust in Abidjan and to assess the non-cancer health risk of these six heavy metals.

II. METHODOLOGY

2.1. Study area

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 Attinguie Tollbooth. These sampling sites were selected based purely on traffic density. The site have an average traffic density of 5000 vehicles/day. The vehicles use either gasoline or diesel fuel. A large number of people frequenting these sites daily are subjected to the dusty environment created by vehicular emissions. Abidjan has a tropical climate with the rainy season from May to October; and a long dry season, with virtually no rainfall, from October to April. Temperatures range between a maximum of 45 degrees in March / April and a minimum of 12°C in December.

2.2. Sample collection

Samples were collected during the dry season from each selected location at 6 days intervals from December 2014 to February 2015. At each sampling site, about 500 g of road dust composite sample was collected by sweeping using a soft touch brush and plastic dust pan from points of road pavement. A minimum of 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 on each sampling day because of heavy traffic. All the samples collected were stored in self sealed polyethylene bags, carefully labelled and transported to the laboratories of the National Nuclear Research Institute of the Ghana Atomic Energy Commission for elemental analysis.

2.3. Sample preparation and analysis

Samples collected from each spot (on each sampling day) were homogenously mixed to form a composite 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 of avoiding cross contamination, the sieves were cleaned with acetone between samples. The size fraction between 250 µm and 112 µm was labelled as +112 µm and those less than 112 µm were labelled as "-112 µm". The analyses were restricted to the size fractions below 112 µm because particles of such sizes are easily resuspended. The samples were then pulverized for 15 minutes into fine powder using the Fritsch Pulverisette-2 to ensure homogeneity and also to avoid particle size effect. 1.5 g of the sample was weighed into a 100 mL polytetraflouroethylene PTEF Teflon bombs. Aqua regia solution (1HCl: 2HNO3) was added followed by 0.25 mL of H2O2. The samples were digested for 21 min using a milestone microwave labstation (Ethos 900). After the digestion, the resulting solution was made up to 20 mL with double distilled H2O. The concentrations of trace metals (Pb, Cr, Cd, Ni, Zn and Cu) in the filtrate was determined using Varian AA240FS Atomic Absorption Spectrophotometer in an acetylene-air flame (Ozaki et al., 2004). The quality controls for the strong acid digestion method included reagent blanks, duplicate samples, and standard reference materials. The Standard Reference Material (SRM) IAEA Soil 7 was used for the validation to verify the accuracy of the results.

III. RESULT AND DISCUSSION

3.1. Heavy metal concentration (mg/kg) in road dust from the selected site

Analytical results of the concentrations of Cu, Zn, Pb, Cd, Cr and Ni in the roadside dusts are summarized in Table 1. The background values 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, Cd, Cr, and Ni in road dust ranged from 143 to 1030, 59 to 114.50, 101 to 312.50, 1.50 to 4, 88 to 161, and 125 to 191.50 mg/kg, with means of 432.58, 85.39, 191.71, 3.10, 105.82 and 151.24 mg/kg, respectively. The concentrations of 6 metals varied widely in this selected site and followed the order of Cu>>Pb>Ni>Cr>Zn>Cd.

The concentrations of these heavy metals was compared with the background value of the average continental crust data. The results showed that the mean Cu, Zn, Pb, Cd, Cr, Cd and Ni concentrations in road dust at the Attinguie tollbooth were higher than background values, indicating pollution of anthropogenic activities.

Cu copper which has high average concentration would come from tire abrasion, corrosion of metal parts of cars, lubricants, industrial emissions and incinerators (O.A.AL-Khashman et al, 2004). The toxicity for humans is not very high (Poggio et al, 2009), it normally accumulate in the surface horizon a phenomenon explained by bioaccumulation of metals and recent anthropogenic activities.

Pb and Ni also had high average concentrations compared to their background concentration. (Pb) comes mainly from automobile exhaust and vehicle emissions, such as tire wear, bearing wear, and brake lining wear (O.A.AL-Khashman et al, 2004) while the Ni in roadside dust would be due to corrosion of vehicle parts (Lu et al, 2009). The rate of high corrosion and wear from old vehicle (as a result of high patronage in imported used cars) plying the roads could have accounted to the significant levels of anthropogenic contributions of Ni in roadside dust.

The mean heavy metal content was compared to the data collected from other cities reported in previous studies (Table 2). These results indicated that the road dust at Attinguie tollbooth in Abidjan contains considerably higher concentrations of Cu and Ni compared with other cities. On the other hand, the concentration of zinc was lower compared to those of other industrial and developed cities.

The mean concentration of Cr in road dusts sampled in Abidjan (this work) was similar to that sampled in Dhaka, higher than those sampled in Luanda, Benha-cairo, Calcutta and Madrid, and lower than those sampled in Shanghai, Accra and Delhi.

The concentration of Cd was close to that measured in Calcutta and higher than those measured in other cities. Even considering the geographical differences, the Pb concentration at Attinguie tollbooth in Abidjan was much higher than other cities, except Shanghai, Luanda, Benha-cairo, Calcutta, Madrid and Kuala Lumpur.

In general, each city has its own characteristics combination of elemental compositions, and the observed similarities as well as variations may not reflect actual natural and anthropogenic diversities among the different urban settings. Therefore, there is an immediate need to establish a standard procedure to represent and analyze urban samples (Duzgoren-Aydin, 2006).

Table 1: Heavy metal concentration of road dust at Attinguie Tollbooth in Abidjan (mg/kg)

Element	Attinguie Tollbooth				Background
	Min	Mean	Max	SD	
Cu	143.00	432.58	1030.00	245.07	55
Zn	59.00	85.39	114.50	19.06	70
Pb	101.00	191.71	312.50	50.44	12.5
Cd	1.50	3.10	4.00	1.24	0.2
Cr	88.00	105.82	161.00	25.01	100
Ni	125.00	151.24	191.50	21.23	75

Table 2: Comparison of heavy metal concentration (mg/kg) in Road dust from some popular cities of the world with data from our study (Abidjan)

City	Cd	Cr	Cu	Ni	Pb	Zn	Size (µm)	Référence
Shanghai	1.23	159.3	196.8	83.9	294.9	733.8	< 125	Shi et al.,2008
Luanda	1.15	26	41.78	10	351.3	316.6	< 100	Aghui et al,1984
Benha-cairo	0.61	39	69	18.6	218.1	309.6	100-250	Hubert P,2003
Accra		166	70.7		112	327	100-250	Hamamci et al.,1997
Calcutta	3.12	54	44	42	536	159	< 600	Chatterjee et al.,1999
Madrid		61	188	44	1927	467	< 100	(De Miguel et al.,1997)
Dhaka		104	46	26	74	154	< 1000	Ahmed and Ishiga (2006)
Kuala Lumpur	2.9		35.5		2466	344	< 63	Ramlan and Badri (1989)
Delhi	2.65	148.8	191.7	36.4	120.7	284.5	< 75	P.V. suryawanshi et al.,1989
ATTINGUIE Tollbooth	3.1	105.8	432.6	151.2	191.7	85.4	< 112	Our study

3.2. Health risk assessment

3.2.1. Exposure dose

In this study, the risk assessment model developed by the Environmental Protection Agency of the United States (US EPA) was used to evaluate the health risks posed by heavy metals in road dust. The average daily dose (ADD) (mg/kg/day) of a pollutant via ingestion, dermal contact and inhalation as exposure pathways can be estimated using Equations (1), (2) and (3) (US Environmental Protection Agency, 1997):

$$ADD_{inh} = (C \times R_{inh} \times EF \times ED)/ (PEF \times BW \times AT) \quad (1)$$

$$ADD_{ing} = (C \times R_{ing} \times EF \times ED \times CF)/ (BW \times AT) \quad (2)$$

$$ADD_{derm} = (C \times SL \times SA \times ABS \times EF \times ED \times CF) / (BW \times AT) \quad (3)$$

Where, ADD_{ing} is daily exposure amount of metals through ingestion (mg/kg/day); ADD_{inh} is daily exposure amount of metals through inhalation (mg/kg/day); ADD_{derm} is daily exposure amount of metals through inhalation (mg/kg/day).The exposure factor for these models are shown in table 3, RfD values of all investigated metals (Junhua Ma et al., 2012; Yiran Du et al., 2013) are presented in table 5.

Table 3 : Exposure factors for dose models

Factor	Definition	Unit	Value		Reference
			Children	Adult	
C	concentration of the contaminant in dusts	mg/kg			This study
R_{ing}	ingestion rate	mg/day	200	100	US EPA.2001a
R_{inh}	inhalation rate	m^3/day	10	20	Van den Berg, 1995
EF	exposure frequency	days/year	250	250	Ferreira-Baptista, L., De Miguel E. 2005
ED	exposure duration	years	6	25	US EPA.2001
BW	average body weight	kg	15	70	US EPA.1989
AT	average time	days	365×ED	365×ED	US EPA.1989
CF	conversion factor	kg/mg	1×10^{-6}	1×10^{-6}	
PEF	particle emission factor	m^3/kg	1.32×10^{9}	1.32×10^{9}	US EPA.2001
SA	surface area of the skin that contacts the dust	cm^2	2800	3800	US EPA.2001
SL	skin adherence factor for dust	mg/(cm^2h)	0.2	0.2	US EPA.2001
ABS	dermal absorption factor (chemical specific)		0.001	0.001	US EPA.2001

Table 4 : Daily dose in three models

		Concentration (mg/kg)	ADD_{ing}(mg/kg/day)		ADD_{inh}(mg/kg/day)		ADD_{derm}(mg/kg/day)	
			children	adult	children	adult	children	adult
Cu	Min	143.00	1.31E-03	1.40E-04	4.96E-08	2.13E-08	3.66E-06	1.06E-06
	Mean	432.58	3.95E-03	4.23E-04	1.50E-07	6.43E-08	1.11E-05	3.22E-06
	Max	1030.0	9.41E-03	1.01E-03	3.57E-07	1.53E-07	2.63E-05	7.66E-06
Zn	Min	59.00	5.39E-04	5.77E-05	2.05E-08	8.77E-09	1.51E-06	4.39E-07
	Mean	85.39	7.80E-04	8.36E-05	2.96E-08	1.27E-08	2.18E-06	6.35E-07
	Max	114.50	1.05E-03	1.12E-04	3.97E-08	1.70E-08	2.93E-06	8.51E-07
Pb	Min	101.00	9.22E-04	9.88E-05	3.50E-08	1.50E-08	2.58E-06	7.51E-07
	Mean	191.71	1.75E-03	1.88E-04	6.65E-08	2.85E-08	4.90E-06	1.43E-06
	Max	312.50	2.85E-03	3.06E-04	1.08E-07	4.65E-08	7.99E-06	2.32E-06
Cd	Min	1.50	1.37E-05	1.47E-06	5.20E-10	2.23E-10	3.84E-08	1.12E-08
	Mean	3.10	2.83E-05	3.03E-06	1.08E-09	4.61E-10	7.93E-08	2.31E-08
	Max	4.00	3.65E-05	3.91E-06	1.39E-09	5.95E-10	1.02E-07	2.97E-08
Cr	Min	88.00	8.04E-04	8.61E-05	3.05E-08	1.31E-08	2.25E-06	6.54E-07
	Mean	105.82	9.66E-04	1.04E-04	3.67E-08	1.57E-08	2.71E-06	7.87E-07
	Max	161.00	1.47E-03	1.58E-04	5.59E-08	2.39E-08	4.12E-06	1.20E-06
Ni	Min	125.00	1.14E-03	1.22E-04	4.34E-08	1.86E-08	3.20E-06	9.30E-07
	Mean	151.24	1.38E-03	1.48E-04	5.25E-08	2.25E-08	3.87E-06	1.12E-06
	Max	191.50	1.75E-03	1.87E-04	6.64E-08	2.85E-08	4.90E-06	1.42E-06

3.2.2. Health risk assessment

For non-carcinogens the doses (ADD) calculated for each element and exposure pathway are subsequently divided by the corresponding reference dose (RfD) to yield a hazard quotient (HQ).

$HQ = ADD/RfD$ (4)

Where RfD is the corresponding reference dose.

An HQ ≤1 indicates no adverse health effects and HQ> 1 indicates that adverse health effects are likely to occur ((US Environmental Protection Agency, 1986) The hazard index (HI) is equal to the sum of HQs and is used to represent the total potential non-carcinogenic risks of different pollutants via three exposure routes described previously.

$HI = \Sigma HQi$ (5)

An HI<1 indicates that there is no significant risk of non-carcinogenic effects. If HI>1, then a noncarcinogenic effect is likely to exist (US Environmental Protection Agency, 2001).

In this study, hazard quotient and hazard index have been used to assess human health risk of metal exposure to road dust.

3.2.3. Health risk assessment in road dusts

The industrial exposure scenario for adults was used in this work. The child scenario was considered to ascertain the possible health effect on children exposed to similar conditions. The HQ and HI for Cu, Zn, Pb, Cd, Cr and Ni in road dust samples at Attinguie tollbooth in Abidjan were calculated (Table 5).

Among the three different exposure pathways, the HQ_{ing} values were the highest and contributed the most to HIs for both children and adults, more than 85%, indicating that ingestion of road dust appears to be the most threatening exposure way to human health at Attinguie tollbooth.

The values of HQ for those pathways of this study decrease in the order of ingestion>dermal contact>inhalation. Inhalation of particles resuspended through the mouth and nose contributing less than 0.44% to HI (the total risk) appears negligible compared to the other two routes, indicating that the non-cancer risks posed by the inhalation of resuspended road dust might be negligible compared with ingestion and dermal contact. Previous researches has achieved similar results (Zheng et al., 2010)

The orders of non-cancer hazard indexes of metals were Pb>Cr>Cu>Ni>Cd>Zn to children and adults. Pb, Cr and Cu were the main contributors to health risks posed by road dust metals exposure for both children and adults, and Zn had the smaller contribution.

The values of HQ_{ing} for children were 9.33 times higher than those for adults and accounted for 93.99% to HI (the total risk), indicated that children had higher health risks by ingestion than adults. This result may be partially attributed to the special behavior patterns of children, particularly frequent hand-to-mouth contact. HQs and HIs of six metals are almost all lower than the safe level (=1) for children and adult, indicating no risks from exposure to road dust metals.

Note that the risk calculation is affected by a high degree of uncertainty. Despite many uncertainties, human health risk assessment has proved to be a powerful tool to distinguish heavy metals and exposure routes of most concern in urban environments.

IV. CONCLUSION

The heavy metal concentrations and human health risk due to exposure to road dust at Attinguie tollbooth in Abidjan was investigated in this present study. The average concentration of Cu, Zn, Pb, Cd, Cr and Ni 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 result of the elemental concentrations obtained in this work compared well with those of similar works done in other cities with slight variations. People are exposed to pollutant via ingestion, dermal contact and inhalation. The exposure pathway which resulted in the highest levels of risk is ingestion followed by dermal contact while inhalation is the least. In this study, the values of HQ for those pathways decrease in the order of ingestion>dermal contact>inhalation. The Hazard Quotient values for single metals and the Hazard Index value for all studied metals are far lower than the safe level for children and adults, indicating no risk from these metals. We conclude that there is no human health risk for selected heavy metals in road dust at Attinguie tollbooth.

Further studies to assess exposure to resuspended road dust among residents, pedestrians, drivers and workers near roads are needed to understand the role that heavy metals, issued in road traffic play on the health of populations.

Table 5: health risk from heavy metals

		Concentration (mg/kg)	RfDing (mg/(kg.d)	RfDinh (mg/(kg.d)	RfDderm (mg/(kg.d)	HQing		HQinh		HQderm		HI	
						Children	Adult	Children	Adult	Children	Adult	Children	Adult
Cu	min	143	4.00E-02	4.02E-02	1.20E-02	3.26E-02	3.50E-03	1.23E-06	5.29E-07	3.05E-04	8.86E-05	3.30E-02	3.59E-03
	mean	432.57				9.88E-02	1.06E-02	3.73E-06	1.60E-06	9.22E-04	2.68E-04	9.97E-02	1.09E-02
	max	1030				2.35E-01	2.52E-02	8.89E-06	3.81E-06	2.19E-03	6.38E-04	2.37E-01	2.58E-02
Zn	min	59	3.00E-01	3.00E-01	6.00E-02	1.80E-03	1.92E-04	6.82E-08	2.92E-08	2.51E-05	7.31E-06	1.82E-03	2.00E-04
	mean	85.39				2.60E-03	2.79E-04	9.88E-08	4.23E-08	3.64E-05	1.06E-05	2.64E-03	2.89E-04
	max	114.5				3.49E-03	3.73E-04	1.32E-07	5.68E-08	4.88E-05	1.42E-05	3.53E-03	3.88E-04
Pb	min	101	3.50E-03	3.50E-02	5.25E-04	2.64E-01	2.82E-02	1.00E-06	4.29E-07	4.92E-03	1.43E-03	2.68E-01	2.97E-02
	mean	191.71				5.00E-01	5.36E-02	1.90E-06	8.15E-07	9.34E-03	2.72E-03	5.10E-01	5.63E-02
	max	312.5				8.15E-01	8.74E-02	3.10E-06	1.33E-06	1.52E-02	4.43E-03	8.31E-01	9.18E-02
Cd	min	1.5	1.00E-03	1.00E-03	1.00E-05	1.37E-02	1.47E-03	5.20E-07	2.23E-07	3.84E-03	1.12E-03	1.75E-02	2.58E-03
	mean	3.1				2.83E-02	3.03E-03	1.08E-06	4.61E-07	7.93E-03	2.31E-03	3.62E-02	5.34E-03
	max	4				3.65E-02	3.91E-03	1.39E-06	5.95E-07	1.02E-02	2.97E-03	4.68E-02	6.89E-03
Cr	min	88	3.00E-03	2.86E-05	6.00E-05	2.68E-01	2.87E-02	1.07E-03	4.58E-04	3.75E-02	1.09E-02	3.06E-01	4.01E-02
	mean	105.81				3.22E-01	3.45E-02	1.28E-03	5.50E-04	4.51E-02	1.31E-02	3.68E-01	4.82E-02
	max	161				4.90E-01	5.25E-02	1.95E-03	8.37E-04	6.86E-02	2.00E-02	5.61E-01	7.33E-02
Ni	min	125	2.00E-02	2.06E-02	5.40E-03	5.71E-02	6.12E-03	2.11E-06	9.02E-07	5.92E-04	1.72E-04	5.77E-02	6.29E-03
	mean	151.24				6.91E-02	7.40E-03	2.55E-06	1.09E-06	7.16E-04	2.08E-04	6.98E-02	7.61E-03
	max	191.5				8.74E-02	9.37E-03	3.23E-06	1.38E-06	9.07E-04	2.64E-04	8.84E-02	9.63E-03

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