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Determination and Risk Assessment of Heavy Metals Concentrations collected from Indoor houses at Lagos State of Nigeria

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ABSTRACT

The aim of this study is to determine the levels of selected heavy metals (As, Pb, Zn, Cu and Cr) at 60 homes from the 20 local governments in Lagos State, Nigeria. Approval was sought from respective residential landlords and occupants of the sampled communities. Three dust samples were collected from each local government. A total of 60 dust samples were collected and labelled according to the first three letters of each Local government. Indoor dust samples from households (furniture, container bags, window slides, ceiling fan and standing fan) were collected using soft paint brushes. 0.5g of the homogenized mixture was measured in triplicate labelled 1, 2 and 3 in different boiling tubes for digestion process. Each triplicate samples were digested using aqua regia for 1 hour at a temperature of about 100 degree celcius. Heavy metal concentrations were determined using Agilent Technologies 4210 MP-AES Atomic Absorption Spectrometer (AAS). The concentration of heavy metals in the indoor dust were dominated by Arsenic with an average concentration of 57.76-111.93 mg/kg followed Lead 13.81-116.60 mg/kg, Zinc 22.73-224.2 mg/kg, Copper 8.27-228.75 mg/kg and Chromium with concentration of 2.53-22.60 mg/kg respectively. The concentrations of heavy metal in the areas investigated followed the order: Ar>Pb>Zn>Cu>Cr. The exposure dose was also estimated through ingestion, inhalation and dermal contacts, and the exposure route was highest for ingestion pathway. The health risk (carcinogenic and non-carcinogenic) of these heavy metals were assessed based on the United States Environmental Protection Agency health risk models. The estimated values were compared to standard guidelines and human health limits by the United States Environmental Protection Agency, USEPA and California Environmental Protection Agency, Ca/EPA. For non-carcinogenic risk, the hazard index values for all the studied metals were lower than the safe level of 1. The Total Lifetime Cancer Risk for adults and children were below the limit ($1x10^{-6}$ – $1x10^{-4}$) as standardized by USEPA except in children which was slightly higher than the permissible limit in two local government areas; (Shomolu L.G.A $1.03x10^{-4}$) and (Lagos Mainland $1.02x10^{-4}$). This indicates that the risk of carcinogenic effect occurring is likely in children with exposure to arsenic

Key words: Lagos, Indoor dust, Heavy metals, Risk Assessment.

1. INTRODUCTION

A good air quality is important for the environment at large. Air is said to be polluted when it constitutes substances which can be harmful to the health of human, animals and vegetation. Polluted air causes life threatening diseases to man, animals and aquatic lives. Air pollution can be indoor or outdoor and has caused a significant problem worldwide. [1] defined dust as matter or particulate in the form of fine powder, lying on the ground or on the surface of objects or blown about by the wind. In 1997, Paustenbach in his publication, defined House dust as a heterogeneous mixture of substances from numerous sources, including tracked-in or resuspended soil particles, clothing, atmospheric deposition of particulates, hair, fibres (artificial and natural), molds, pollen, allergens, bacteria, viruses, arthropods, ash, soot, animal fur and dander, smoke, skin particles, cooking and heating residues, and building components among others [2]. The quality of indoor air is an environmental health concern as most people spend up to 85% of their time indoors in places, such as homes, offices and schools. Indoor settled dusts contain various hazardous materials including heavy metals, which can affect human health [3]. Heavy metals in indoor dust are an important indicator of pollution in urban environments [4]. Dust can be found as a suspension in the air or settled on surfaces. It originates

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from a number of sources including soil, abrasion of materials, pesticides, asbestors, pollen, bacteria, shed skin, cigarette smoke and dust mites [5].

Industrialization and large population in Lagos has led to the migration of people from one part to the other, in the process, generating thousands of tons of dust daily. The dust generated is expected to increase significantly in the near future as the state strives to attain an industrialized state status by the year 2020. Activities like the burning of local and assorted incenses, cooking with wood and other combusted fuels, burning of mosquito coils and application of aerosols as insect repellents indoor and outdoor also generate particulates and other pollutants such as organic compounds that may linger in the air or cling to dust particles.

Lagos is one of the 36 states in Nigeria. It is located on coordinates of $6^0$35’N and $3^0$45’E in the south-western part of Nigeria with an area of 3577km^2 and a population of approximately 20million based on the 2006 Census. It is the smallest in area out of the Nigeria’s 36 states. It is arguably the most economically important state of the country, if it were a country, it would be the fifth largest economy in Africa. It is bounded by Ogun State on the North and East. It shares boundaries with the Republic of Benin in the West. Just behind its southern borders lies the Atlantic.

Lagos is globally referred to as a megacity being a commercial and Industrial hub, with the presence of one of the largest and busiest parts in the world. Lagos state consist of 20 local government areas with Ikeja as the capital taking a significant 37 percent of the state’s total land area. The 20 local governments contains two main divisions; Lagos mainland and Lagos Island and are Agege, Alimosho, Ifako Ijaiye, Ikeja, Kosofe, Mushin, Oshodi-Isolo, Ajeromi, Ojo, Ikorodu, Surulere, Shomolu, Amuwo-Odofin, Lagos Mainland, Eti-Osa, Badagry, Apapa, Lagos Island, Epe and Ibeju Lekki.

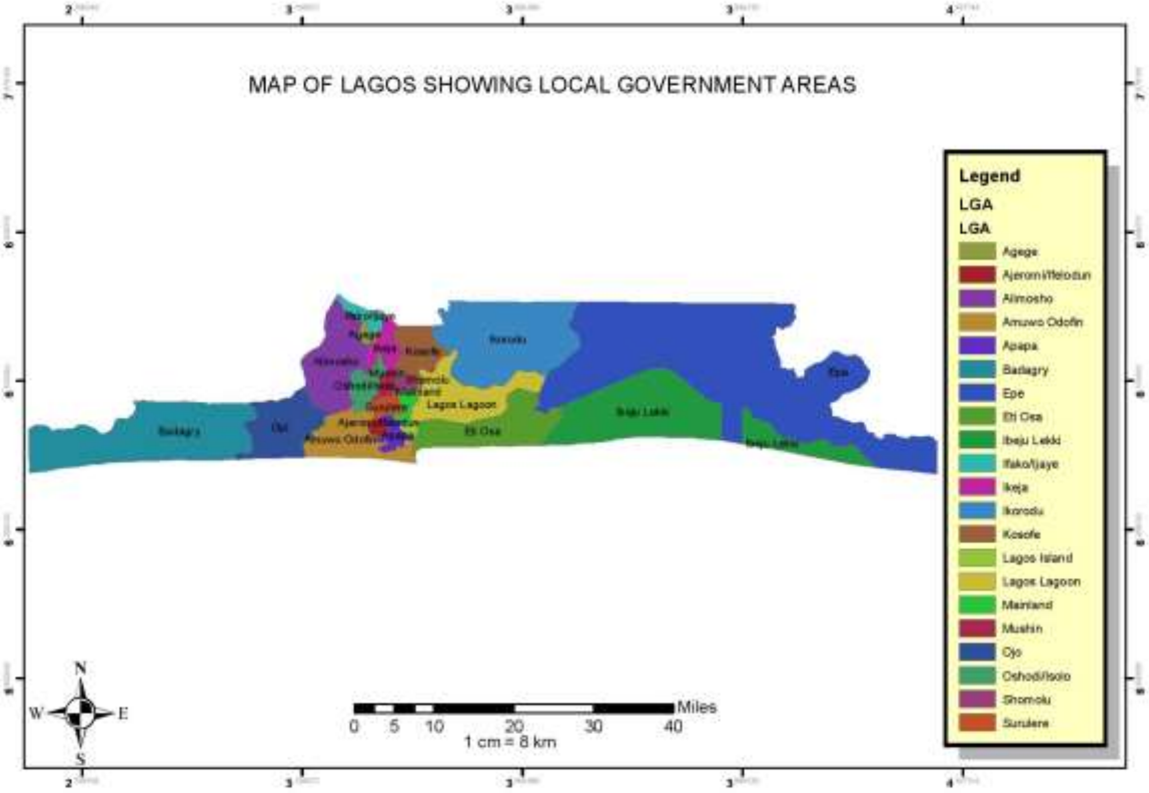

Fig 1.0 Lagos State map showing the 20 Local Government Areas

Presently in Lagos state, no published data is available for deposited and composition of indoor dust in households, including their composition. There is a need therefore to embark on studied focus on composition of the outdoor dust as well as indoor particles. This will highlight the possible risk to health of the Lagos State population.

The main objectives of the study are to

i Determine levels of iron, manganese cadmium, lead, chromium and arsenic in deposited indoor dust samples collected from the 20 Local government areas.

ii Compare the results of heavy metal concentrations with the values reported in past literatures

iii Assess the health risk of the selected heavy metals in children and adults

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2.0 METHODOLOGY

2.1. Sampling Area

Lagos is one of the 36 states in Nigeria. It is located on coordinates of 6^{0}35’N and 3^{0}45’E in the south-western part of Nigeria with an area of 3577km^{2} and a population of approximately 20million based on the 2006 Census. It is the smallest in area out of the Nigeria’s 36 states. It is arguably the most economically important state of the country, if it were a country, it would be the fifth largest economy in Africa. It is bounded by Ogun State on the North and East. It shares boundaries with the Republic of Benin in the West. Just behind its southern borders lies the Atlantic.

2.2 Sample Preparation and Methods

2.2.1 Sample Collection

Approval was sought from respective residential Landlords and occupants of the sampled communities. Sampling was done between the month of January and March 2018. Samples were collected from all the 20 local Government Areas in Lagos state. Three dust samples were collected from each local government. A total of 60 dust samples were collected and labelled using the first three letters of each Local Government Areas. Samples were collected with the use of a paint brush into a plastic pan from items of furniture (desks, chairs), windows, fans, lamp covers, ceiling, standing and wall fans, window sills, cabinet tops and cleaner bags.

Table 1.0 Identification of Sampling Locations and Geographical Positions

LOCAL GOVERNMENT	COMMUNITIES	CODE	GEOGRAPHICAL COORDINATES
OJO	IJEODODO	OJO 1	6°29'40"N, 3°15'18"E
	IGBO ELERIN	OJO 2	6°28'57"N, 3°11'16"E
	IYANA IBA	OJO 3	6°27'57"N, 3°12'14"E
ALIMOSHO	ALIMOSHO	ALM 1	6°37'07"N, 3°17'49"E
	AYOBO-IPAJA	ALM 2	6°35'46"N, 3°14'19"E
	IGANDO	ALM 3	6°33'23"N, 3°16'05"E
IFAKO-IJAIYE	ALAKUKO	FKJ 1	6°41'10"N, 3°15'43"E
	EKORO JUNCTION	FKJ 2	6°38'35"N, 3°17'18"E
	ABORU	FKJ 3	6°38'04"N, 3°17'01"E
IKORODU	ODONGUNYAN	KRD 1	6°42'02"N, 3°25'40"E
	AGRIC	KRD 2	6°37'28"N, 3°28'31"E
	IMOTA	KRD 3	6°39'07"N, 3°38'22"E
OSHODI	CGAC IYANA ISOLO	OSHO 1	6°32'10"N, 3°19'48"E
	MAFOLUKU	OSHO 2	6°32'53"N, 3°21'08"E
	AJAO ESTATE	OSHO 3	6°33'22"N, 3°19'42"E
AGEGE	PEN CINEMA	AGG 1	6°37'56"N, 3°20'28"E
	OGBA	AGG 2	6°37'11"N, 3°19'51"E
	ORILE	AGG 3	6°40'37"N, 3°17'40"E
IBEJU-LEKKI	AJAH	IBJ 1	6°25'22"N, 3°42'39"E
	AWOYAYA	IBJ 2	6°28'27"N, 3°42'29"E
	ILAJE	IBJ 3	6°27'50"N, 3°33'41"E
BADAGRY	AGBARA	BDG 1	6°30'20"N, 3°06'05"E
	OKO-AFO	BDG 2	6°29'12"N, 3°01'45"E
	IBEREKO	BDG 3	6°18'18"N, 3°01'30"E
SHOMOLU	DUROSIMI	SHM 1	6°31'59"N, 3°22'12"E
	SALVATION ARMY	SHM 2	6°32'01"N, 3°22'09"E
	CENTRAL MOSQUE	SHM 3	6°32'07"N, 3°22'19"E
LAGOS MAINLAND	MAKOKO	LSM 1	6°29'44"N, 3°23'09"E
	EBUTTE META	LSM 2	6°29'18"N, 3°22'38"E
	ST FINBARS AKOKA	LSM 3	6°31'18"N, 3°23'12"E
MUSHIN	OLATEJU	MSH 1	6°31'57"N, 3°21'28"E
	ITIRE	MSH 2	6°31'13"N, 3°20'45"E

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	KELANI	MSH 3	6°31'35"N, 3°21'23"E
APAPA	IJORA	APP 1	6°33'54"N, 3°19'03"E
	KIRIKIRI	APP 2	6°26'42"N, 3°18'26"E
	BEACH LAND ESTATE	APP 3	6°26'33"N, 3°19'20"E
AMUWO-ODOFIN	1ST AVENUE	AMU 1	6°28'15"N, 3°17'42"E
	K CLOSE 7TH AVENUE	AMU 2	6°28'08"N, 3°16'14"E
	2ND AVENUE	AMU 3	6°28'17"N, 3°16'22"E
EPE	MAGBON	EPE 1	6°36'36"N, 3°56'46"E
	IBEJU	EPE 2	6°36'07"N, 3°56'32"E
	MEJINDADE CLOSE	EPE 3	6°36'44"N, 3°57'04"E
IKEJA	OBA AKRAN	IKJ 1	6°36'29"N, 3°20'12"E
	OPEBI LINK ROAD	IKJ 2	6°33'50"N, 3°19'48"E
	SECRETARIAT	IKJ 3	6°36'38"N, 3°21'20"E
ETI-OSA	LEKKI PHASE 1	ETI 1	6°26'41"N, 3°24'30"E
	IKOYI	ETI 2	6°26'53"N, 3°21'40"E
	VICTORIA ISLAND	ETI 3	6°26'07"N, 3°25'04"E
LAGOS ISLAND	MARINA	LSD 1	6°26'56"N, 3°23'00"E
	CMS	LSD 2	6°27'22"N, 3°23'30"E
	APONGBON	LSD 3	6°27'27"N, 3°22'32"E
KOSOFE	OGUDU	KSF 1	6°34'26"N, 3°23'47"E
	MILE 12	KSF 2	6°36'34"N, 3°23'57"E
	DEEPER LIFE	KSF 3	6°36'00"N, 3°23'57"E
AJEROMI	AMUKOKO	AJE 1	6°28'12"N, 3°20'33"E
	SURU ALABA	AJE 2	6°27'46"N, 3°19'28"E
	AWODIORA ESTATE	AJE 3	6°27'07"N, 3°19'26"E
SURULERE	SHITTA	SRL 1	6°29'57"N, 3°21'31"E
	BODE THOMAS	SRL 2	6°29'19"N, 3°21'30"E
	OJUELEGBA	SRL 3	6°30'34"N, 3°21'54"E

2.2.1 Sample Preparation

The 3 dust samples from each local Government Areas were mixed to have a composite sample and screened to remove any visible hair, soil, and grit. The samples were then air dried for 7 days and homogenized using a mortar and pestle. The samples were sieved through 1mm mesh sieve to remove small stones. 0.5g of the homogenized mixture was measured in triplicate labelled 1, 2 and 3 in different boiling tubes for digestion process.

2.2.2 Sample Digestion and Metal Analysis

Dust samples were digested in a fume cupboard. Each triplicate samples was digested using aqua regia for 1 hour at a temperature of about 100 degrees celcius. The outcome mixture was filtered using Whatman No. 42 Filter paper. The filtrate was made up to 50 mL with distilled water and stored in plastic bottles until analysis. Heavy metal concentrations were determined using Agilent Technologies 4210 MP-AES Atomic Absorption Spectrometer (AAS).

2.2.3 Mapping

Maps representing concentration were generated for each metal across all Local government using Digital mapping by Land referencing services.

2.2.4 Health Risk Assessment

The method used in calculating the exposure of children and adults to metals in dust is as described by [6], based on the models developed by US Environmental Protection Agency [7]. Children are exposed to dust through three main pathways: ingestion of dust, inhalation of dust particles through mouth and nose, and dermal contact ([8], [9]). Receiver of the dose through these three paths was estimated by USEPA, ([10], [7]) as described thus;

$$D_{ing} = \frac{C \text{ x } (IngR \text{ x } EF \text{ x } ED) \text{ x } 10^{-6}}{BW \text{ x } AT}$$

$$D_{inh} = \frac{C \text{ x } (InhR \text{ x } EF \text{ x } ED)}{}$$

PEF x BW x AT

$$D_{dermal} = \frac{C \times SA \times SL \times ABS \times EF \times ED) \times 10^{-6}}{BW \times AT}$$

Where;

C is the concentration in $mgkg^{-1}$ of metal in indoor dust

D ($mgkg^{-1}day^{-1}$) is the dose contacted through ingestion (D_{ing}), inhalation (D_{ing}) and dermal contact (D_{dermal})

IngR is the ingestion rate, taken to be 200 $mgday^{-1}$ for children and 100 $mgday^{-1}$ for adults according to USEPA ,[11]

InhR is the inhalation rate which was taken as 7.6 m^3day^{-1} for the children and 20 m^3day^{-1} for adults [12].

EF is the exposure relative frequency ($dayyear^{-1}$), taken as 180 days per year [13].

ED is the exposure duration in years, taken as 6years for children and 24years for adults [14]

SA is the exposed skin area in cm^2, and was assumed to be 2800cm^2 for children and 5700cm^2 for adults [14].

SL is the skin adherence factor in $mgcm^2day^{-1}$. In this study, SL was assumed to be 0.2$mgcm^{-2}day^{-1}$ for children and 0.7$mgcm^{-2}day^{-1}$ for adults [14].

ABS is the dermal factor, which was taken to be 0.001 for all elements except arsenic which ABS equals 0.03 [15]

PEF is the particle emission factor, which in this study was given as 1.36×10^9 m^3kg^{-1} [11]

BW is the average body weight. In this study, 15kg was taken for children and 70kg for adults [14].

AT is the averaging time given in days. It is calculated thus; ED × 365 days for non-carcinogens and 70×365 days for carcinogens.

i. Hazard Quotient (HQ) or Non-Cancer Risk

This was calculated by dividing the average daily dose derived for each element and exposure pathway by the metal corresponding reference dose (RfD) in $mgkg^{-1}day^{-1}$, given thus;

$$HQ = \frac{DD}{RfD}$$

HQ = Hazard quotient or Non-cancer risk

DD = Average Daily Dose which may be D_{ing}, D_{inh}, D_{dermal}

The hazard index (HI) is equal to the summation of HQs of the three exposure pathways, $HI=HQ_{ing}+HQ_{inh}+HQ_{dermal}$, i.e., the total hazard quotient (HQ) of the three exposure pathways (ingestion, inhalation and dermal contact) ([16],[9]).

Where;

HQ_{ing} is the Hazard quotient for total ingestion

HQ_{inh} is the Hazard quotient for total inhalation

HQ_{dermal} is the Hazard quotient for total dermal

If HI<1, it is believed that there is chance that non-carcinogenic effects may occur, with a probability which tends to increase as HI increases.

ii. Carcinogenic Risk

This is the probability of an individual developing any type of cancer from lifetime exposure to carcinogenic hazards [6]. The carcinogenic risk is represented by LCR which is calculated by multiplying the Average Daily Dose by the corresponding slope factor (SF).

$$LCR = ADD \times SF$$

Where;

LCR = Lifetime Carcinogenic Risk

ADD = Average Daily Dose

SF = Slope factor

Total Lifetime Carcinogenic Risk is calculated by the addition of all the LCRs calculated for ingestion, inhalation and dermal.

$$TLCR = LCR_{ing} + LCR_{inh} + LCR_{dermal}$$

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The tolerable or acceptable risk for regulatory purposes is in the range $10^{-6} – 10^{-4}$ [6]. This however implies that if the given range is exceeded, carcinogenic risk is most likely to occur over time.

Table 2.0 Reference Dose and Cancer Slope Factors for Metals

	As	Cr	Cu	Pb	Zn
RfD$_{ing}$	3.00×10^{-4}	3.00×10^{-3}	4.00×10^{-2}	3.50×10^{-3}	3.00×10^{-1}
RfD$_{inh}$	3.01×10^{-4}	2.86×10^{-5}	4.02×10^{-2}	3.52×10^{-3}	3.00×10^{-1}
RfD$_{dermal}$	1.23×10^{-4}	6.00×10^{-5}	1.20×10^{-2}	5.25×10^{-4}	6.00×10^{-2}
SF	1.51×10^{1}	4.20×10^{1}			

3. RESULTS AND DISCUSSION

The mean and standard deviation concentration of all the elements (As, Cd, Cr, Pb and Zinc) in all the 20 local government areas in Lagos state were calculated. Table 3.0 shows the mean concentration of each metal across local governments.

Table 3.0 Mean Concentration of all metals (As, Zn, Cu, Pb and Cr) in the whole Local Government Areas

LOCAL GOVT AREA	Mean concentration of As	Mean concentration of Zn	Mean concentration of Cu	Mean concentration of Pb	Mean concentration of Cr
OSHODI	101.73 ±2.76	51.93±2.27	16.13±0.31	84.73±0.50	11.20±1.04
AGEGE	107.13±9.45	22.73±0.99	10.60±0.00	72.40±1.06	8.80±0.00
IBEJU LEKKI	103.27±6.72	26.93±4.97	13.93±3.93	78.27±3.78	4.47±0.42
BADAGRY	86.00±13.17	31.40±2.09	19.40±2.08	117.00±5.74	22.60±2.96
SHOMOLU	111.93±3.14	27.47±2.89	19.47±6.29	80.00±0.35	6.80±0.35
LAGOS MAINLAND	110.80±5.39	14.40±0.92	8.27±0.81	77.93±0.76	2.53±0.58
MUSHIN	93.60±10.41	93.80±18.41	23.07±5.77	129.87±16.36	11.07±1.79
APAPA	107.40±8.93	169.53±1.33	17.00±1.91	85.73±0.76	14.00±0.35
IFAKO IJAIYE	106.27±1.01	29.87±7.41	168.22±12.97	75.47±0.50	6.47±0.31
IKORODU	106.27±1.97	36.60±5.54	17.13±3.23	81.27±1.47	10.53±2.72
AMUWO ODOFIN	104.27±2.14	25.47±2.55	11.27±0.81	78.47±0.83	7.13±0.92
EPE	106.27±4.69	139.27±34.07	14.87±3.23	84.27±2.72	16.67±5.83
IKEJA	105.00±1.93	20.60±2.12	18.60±3.82	79.07±5.72	9.07±0.31
OJO	105.13±1.70	20.53±1.40	10.67±0.23	73.60±0.20	8.80±0.53
ETI-OSA	57.76±36.60	11.57±2.92	20.10±8.03	13.81±1.68	10.13±0.99
LAGOS ISLAND	104.33±4.23	16.60±4.36	15.53±4.97	75.93±1.42	5.53±1.50
KOSOFE	101.33±5.60	39.93±3.67	17.67±4.24	84.60±4.42	8.00±0.35
AJEROMI	99.80±3.90	74.20±2.51	14.67±0.31	116.60±1.31	11.80±0.20
SURULERE	97.80±2.99	224.2±9.07	76.07±1.61	66.47±12.24	20.6±1.84
ALIMOSHO	98.27±5.32	33.73±8.49	16.87±4.56	85.60±3.17	11.60±1.56

3.1. Heavy Metals Concentration in Indoor Dust

The concentrations of As, Pb, Zn, Cu and Cr in the indoor dust samples from the 20 Local governments Areas were presented in Table 4.6. Arsenic, was recorded as having the highest concentration among the heavy metals analysed, with an average concentration of 102.89 mg/kg followed by Pb (85.77 mg/kg), Zn (54.04 mg/kg), Cu (25.37 mg/kg) and Cr (9.23 mg/kg).

Arsenic concentration across the local government areas ranged from 86.60 mg/kg – 111.93 mg/kg with Badagry having the lowest and Shomolu having the highest concentration. Only five local governments have less than 100 mg/kg concentration of Arsenic. They include Badagry (86.00 mg/kg), Mushin (93.60 mg/kg), Ajeromi (99.80 mg/kg), Surulere (97.80) and Alimosho (98.27 mg/kg). [17] reported the concentration of Arsenic to range from 24 mg/kg -3740 mg/kg and 33 mg/kg -1160 mg/kg in two separate mining locations. The concentration of Arsenic previously reported for abandoned mine site by [18]as well as (2006) [19] were 1 mg/kg – 330 mg/kg, and 43 – 486 mg/kg respectively. In comparison with the earlier literatures, the high concentrations observed for Lagos State in this study may be due to the high rate of combustion of wastes in the metropolis. The presence of Arsenic from this study may also be due to large population [20]. The concentrations of arsenic were well above the Ca/EPA screening level (0.07mgkg^{-1}) and the USEPA screening level (0.68 mgkg-1) ([21],[22]).

The concentration of Zn ranged from 14.40 mg/kg – 169.53 mg/kg with Lagos mainland indicating the lowest and Apapa indicating the highest concentration. There were variance in Zn concentrations between local government areas. Surulere and Epe also have concentrations higher than 100 mg/kg. The high concentration of Zn may be through wear and tear of automobile tyres and during traffic congestion, which is a main problem on Apapa road to Lagos seaport where trucks and containers are packed. The elevated Zn content may have originated due to wear and tear of vulcanized vehicle tires, and corrosion of galvanized automobile parts ([23], [24]; [25]). Dustiness on the other hand may be the reason for the high concentration of Zinc. There are a number of sources of zinc in the houses such as rubber, paints and fillers [26].

The concentration of Pb ranged from 66.47 mg/kg – 129.87 mg/kg. Surulere indicated the lowest concentration (66.47 mg/kg) while the highest was recorded in Mushin. This is not mainly from the use of leaded paints as always mentioned by most authors, the number of occupants in households might be a likely significant factor as reported also by [27]. Generally, Pb is high in all local government areas, as lead is a major pollutant in urban cities. Just like other cities, it is still a major pollutant as reported in Shah Alam city by [28]. Similar result was also reported by [29]. The age of the buildings in Mushin might also be a factor for high concentration as well as the presence of motor parks.

Copper and Chromium were found at lower concentrations than other heavy metals reported. The concentration of copper ranged from 8.27 mg/kg – 162.27 mg/kg with the lowest concentration at Lagos Mainland local government and then highest at Ifako-Ijaiye local government area. Chromium being the metal with the lowest concentration ranged from 1.56 mg/kg – 22.60 mg/kg with Alimosho local government as the lowest and Badagry having the highest, Activities of nearby industries might be responsible for the values reported [30]. The range of chromium concentration is within limits for residential levels and lead concentration for most of the sampling locations indicated that the concentration range for these locations are well above the 50th percentile of the limit set by California Human Health Limits [31]. It was also the metal with the lowest concentration in then study carried out by [32] in Malaysia.

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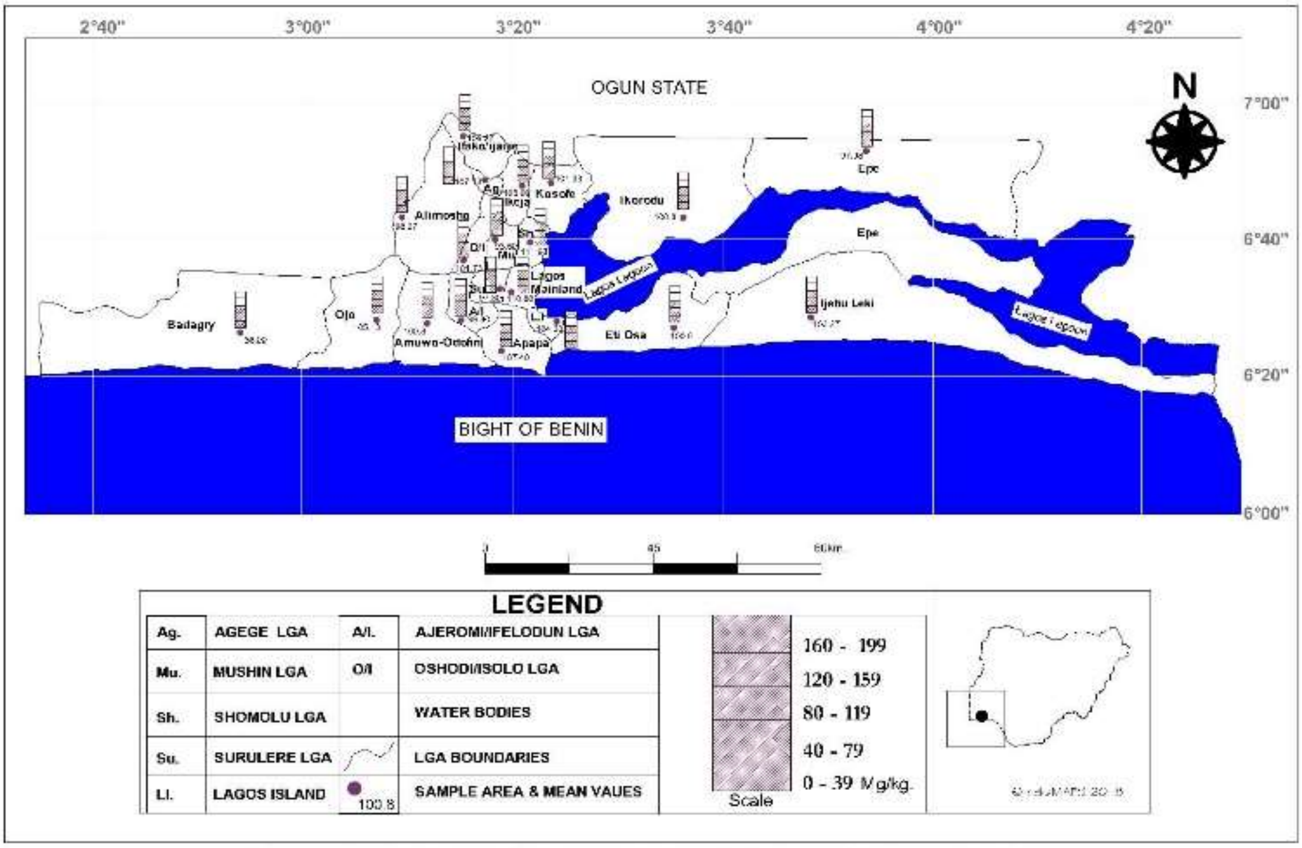
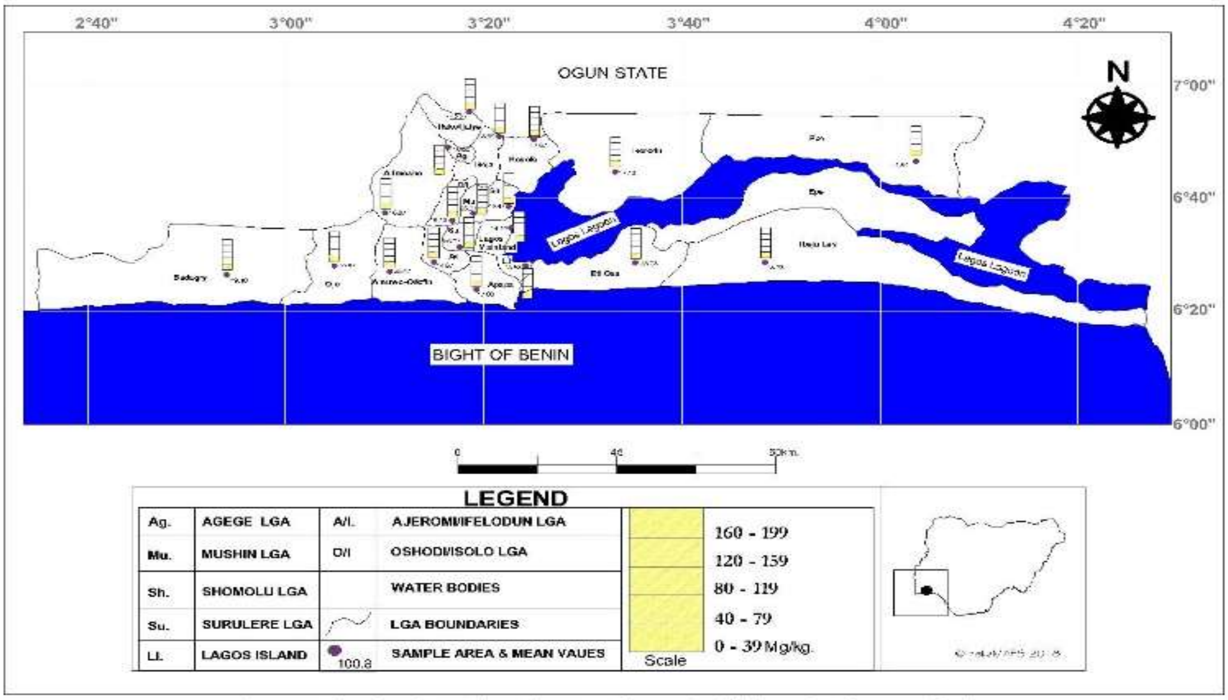


Lagos, showing Sampling Areas & Recorded Values for Arsenic (As.)

Figure 2.0: Map of Lagos State showing the metal concentration of Arsenic



Lagos, showing Sampling Areas & Recorded Values for Copper. (Cu.)

Figure 3.0: Map of Lagos State showing the metal concentration of Copper

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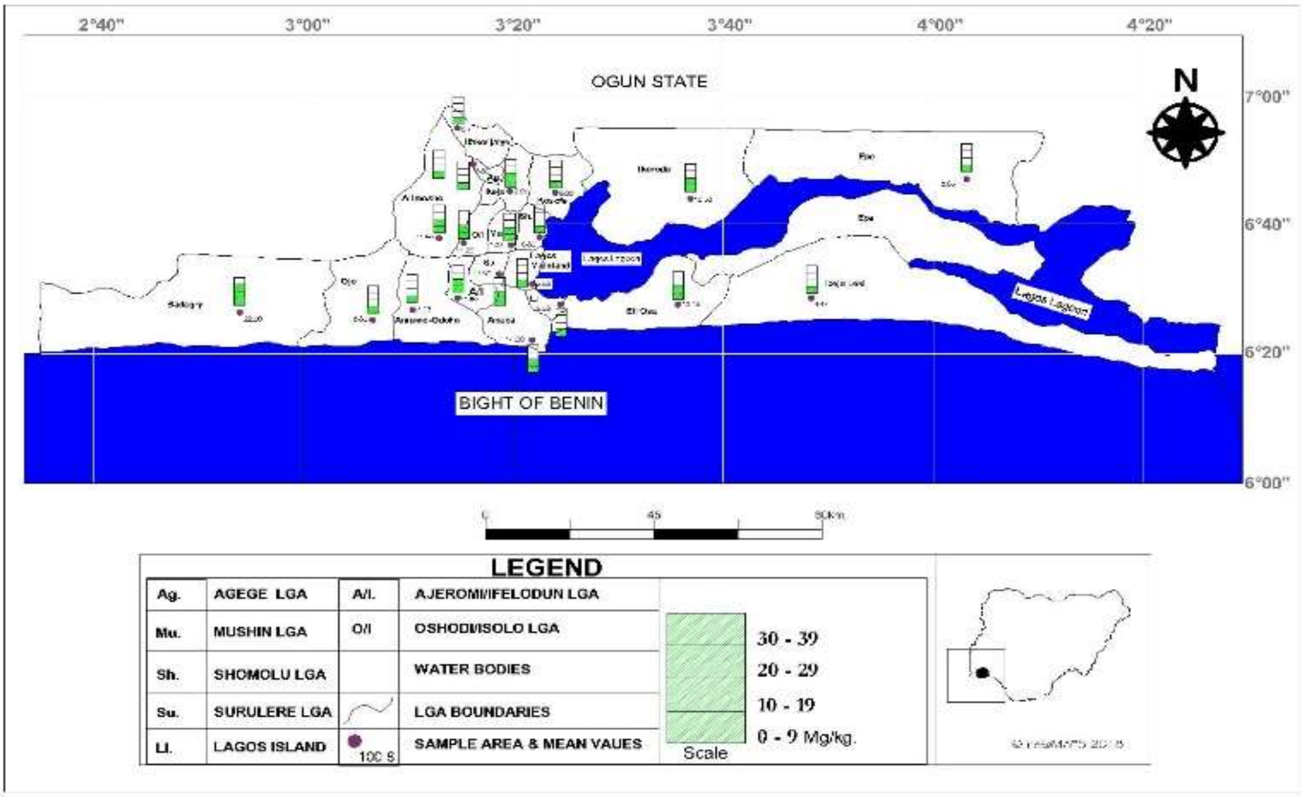

Lagos, showing Sampling Areas & Recorded Values for Chromium. (Cr.)

Figure 4.0: Map of Lagos State showing the metal concentration of Chromium

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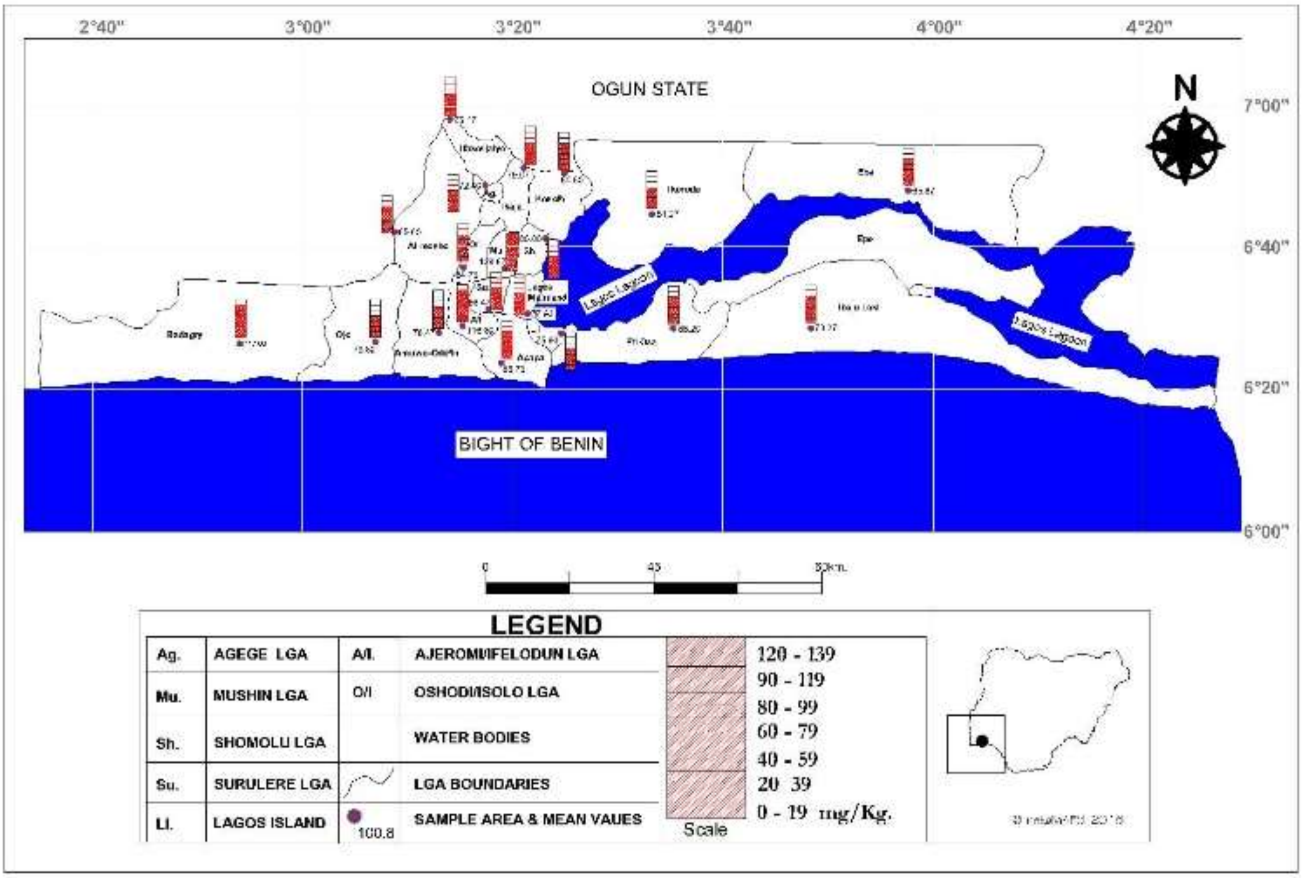

Lagos, showing Sampling Areas & Recorded Values for Lead. (Pb.)

Figure 5.0 Map of Lagos State showing the metal concentration of Lead

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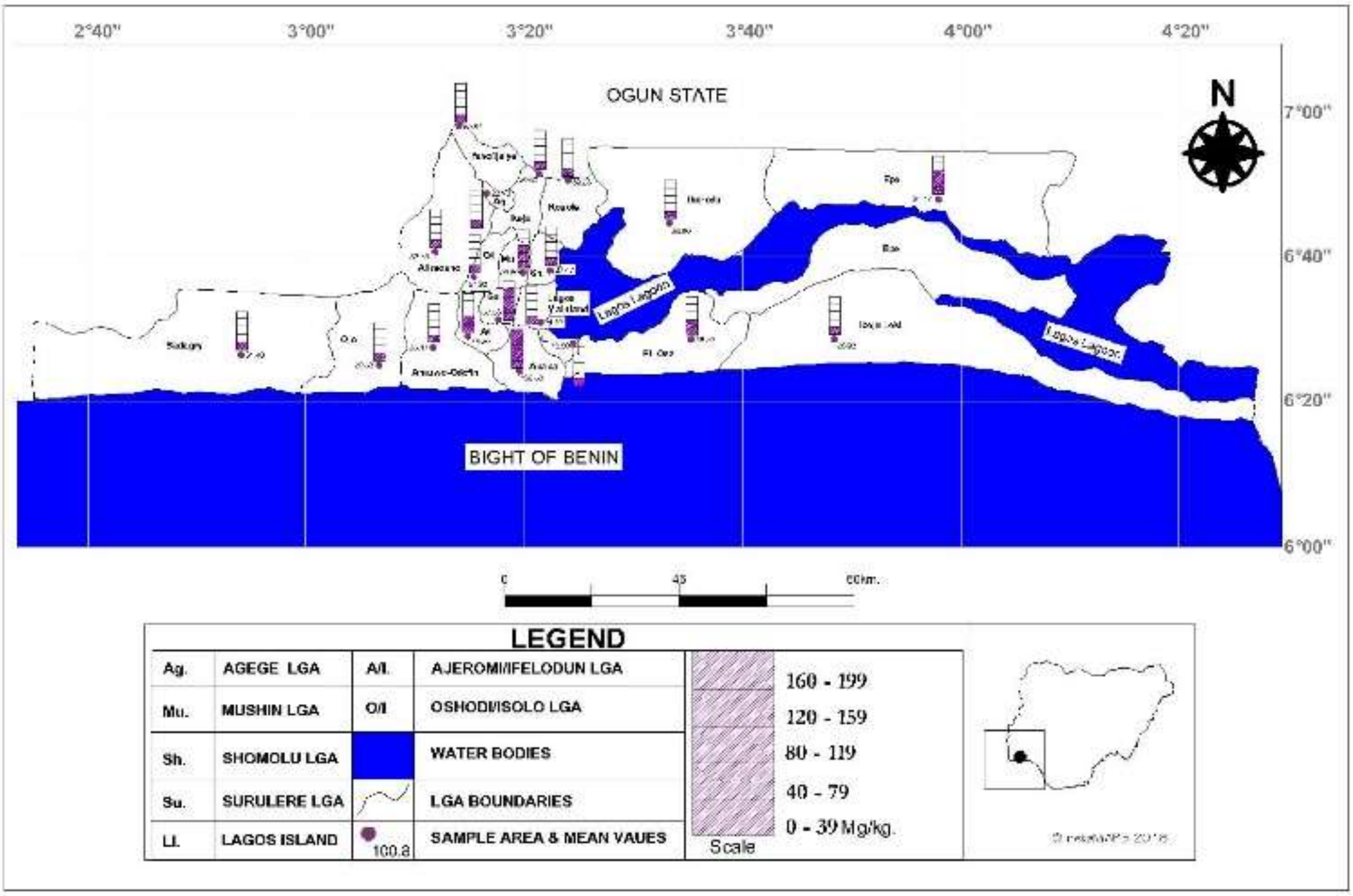

Lagos, showing Sampling Areas & Recorded Values for Zinc. (Zn.)

Figure 6.0 Map of Lagos State showing the metal concentration of Zinc

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Table 4.0 Comparison of the heavy metals (in mg/kg) from this study to other studies

Sources and references	**Sample Area**	**Concentration (mg/kg)**				
		Pb	**Zn**	**Cr**	**As**	**Cu**
This study	Housing areas, Lagos, Nigeria	85	54.04	9.23	102.89	25.37
Tong, (1998)	Nursery school and Kindergarten, Hong Kong	199.96	2229.56	-	-	-
Rasmussen *et al.* (2001)	Housing areas, Ottawa, Canada	405.56	716.90	86.70	-	-
Chattopadhyay *et al.* (2003)	Housing areas, Sydney, Australia	85.2	437.0	64.3	-	-
Jaradat *et al.* (2004)	Industrial area, Jordan	128	746	38	-	-
Turner, (2011)	Housing areas, United Kingdom	181	666	-	-	-
Mohd *et al.* (2007)	Nursery in Dungun Town, china	51	558	-	-	-
Wang *et al.* (2011)	Kindergarten, Kaifeng, China	242.99	297.32	82.13	-	-
Habil and Taneja (2011)	School, Agra, India	18.65	58.47	3.71		
Mohd *et al.* (2013)	Preschool, Malaysia	253.5	144.9	11.9		
Saeed and Sayed (2017)	Household, Iran	93.4	-	83.5	-	189
Dundar and Ozdemir (2005)	Housing areas	121	-	104		27
Amjad *et al.* (2016)	Residential Houses, United Kingdom	13.2	-	9.89	-	25.0
Hao *et al.* (2014)	Nursey and Primary school in China	180.9	461.5	149.2	13.2	70.8
Culbard and Johnson (1984)	Household, South west England	-	-	-	1160	-
Rieuwerts *et al.* (2006)	Household, South west England	-	-	-	486	-
Daniel *et al.* (2017)	Household , South west England	-	-	-	104	-

The concentration of heavy metals in this study is compared with previous investigated values from other cities in the world as shown in Table (4.1). The result however, showed that heavy metals studied here have an approximately lower concentration than reported from other previously studied cities. This may be attributed to the fact that most of the cities are more industrialized than Lagos as also mentioned by [30]. The metals with the highest concentration from this study was As and on the other hand, the concentration was found to be in a slightly close range with investigated data from household in Southwest England [20]. The low level of the concentration of Arsenic in this study compared to the value presented by [18] and [19], might be attributed to the fact that the previous studies study areas were two separated former mining village. These concentrations can therefore be considered high compared to a non-mining area in Lagos metropolis. The study presented Chromium to be the metal with the lowest concentration and

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obviously lower than all the values reported in the compared researches, only in a school, in Agra, India [20], which has a concentration three times lower than that reported in Lagos according to the study.

3.3 Risk Assessment

5.0 Daily Intake of Heavy Metals

Heavy Metal		**D_{ing}**			**D_{inh}**			**D_{dermal}**	
	Level	**Children**	**Adult**	**Level**	**Children**	**Adult**	**Level**	**Children**	**Adult**
Zn	**Minimum**	7.16×10^{-5}	8.15×10^{-6}	**Minimum**	2.13×10^{-9}	1.20×10^{-9}	**Minimum**	2.13×10^{-7}	3.25×10^{-7}
	Maximum	1.11×10^{-3}	1.19×10^{-4}	**Maximum**	2.89×10^{-9}	1.76×10^{-8}	**Maximum**	3.12×10^{-6}	4.77×10^{-6}
As	**Minimum**	3.26×10^{-5}	1.40×10^{-5}	**Minimum**	3.47×10^{-10}	2.05×10^{-9}	**Minimum**	2.73×10^{-6}	1.67×10^{-5}
	Maximum	6.31×10^{-5}	2.70×10^{-5}	**Maximum**	2.05×10^{-9}	3.98×10^{-9}	**Maximum**	5.30×10^{-6}	3.24×10^{-5}
Cu	**Minimum**	5.44×10^{-5}	5.83×10^{-6}	**Minimum**	1.52×10^{-9}	8.57×10^{-10}	**Minimum**	1.52×10^{-7}	2.32×10^{-7}
	Maximum	3.69×10^{-4}	1.14×10^{-4}	**Maximum**	2.98×10^{-8}	1.68×10^{-8}	**Maximum**	2.99×10^{-6}	4.56×10^{-6}
Pb	**Minimum**	1.24×10^{-5}	5.32×10^{-6}	**Minimum**	9.10×10^{10}	2.36×10^{-9}	**Minimum**	1.05×10^{-7}	2.12×10^{-7}
	Maximum	7.32×10^{-5}	3.14×10^{-5}	**Maximum**	1.69×10^{-9}	4.61×10^{-9}	**Maximum**	3.47×10^{-7}	1.25×10^{-6}
Cr	**Minimum**	1.43×10^{-6}	6.11×10^{-7}	**Minimum**	3.98×10^{-11}	8.99×10^{-11}	**Minimum**	3.99×10^{-9}	2.44×10^{-8}
	Maximum	1.27×10^{-5}	5.46×10^{-6}	**Maximum**	3.56×10^{-10}	8.03×10^{-10}	**Maximum**	3.57×10^{-8}	2.18×10^{-7}

For non-cancer risk in children, ingestion appears to be the main exposure route followed by dermal contact and exposure by inhalation. The same thing applies to adult as well and this is similar to other reports ([7],[8]). The highest D_{ing} value was 1.11×10^{-3} for Zinc and the lowest D_{ing} value was 1.27×10^{-3}. These findings can be attributed to the more vulnerability of children to the toxic substances [33]. Furthermore, children are also more sensitive to heavy metals in indoor dust due to their behavior such as hand-to-mouth activities, crawling and fast growth rate [34]. [35] mentioned that indoor dust particles ingestion is the main exposure route of toxic metals by children as they like to play on the floor of the house and indirectly ingest it.

The exposure route by ingestion was significantly higher than Inhalation and dermal in the order ingestion >dermal>inhalation. However, daily intake of dust via Inhalation was higher in adult than children for all heavy metals studied except for copper. By dermal contact, children exposure to dust particles was higher than in adult for Zinc, lower than adult for Arsenic, lower than adult for copper, lower than adult for lead and lower than adult for chromium as well.

Across all metals of study, the metal with the lowest value via the three route of exposure (ingestion, inhalation and dermal) in adult and children was chromium and the highest was zinc in both children and adult.

3.3.2 Heavy metals Non-Carcinogenic Risk Assessment.

Table 6.0 Hazard Indexes and Quotients for Metals Exposure in Children and Adults

	Arsenic		Zinc		Copper		Lead		Chromium	
	Children **HI**	Adult **HI**	Children **HI**	Adult **HI**	Children **HI**	Adult **HI**	Children **HI**	Adult **HI**	Children **HI**	Adult **HI**
1	2.16×10^{-1}	3.21×10^{-1}	1.15×10^{-3}	1.46×10^{-4}	2.65×10^{-3}	3.22×10^{-4}	1.39×10^{-2}	1.56×10^{-3}	2.40×10^{-3}	2.71×10^{-3}
2	2.25×10^{-1}	3.38×10^{-1}	5.05×10^{-4}	6.40×10^{-5}	1.74×10^{-3}	2.12×10^{-4}	1.19×10^{-2}	1.33×10^{-3}	1.89×10^{-3}	2.13×10^{-3}

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3	2.14×10^{-1}	3.26×10^{-1}	5.99×10^{-4}	7.59×10^{-5}	2.29×10^{-3}	2.78×10^{-4}	1.30×10^{-2}	1.44×10^{-3}	9.60×10^{-4}	1.08×10^{-3}
4	1.87×10^{-1}	2.71×10^{-1}	6.98×10^{-4}	8.85×10^{-5}	3.19×10^{-3}	3.87×10^{-4}	1.91×10^{-2}	2.15×10^{-3}	4.85×10^{-3}	5.48×10^{-3}
5	2.36×10^{-1}	3.53×10^{-1}	6.11×10^{-4}	7.74×10^{-5}	3.20×10^{-3}	3.89×10^{-4}	1.31×10^{-2}	1.47×10^{-3}	1.46×10^{-3}	1.65×10^{-3}
6	2.30×10^{-1}	3.50×10^{-1}	3.20×10^{-4}	4.06×10^{-5}	1.36×10^{-3}	1.65×10^{-4}	1.29×10^{-2}	1.43×10^{-3}	5.43×10^{-4}	6.13×10^{-4}
7	2.00×10^{-1}	2.95×10^{-1}	2.08×10^{-3}	2.64×10^{-4}	3.79×10^{-3}	4.60×10^{-4}	2.12×10^{-2}	2.38×10^{-3}	2.38×10^{-3}	2.68×10^{-3}
8	2.26×10^{-1}	3.39×10^{-1}	3.77×10^{-3}	4.78×10^{-4}	2.79×10^{-3}	3.39×10^{-4}	1.40×10^{-2}	1.57×10^{-3}	3.01×10^{-3}	3.39×10^{-3}
9	2.24×10^{-1}	3.35×10^{-1}	6.64×10^{-4}	8.41×10^{-5}	2.67×10^{-2}	3.24×10^{-3}	1.24×10^{-2}	1.39×10^{-3}	1.39×10^{-3}	1.57×10^{-3}
10	2.23×10^{-1}	3.35×10^{-1}	8.13×10^{-4}	1.03×10^{-4}	2.82×10^{-3}	3.42×10^{-4}	1.33×10^{-2}	1.49×10^{-3}	2.26×10^{-3}	2.55×10^{-3}
11	2.20×10^{-1}	3.29×10^{-1}	5.66×10^{-4}	7.18×10^{-5}	1.85×10^{-3}	2.25×10^{-4}	1.29×10^{-2}	1.44×10^{-3}	1.53×10^{-3}	1.73×10^{-3}
12	2.24×10^{-1}	3.35×10^{-1}	3.10×10^{-3}	3.92×10^{-4}	2.44×10^{-3}	2.97×10^{-4}	1.38×10^{-2}	1.55×10^{-3}	3.58×10^{-3}	4.04×10^{-3}
13	2.21×10^{-1}	3.31×10^{-1}	4.58×10^{-4}	5.80×10^{-5}	3.06×10^{-3}	3.71×10^{-4}	1.30×10^{-2}	1.45×10^{-3}	1.95×10^{-3}	2.20×10^{-3}
14	2.11×10^{-1}	3.32×10^{-1}	4.56×10^{-4}	5.78×10^{-5}	1.75×10^{-3}	2.13×10^{-4}	1.19×10^{-2}	1.35×10^{-3}	1.89×10^{-3}	2.13×10^{-3}
15	1.32×10^{-1}	1.82×10^{-1}	2.57×10^{-4}	3.26×10^{-5}	3.30×10^{-3}	4.01×10^{-4}	3.77×10^{-3}	4.04×10^{-4}	2.18×10^{-3}	2.46×10^{-3}
16	2.19×10^{-1}	3.29×10^{-1}	3.69×10^{-4}	4.68×10^{-5}	2.55×10^{-3}	3.10×10^{-4}	1.25×10^{-2}	1.39×10^{-3}	1.19×10^{-3}	1.34×10^{-3}
17	2.13×10^{-1}	3.20×10^{-1}	8.87×10^{-4}	1.12×10^{-4}	2.91×10^{-3}	3.53×10^{-4}	1.40×10^{-2}	1.55×10^{-3}	1.72×10^{-3}	1.94×10^{-3}
18	2.10×10^{-1}	3.15×10^{-1}	1.65×10^{-3}	2.09×10^{-4}	2.41×10^{-3}	2.93×10^{-4}	1.90×10^{-2}	2.14×10^{-3}	2.53×10^{-3}	2.86×10^{-3}
19	2.06×10^{-1}	3.09×10^{-1}	3.50×10^{-3}	4.44×10^{-4}	9.22×10^{-3}	1.12×10^{-3}	1.10×10^{-2}	1.22×10^{-3}	3.75×10^{-3}	4.23×10^{-3}
20	1.85×10^{-1}	3.10×10^{-1}	7.50×10^{-4}	9.50×10^{-5}	2.77×10^{-3}	3.37×10^{-4}	1.14×10^{-2}	1.57×10^{-3}	2.49×10^{-3}	2.81×10^{-3}

Hazard Quotients for arsenic in children followed the order $HQ_{ing}>HQ_{dermal}>HQ_{inh}$ and HQ for arsenic in adult followed the order $HQ_{dermal}>HQ_{ing}>HQ_{inh}$. The Hazard Quotient for zinc in children followed the order $HQ_{inj}>HQ_{dermal}>HQ_{inh}$ and HQ for adult in zinc had the HQ_{inj} and HQ_{dermal} slightly the same but greater than HQ_{inh}. The Hazard Quotient for copper in Children and adult followed the same order and was $HQ_{inj}>HQ_{dermal}>HQ_{inh}$ and the HQ for copper in adult was in the order. The same was also found in Lead for both children and adult. The Hazard Quotient for chromium in children followed the order $HQ_{inj}>HQ_{dermal}>HQ_{inh}$ and the HQ for chromium in adult followed the order $HQd_{ermal}>HQ_{inj}>HQ_{inh}$.

The Hazard Index (HI) in adults was a bit higher than children in arsenic. In zinc and copper, the HI was higher in children than in adult; the same thing appears in lead and similar HI was recorded in chromium as well.

According to [10], indoor dust post adverse non-carcinogenic effect if its value is above 1, and from the study, none of the metals showed a HI value higher than 1. This indicates that the indoor dust samples collected from the 20 local government areas in Lagos state pose no adverse non-carcinogenic health effect to the children and adults of the population. Similar values have been reported for indoor dust in precious researches ([33], [6]and [35]).

3.3.3 Carcinogenic Risk Assessment

Table 7.0 Lifetime Cancer Risk and Total Lifetime Cancer Risk Values for Chromium

	Arsenic		Lead		Chromium	
	Children	Adult	Children	Adult	Children	Adult
	TLCR	**TLCR**	**TLCR**	**TLCR**	**TLCR**	**TLCR**
1	9.32×10^{-5}	8.10×10^{-5}	3.48×10^{-7}	1.81×10^{-7}	1.90×10^{-8}	8.44×10^{-9}
2	9.82×10^{-5}	8.53×10^{-5}	3.76×10^{-7}	1.55×10^{-7}	1.49×10^{-8}	6.63×10^{-9}
3	9.46×10^{-5}	8.22×10^{-5}	5.62×10^{-7}	1.67×10^{-7}	7.58×10^{-9}	3.37×10^{-9}
4	7.88×10^{-5}	6.85×10^{-5}	3.85×10^{-7}	2.50×10^{-7}	3.83×10^{-8}	1.70×10^{-8}
5	1.03×10^{-4}	8.91×10^{-5}	3.74×10^{-7}	1.71×10^{-7}	1.15×10^{-8}	5.12×10^{-9}
6	1.02×10^{-4}	8.82×10^{-5}	6.23×10^{-7}	1.66×10^{-7}	4.29×10^{-9}	1.91×10^{-9}
7	8.58×10^{-5}	7.45×10^{-5}	4.12×10^{-7}	2.77×10^{-7}	1.88×10^{-8}	8.34×10^{-9}
8	9.84×10^{-5}	8.55×10^{-5}	3.63×10^{-7}	1.83×10^{-7}	2.37×10^{-8}	1.06×10^{-8}
9	9.74×10^{-5}	8.46×10^{-5}	3.90×10^{-7}	1.61×10^{-7}	1.10×10^{-8}	4.88×10^{-9}
10	9.74×10^{-5}	8.46×10^{-5}	3.77×10^{-7}	1.74×10^{-7}	1.79×10^{-8}	7.94×10^{-9}
11	9.56×10^{-5}	8.30×10^{-5}	4.05×10^{-7}	1.68×10^{-7}	1.21×10^{-8}	5.37×10^{-9}
12	9.74×10^{-5}	8.46×10^{-5}	3.80×10^{-7}	1.80×10^{-7}	2.83×10^{-8}	1.26×10^{-8}
13	9.62×10^{-5}	8.36×10^{-5}	3.54×10^{-7}	1.69×10^{-7}	1.54×10^{-8}	6.84×10^{-9}
14	9.63×10^{-5}	8.37×10^{-5}	1.06×10^{-7}	1.57×10^{-7}	1.49×10^{-8}	6.63×10^{-9}
15	5.29×10^{-5}	4.60×10^{-5}	3.64×10^{-7}	4.70×10^{-8}	1.72×10^{-8}	7.63×10^{-9}
16	9.56×10^{-5}	8.31×10^{-5}	4.06×10^{-7}	1.62×10^{-7}	9.38×10^{-9}	4.17×10^{-9}
17	9.29×10^{-5}	8.07×10^{-5}	5.60×10^{-7}	1.81×10^{-7}	1.36×10^{-8}	6.03×10^{-9}
18	9.15×10^{-5}	7.94×10^{-5}	3.20×10^{-7}	2.49×10^{-7}	2.00×10^{-8}	8.89×10^{-9}
19	8.96×10^{-5}	7.79×10^{-5}	3.39×10^{-7}	1.42×10^{-7}	2.96×10^{-8}	1.32×10^{-8}
20	9.01×10^{-5}	7.82×10^{-5}	1.16×10^{-9}	1.83×10^{-7}	1.97×10^{-8}	8.74×10^{-9}

The highest TLCR value for Arsenic in children was 1.03×10^{-4} and the lowest TLCR for Arsenic in children was 5.29×10^{-5} while the highest TLCR for Arsenic in adults was 8.9×10^{-5} and the lowest TLCR for Arsenic in adult was 4.60×10^{-5}.

The highest TLCR for lead in children was 6.23×10^{-7} and the lowest TLCR for lead in children was 1.16×10^{-9} while the highest TLCR for lead in adult was 2.77×10^{-7} and the lowest TLCR for lead in adult was 4.70×10^{-8}.

The Lifetime Carcinogenic Risk in children across all heavy metals studied ranged from LCR_{inj}> LCR_{dermal}>LCR_{inh}. In adult, the same thing applies to lead and chromium, except for arsenic which had LCR_{inj} similar to LCR_{dermal} but both higher than $LCR_{inh.}$

The TLCR for adults and children were below the limit ($1x10^{-6}$ – $1x10^{-4}$) given by USEPA (2001) except in children which was slightly higher than the permissible limit in two local government areas; (Shomolu L.G.A $1.03x10^{-4}$) and (Lagos Mainland $1.02x10^{-4}$). This indicates that the risk of carcinogenic effect occurring is likely in children with exposure to arsenic. [6] also reported a TLCR value ($4.01x10^{-9}$) and ($4.97x10^{-9}$) higher than the permissible limit for Arsenic in Children in nursery and primary school respectively in China.

4. CONCLUSION

This study presents a report of selected heavy metals (As, Pb, Zn, Cu and Cr) which are found in indoor dust samples collected in the 20 local government areas in Lagos State. The average concentration of the heavy metals reported were dominated in Arsenic followed by Zinc, Lead, Copper and Chromium. Arsenic showed the highest concentration. The whole local government is highly concentrated in Arsenic. However, Lagos is an industrial suburb, the uniqueness from this research is the high level of Arsenic. Lead is concentrated more in Mushin and Badagry. Zinc is very concentrated in Apapa, Surulere, Epe, Mushin and Agbado Ijaiye. Surulere is the most concentrated in Copper.

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Non-carcinogenic value was lower than 1 which is the permissible limit. This however indicated that the indoor dust samples collected from the 20 local government areas in Lagos state pose no adverse non-carcinogenic health effect to the children and adults. Carcinogenic risk assessment showed that only arsenic of all studied metals had a TLCR value lower than the permissible range of 1 x 10^{-6} – 1 x 10^{-4} in two Local governments (Shomolu and Lagos Mainland). Therefore, exposure to arsenic might likely cause carcinogenic risk.

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