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CHARACTERISTIC DISTRIBUTION AND SOURCE APPORTIONMENT OF SOME HEAVY METALS IN STREET DUST OF IKORODU AREA OF LAGOS STATE, SOUTHWESTERN NIGERIA

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ABSTRACT
This research reports the characteristic distribution and source apportionment of some heavy metals in dust of Ikorodu area of Lagos State. The dust samples were collected randomly four times a month at ten different locations in Ikorodu area. Dust samples were obtained by sweeping surface dust into plastic waste packer using plastic brush and transferred into pre-labeled polythene bags. The samples were filtered through 75 µm stainless steel sieve, weighed, digested with appropriate amount of HNO_3 and H_2O for 2 h. The concentrations of heavy metals were analyzed using Atomic Absorption Spectrophotometer (AAS). Results showed that the percentage contribution of each heavy metal at Ikorodu area were: Zn 79.4, Pb 14.8, Cu 0.9, Ni 4.9 and Cd 0.01. The most abundant heavy metal was Zn 2869.70 $\pm$ 0.01 mg/kg while the least was Cd 0.69 $\pm$ 0.01 mg/kg. The most polluted site was Residential Area 1 (993.674 mg/kg) while the least polluted was Industrial Area 3 (81.397 mg/kg). The major roads (38.1%) had the highest concentration of heavy metal pollution while the agricultural area (5.7%) had the least pollution. The sequence and distribution follow the pattern: Zn > Pb > Ni > Cu > Cd. The Principal Component Analysis PCA showed that the major sources of heavy metals in Ikorodu dust are anthropogenic. Pearson correlation analysis also showed that there was strong positive correlation (0.887) between the heavy metals. The concentrations of Heavy metals Zn, Pb, Ni, Cu exceeded the recommended limits of the Federal Ministry of Environment (FME), European communities (EC) and United Nations Environmental Programme (UNEP) permissible levels for dust suggesting that the study area is polluted.

Keywords: Anthropogenic, concentration, dust, environment, heavy metals, pollution

INTRODUCTION
With increase in the level of industrialization and urbanization, the quality of air in major cities around the world especially in a developing city like Lagos, Nigeria particularly Ikorodu area is rapidly deteriorating as a result of the presence of heavy metals contamination arising from energy generation, vehicular traffic, combustion of fossil fuel and poor waste management policies. The Characteristic distribution of Heavy metals in Street road dust may depend upon different functional sites of an urban area because of the types and intensities of anthropogenic activities in the study area (Wang *et al.*, 2016; Chen *et al.*, 2017). Dusts are fine solid particles in the atmosphere from various sources such as soil, dust lifted by wind and pollutions. It acts as the sink and source of toxic metals to its corresponding environment especially soil and air (Men *et al.*, 2020). Dust may be described as fine solid particles that exist in the environment through diverse processes and can accumulate outdoor, especially on cemented roads and hard pavements (Lu *et al.*, 2014; Rahman *et al.*, 2019). Resuspension of surface particle loading is an important source of road dust emission. However, the main mechanisms leading to road dust emissions are still unidentified (Qin-Qin *et al.*, 2023). The chemical contents of street dust and airborne particulates are similar (Liu *et al.*, 2007). Chemical composition of Street dust can be used as an indicator for environmental pollution (Han *et al.*, 2006), a valuable medium for characterizing urban environmental quality (Liu *et al.*, 2007) and exposure health risk assessment (Hussain *et al.*, 2015).

Heavy metal levels in dust are important indicators of environmental contamination (Yadav *et al.*, 2019; Jahandari *et al.*, 2020; Dytlow *et al.*, 2021). Dust can be a major exposure route for some hazardous substances, leading to potential health risks (Schweizer *et al.*, 2007). People on the street and those residing in the vicinity inhale dust through the skin and in hand-to-mouth eating of poorly washed fruits and vegetables (Lorenzi *et al.*, 2011). There are various methods of sampling dust, already reported include the use of : a plastic dustpan and a brush (Wei *et al.*, 2009; Aguilera *et al.*, 2019; Preveena *et al.*, 2019), a plastic hand broom and dustpan (Zhang *et al.*, 2012, Soltani *et al.*, 2015), brushing 1 m^2 of previously delimited surface of asphalt (Reyes *et al.*, 2013), an ABA- 1-120-02A portable aspirator (Saghatelyan *et al.*, 2014; Sahakyan *et al.*, 2016) a brush and plastic hand shovel

(Trujillo-Gonzalez *et al.*, 2016), a vacuum cleaner (Tanner *et al.*, 2008; Yu *et al.*, 2016) and a portable high-pressure washer device with a piston fitted into a rigid, sealed rubber dome (Budai *et al.*, 2018). They are made up of solid particles deposited on permeable materials that originate from the interaction of solids, liquids, and gases in the environment (Keshavarzi *et al.*, 2018). Heavy metals are the stable metals or metalloids whose densities are greater than 4.5 g/cm^3, namely Pb, Cu, Ni, Cd, Zn, Hg and Cr, etc. (Chopra *et al.*, 2009). Some of these metals are essential for life at very low concentration levels but at high levels of concentration they may lead to harmful effects in humans, plants and animals (Cao *et al.*, 2009). Those that are of grave concern are the non - essential heavy metals like As, Pb, Cd and Cr which are considered major air and land pollutants in areas where they are most concentrated (Moses *et al.*, 2009). Heavy metals are dangerous because they bio-accumulate (Bawuro *et al.*, 2018). Long term exposure to the polluted road dust would cause severe damage through inhalation, ingestion, and dermal contact (Lu *et al.*, 2010). Chemical composition of Street dust can be used as an indicator for environmental pollution (Han *et al.*, 2006), a valuable medium for characterizing urban environmental quality (Liu *et al.*, 2014) and exposure health risk assessment (Hussain *et al.*, 2015). Heavy metal levels in dust are an important indicator of environmental contamination (Yadav *et al.*, 2019; Jahandari *et al.*, 2020; Dytlow *et al.*, 2021). The five metals addressed in this study (Zn, Pb, Ni, Cu and Cd) are among the most often found heavy metals in the atmosphere including dust and to a large extent are harmful to human beings and the entire ecosystem. For instance, consumption of excessive amounts of zinc might results in pancreatic problems, anemia, and muscle sorenes (Roney *et al.*, 2006). Studies on atmospheric dust fall reported that Zn likely comes from the fossil fuels, tire wear, vehicular emissions (Valotto *et al.*, 2015; Hwang *et al.*, 2016; Valotto *et al.*, 2017; Wang *et al.*, 2020). Lead in the road dust might accumulate from traffic emission, industrial activity and as pollution from the use of arsenical pesticides, herbicides, crop desiccants and metal smelting (Bhuiyan *et al.*, 2015; Men *et al.*, 2018; Rahman *et al.*, 2019; Xiao *et al.*, 2020). Copper is regarded as a tracer for non - exhaust vehicle (Cui *et al.*, 2019; Rai *et al.*, 2021). Copper is used in lubricants to improve friction stability and is emited during brake abrasion (Querol *et al.*, 2007; Amato *et al.*, 2014). Sources of Copper also include non - ferrous metallurgical industry, metal processing and refinery industry (Men *et al.*, 2018; Ramírez *et al.*, 2018). High levels of copper exposure can impair the immune system, induce liver, renal, and gastrointestinal problems, as well as Wilson's syndrome and anxiousness (Briffa *et al.*, 2020; Taylor *et al.*, 2020). Exposure to excessive amounts of Cadmium has been linked to renal disease, infertility, mental and digestive issues, and cancer (Faroon *et al.*, 2012). A number of health problems are associated with prolonged exposure to cadmium particularly in children, including neurologic problems, kidney problems, high blood pressure, heart disease, and reproductive system problems (Abadin *et al.*, 2007). The major sources of Cd in road dust might be lubricating oil, diesel fuel, tire and brake wear, batteries, plastic and building materials (Wei *et al.*, 2010; Foti *et al.*, 2017; Men *et al.*, 2020; Heidari *et al.*, 2021).

Human exposure to Nickel, could led to respiratory problems, cardiovascular disease and cancer (Buxton *et al.*, 2019). Although, there are enormous studies on the levels of Heavy metals in Street dust in the world (Liu *et al.*, 2015; Abbasi *et al.*, 2020; Li *et al.*, 2020; Kara *et al.*, 2020; Wang *et al.*, 2020; Salwan *et al.*, 2020; Zhe *et al.*, 2021) currently there are few literatures on Heavy metals in Street dust in Nigeria but little or literatures in Lagos State, particularly in Ikorodu except those of (Ojiodu *et al.*, 2022a; Ojiodu *et al.*, 2022b; Ojiodu *et al.*, 2023a; Qin - Qin *et al.*, 2023; Shinggu *et al.*, 2007).

Ikorodu is an urban area with a large market characterized with high Population density with high Commercial and vehicular activities. Therefore, the objectives of the present study were to assess and evaluate the levels of Zinc, Lead, Copper, Nickel and Cadmium in Street dust of Ikorodu area, determine the degree of bioaccumulation and Characteristic distribution of these Heavy Metals and determine whether there is a significant difference in the levels of Heavy metals from one location to another within the study area. It is hopeful that this study will provide the percentage contributions of each Heavy Metal and their potential sources.

MATERIALS AND METHODS

Study area/sampling locations

The study was conducted in the following areas of Ikorodu (N6^0 60748, E 3^0 6184 - N6^0 03052, E3^0 64452). Lagos state which include the major roads - Agric, Ile - Epo oba, Roundabout; Residential areas - Residential areas 1 and 2; Industrial areas - Industrial areas 1, 2 and 3 and Agricultural areas - Farm 1 and Farm 2. Epe - Odogbonle Noforija was used as the control site (Figure 1).

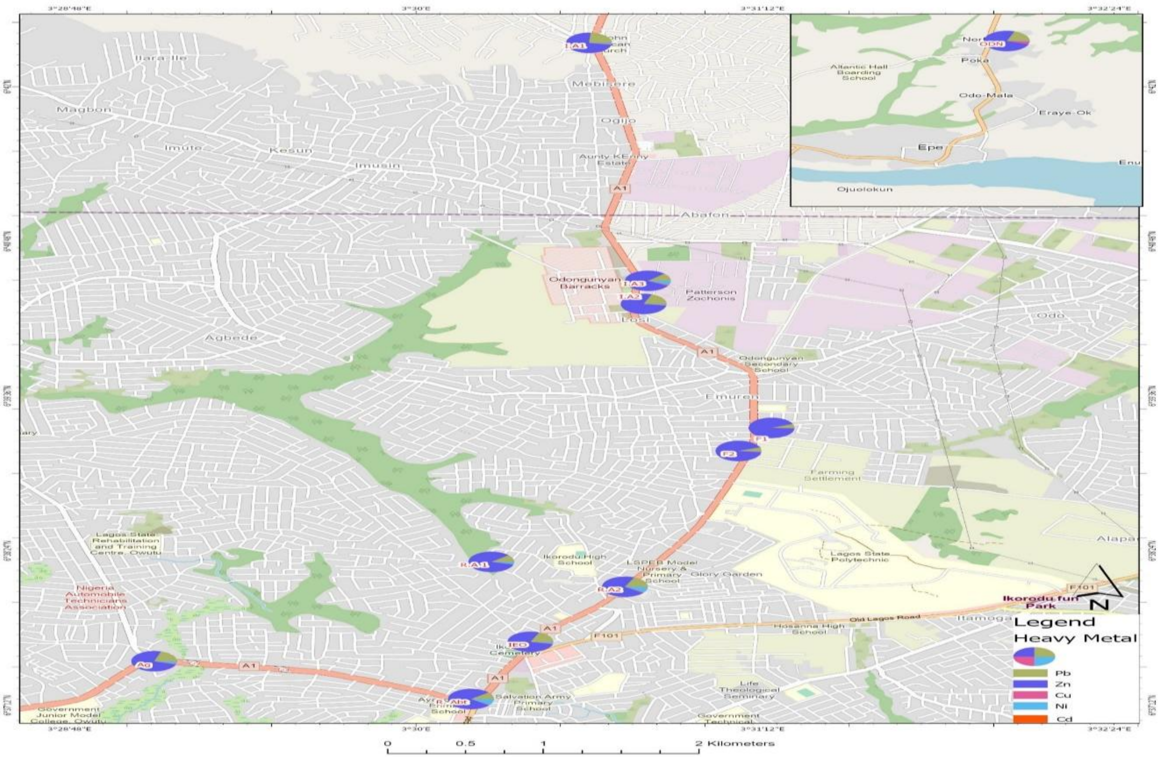

Figure 1: GIS map showing the percentage composition of the selected heavy metals in each site in Ikorodu area

Table 1: Sampling sites, characteristics and coordinates in Ikorodu area

S/N	Location	Codes	Coordinates		Site description
			Latitude	Longitude	
1	Agric	AG	$N6^0.60748$	$E3^0.6164$	It is a commercial area with high vehicular and human activities.
2	Ile - Epo Oba	IEO	$N6^0.62548$	$E3^0.76972$	It is an area with high vehicular activities and filling station.
3	Roundabout	RA	$N6^0.00492$	$E3^0.42784$	It is a commercial area with high vehicular activities, motor park and clusters of filling stations.
4	Residential Area 1	RA1	$N6^0.852$	$E3^0.4596$	It is a residential area with mechanic workshops, abandoned vehicles and metal works.
5	Residential Area 2	RA2	$N6^0.05704$	$E3^0.75108$	It is a residential area with few vehicular activities.
6	Industrial Area 1	IA1	$N6^0.48472$	$E3^0.9406$	It is an industrial area with high vehicular activities with generating plant emissions.
7	Industrial Area 2	IA2	$N6^0.69604$	$E3^0.3004$	It is an industrial area with high vehicular activities with generating plant emissions.
8	Industrial Area 3	IA3	$N6^0.897$	$E3^0.3004$	It is an industrial area with high vehicular activities.
9	Farm 1	F1	$N6^0.46648$	$E3^0.8744$	It is an agricultural area with few vehicular activities, farm houses and animal houses.
10	Farm 2	F 2	$N6^0.49552$	$E3^0.77396$	It is an agricultural area with few vehicular activities, farm houses, animal houses such as pigs and building under construction.
11	Odogbonle Noforija (control)	ODN	$N6^0.03052$	$E3^0.64452$	It is a residential area with little or no anthropogenic activity.

Selection of sampling sites

The eleven sites including the control site, as shown in Table 1 were carefully chosen based on accessibility, availability of open spaces and of course area with maximum influence from anthropogenic activities such as vehicular traffic density, human activities as well as industrial activities. The geo-referencing was carried out by using GPS MAP 76S (Garmin).

Sample collection

Dust samples were collected from eleven sites within the study area, at least 100 m apart, four times a month from October, 2022 - March, 2023. Samples were collected in the morning while the dust has settled well throughout the night and before heavy morning traffic movement that can disrupt the dust. The samples were randomly collected from both sides of the road by weeping surface dust into plastic waste packers using plastic brush and transferred into pre - labeled polythene bags (Shabbaj *et al.*, 2018; Aguilera *et al.*, 2019; Praveena *et al.*, 2019).

All irrelevant materials such as cigarette ends, papers, plastics etc. were carefully handpicked. Thereafter, samples collected at each location were filtered through 75 µm stainless steel sieve. The samples were then taken to the laboratory for further treatment and analysis.

Sample preparation and digestion

The 2.0 g of sieved dust was weighed using an analytical balance and transferred into a conical flask for digestion. 30 ml Trioxonitrate v acid and 10 ml concentrated hydrochloric acid prepared in the ratio 3:1 was added. The solution was mixed thoroughly and heated on magnetic stirrer, then refluxed at 90^0C for 20 minutes. After the disappearance of brown fumes, the digest was cooled and then filtered through Whatman type 589/2 filter paper. The filtrate was diluted to 50 cm^3 with de-ionized water. The metal contents in the filtrate were determined using an Atomic absorption spectrophotometer (AAS) PG-990 (Benhaddya *et al.*, 2016; Men *et al.*, 2019).

Statistical analysis

Analysis of Heavy metals was carried out using ANOVA to check for the standard error and Significant differences of the mean concentration of the results from October, 2022 - March, 2023 in Ikorodu area (Table 3). Kaiser-Meyer- Olkin and Battlet's test were carried out to confirm the Sampling Adequacy (Table 2).

Table 2: Kaiser - Meyer- Olkin and Battlet's test

Kaiser - Meyer- Olkin and Battlet's test		Heavy metals
Kaiser-Meyer-Olkin measure of sampling adequacy		0.822
Bartlett's Test of Sphericity	Approx. Chi-Square	2674.263
	Df	55
	Sig.	0.000

RESULTS AND DISCUSSION

Characteristic distribution of selected heavy metals in Ikorodu area

Residential Area 1 (993.674 mg/kg; 27.5%) is the most polluted site in Ikorodu (Table 3). This is due to anthropogenic activities in and around the site such as release of fumes from generators and emissions from numerous heavy duty vehicular/traffic and commercial activities in and around the site while the least polluted site is Industrial Area 3 (81.397 mg/kg; 2.3%). The most abundant heavy metals is Zinc (2869.699 mg/kg; 79.4%) while the least abundant heavy metal is Cadmium (0.692 mg/kg; 0.01%) (Figure 2). This may be attributed to the versatile use of Zinc in form of Zinc oxide present in paints, rubber , cosmetics, pharmaceuticals, wearing of brake lining of vehicles, loss of oil and cooling liquids from automobile, corrosion of galvanized steels, scrap iron bars and improper disposal of industrial waste in the area. There is a significant difference in the levels of Zinc metal in Ikorodu Area compared to other sites ($p < 0.05$). The highest Concentrations of Zn (836.704 mg/kg) and Pb (113.126 mg/kg) were recorded at Residential Area 1 while the highest concentrations of Cu (5.972 mg/kg), Cd(0.209 mg/kg) and Ni (77.639 mg/kg) were recorded at Roundabout. The high Concentration of Pb in Residential Area 1 may be due to the high commercial and vehicular activities, spillage of petroleum products, smoking of cigarettes, paint chips from the walls of industrial buildings, careless discard of lead acid batteries used in automotive as well as the use of industrial grade and non - domestic paints by the surrounding industries. The level of Pb in Residential Area 1 was significantly different ($p < 0.05$) from all other sites. The highest concentration of Copper, Nickel and Cadmium at Roundabout may be due to manufacturing of electrical cables, production of cans and the use of pesticides, combustion of fossil fuels, smelting of metals, vehicular emission, traffic congestion and industrial processes that use these metals or their compounds fuel combustion by generators as well as frequent bush burning in that environment. The level of Nickel at Roundabout is significantly different from all other sites ($p < 0.05$). There is significant difference in the levels of heavy metals in the study area ($P < 0.05$) (Table 3). The Characteristics distribution and degree of bioaccumulation of Heavy metals content of Ikorodu dust is as follows: Zn > Pb > Cu > Ni > Cd with the mean concentrations of 286.9699, 53.3344, 17.8706, 3.3350 and 0.0692 mg/kg, respectively.

Table 3: Mean ± standard error of instrument reading of digested sample (mg/kg)

Locations	Pb	Zn	Cu	Cd	Ni
Agric	46.65 ± 1.33^e	171.30 ± 1.52^f	3.15 ± 1.46^{bcd}	0.09 ± 0.02^c	10.09 ± 1.51^d
Ile - Epo Oba	69.49 ± 1.60^c	288.03 ± 1.81^d	4.75 ± 1.84^{ab}	0.15 ± 0.05^b	10.16 ± 1.52^d
Roundabout	86.63 ± 1.65^b	603.35 ± 1.75^b	5.97 ± 1.77^a	0.23 ± 0.03^a	77.64 ± 1.44^a
Residential Area 1	113.13 ± 1.64^a	836.70 ± 1.73^a	4.74 ± 1.80^{ab}	0.07 ± 0.01^c	38.93 ± 1.52^b
Residential Area 2	36.55 ± 1.58^f	141.30 ± 1.48^g	2.39 ± 1.59^{cde}	0.01 ± 0.00^d	18.72 ± 1.51^c
Industrial Area 1	66.25 ± 1.52^d	202.10 ± 1.48^e	3.30 ± 1.40^{bc}	0^d	6.21 ± 1.60^e
Industrial Area 2	85.93 ± 1.62^b	346.79 ± 1.76^c	4.18 ± 1.37^b	0.03 ± 0.00^d	9.30 ± 1.64^d
Industrial Area 3	9.97 ± 1.41^g	63.98 ± 1.26^j	1.47 ± 0.91^{def}	0^d	5.45 ± 1.48^e
Farm 1	6.60 ± 1.65^h	86.98 ± 1.79^i	0.55 ± 0.13^f	0^d	6.44 ± 1.13^e
Farm 2	9.99 ± 1.55^g	103.14 ± 1.49^h	1.37 ± 1.03^{ef}	0.01 ± 0.00^d	1.22 ± 0.13^f
Odogbonle Noforija (Control)	6.65 ± 1.63^h	25.52 ± 1.71^k	1.48 ± 0.74^{def}	0.01 ± 0.00^d	0.36 ± 0.06^f
F Statistics	3527.292	141038.805	9.613	73.397	1716.098
(p - value)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)

Mean difference is significant at $P < 0.05$

Table 4: Mean concentration of heavy metals in all the sites in Ikorodu area (mg/kg)

Sample Sites/ Locations	Lead (Pb)	Zinc (Zn)	Copper (Cu)	Cadmium (Cd)	Nickel (Ni)	Total	Percent	Percent
Agric	46.651	171.302	3.147	0.099	10.156	231.355	6.4	38.1
Ile - Epo Oba	69.486	288.025	4.748	0.159	10.285	372.703	10.3	
Roundabout	86.136	603.349	5.973	0.209	77.639	773.306	21.4	
Residential Area 1	113.126	836.704	4.741	0.169	38.934	993.674	27.5	33.0
Residential Area 2	36.552	141.302	2.392	0.009	18.716	198.971	5.5	
Industrial Area 1	66.246	202.097	3.301	ND	6.210	277.854	7.7	22.3
Industrial Area 2	85.931	346.788	4.183	0.029	9.300	446.231	12.3	
Industrial Area 3	9.968	64.501	1.475	ND	5.453	81.397	2.3	
Farm 1	5.990	86.978	0.545	ND	0.437	93.950	2.6	5.7
Farm 2	6.605	103.137	1.369	0.009	1.22	112.340	3.1	
Odogbonle Noforija (Control)	6.653	25 .516	1.476	0.009	0.356	34.010	0.9	0.9
Total	533.344	2869.699	33.350	0.692	178.706	3615.791	100	
Percent	14.8	79.4	0.9	0.01	4.9			

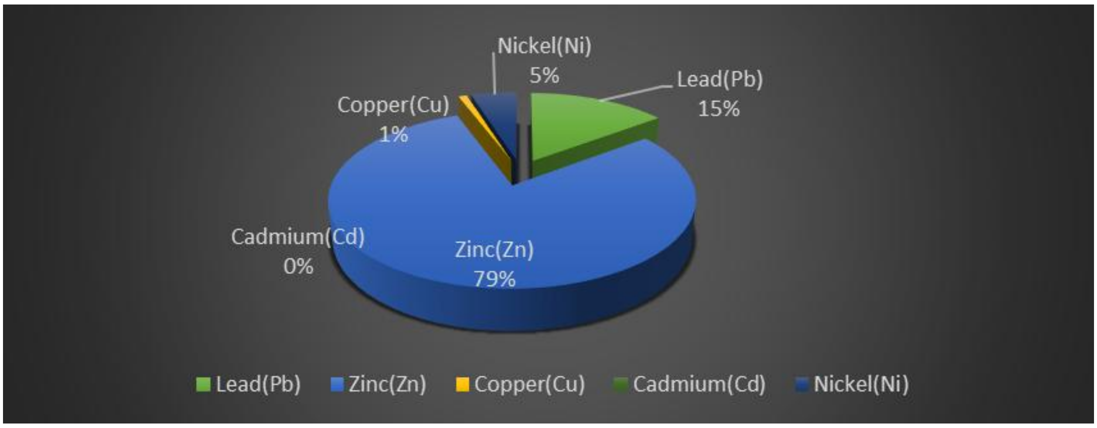

Figure 2: Percentage contribution of heavy metals to pollution in the dust of Ikorodu

Roundabout (773.306 mg/kg; 21.4%) is the most polluted site in Major roads while the least polluted is Agric (231.355 mg/kg; 6.4%). This may be due to high vehicular activities within and around the Major roads in the area. At the Major roads, the highest concentration of Zn 603.349, Pb 86.136, Cu 5.973, Ni 77.639 and Cd 0.209 mg/kg was recorded at Roundabout while the lowest Concentration was recorded at Agric site Zn 171.302, Pb 46.651, Cu 3.147, Ni 10.156 and Cd 0.099 mg/kg.

At the Industrial areas, the most industrialized area is Industrial area 2 (446.231 mg/kg; 12.3%) with the highest concentration of Zn 346.788, Pb 85.931 , Cu 4.183 and Ni 9.300 mg/kg and Cd 0.029 mg/kg while the least industrial area was recorded at Industrial area 3 (81.397 mg/kg; 2.3%) with the lowest concentrations Zn 64.501 mg/kg; Pb 9.968 mg/kg; Cu 1.475 mg/kg and Ni 5.453 mg/kg and Cd 0 mg/kg.

The most polluted Residential area is Residential area 1 (993.674 mg/kg; 27.5%) with the highest concentration of Zn 836.704, Pb 113.126, Cu 4.741 , Ni 38.934 and Cd 0.169 mg/kg and the least polluted Residential area 2 (198.971 mg/kg, 5.5%). Residential area 1 is polluted due to high Anthropogenic activities (commercial) of Man.

The most polluted Agricultural area is Farm 2 (112.340 mg/kg; 3.1%) with the highest concentration of Zn 103.137 , Pb 6.605, Cu 1.369 , Ni 1.22 and Cd 0.09 mg/kg and the least polluted Agricultural area is Farm 1(93.950 mg/kg; 2.6%). Farm 2 is polluted due to high use of fertilizers, Agricultural chemicals including Pesticides, herbicides. There is a significant difference between the levels of Zn, Pb, Cu, Cd and Ni in Industrial, Major roads, Residential Areas and Agricultural Areas ($P_V < 0.05$).

The major roads, residential, industrial and agricultural areas contributed 38.1, 33.0, 22.3 and 5.7% respectively to dust pollution in Ikorodu. The high concentration of heavy metals in the major roads may be attributed to high anthropogenic activities i.e. (human and vehicular activities) while the low concentration in the agricultural area is due to low anthropogenic activities i.e. (low vehicular emissions and majorly rearing of pigs, fish and farm houses). The level of bioaccumulation of heavy metals in street dust of Ikorodu is as follows: Residential area1 > Roundabout > Industrial Area 2 > Ile-Epo oba > Industrial Area 1 > Agric > Residential Area 2 > Farm2 > Farm1 > Industrial Area 3 (Figure 3). There was progressive increase in the levels of bioaccumulation of these heavy metals from October, 2022 - March, 2023. There is significant variation in the level of heavy metals in the study area ($P_v < 0.05$). The high significant levels of Zn, Pb, Ni and Cu obtained in the samples from Ikorodu is an indication of their concentrations in the dust while the low concentration of cadmium Cd suggest low contributing factors to their spread and as well as dust inability to preferentially accumulate these metals (Table 3). The trend and percentage contribution of each site to pollution in Ikorodu dust is as follows: RAI 27.5% > RA 21.4% > IA2 12.3% > IEO 10.3% > IA1 7.7% > AG 6.4% > RA2 5.5% > F2 3.1% > F1 2.6% > IA3 2.3% > ODN 0.9%. The result of this research agrees with the results obtained in Nigeria and in other areas of the world (Kara, 2020; Li *et al.*, 2020; Xu *et al.*, 2020; Ojiodu *et al.*, 2023a,b; Wang *et al.*, 2021; Ojiodu *et al.*, 2023a,b). This results also showed that concentrations of heavy metals depends on the nature of activities in and around the sites (Karbassi *et al.*, 2005; Christoforidis *et al.*, 2009; Adie *et al.*, 2014; Ekpo *et al.*, 2012; Mohsen *et al.*, 2012; Adie *et al.*, 2014; Ojiodu and Elemike, 2017; Ojiodu and Olumayede, 2018; Ojiodu *et al.*, 2018).

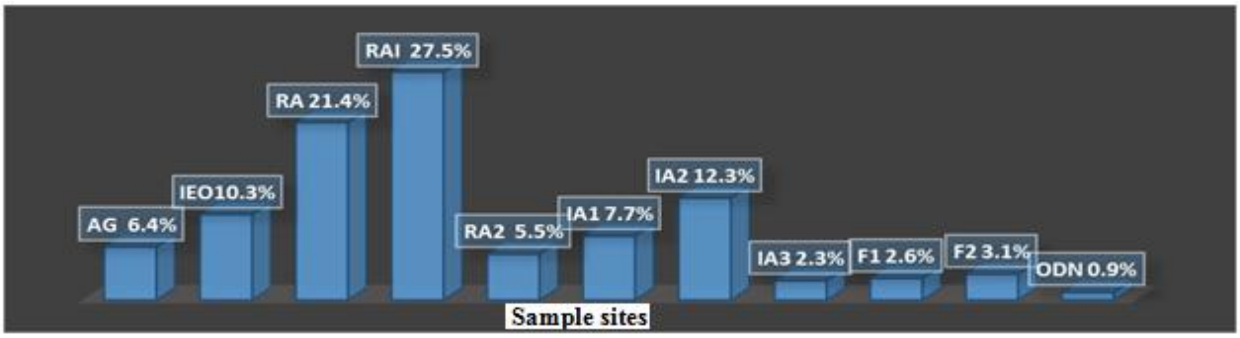

Figure 3: Percentage contribution of each site to pollution in the study area

Table 5: Mean concentration of heavy metals in street dust of Ikorodu and other selected cities of the world (mg/kg)

CITY	Pb	Zn	Cu	Cd	Ni
Ikorodu (this study)	**533.34**	**2869.69**	**33.35**	**0.692**	**178.706**
Ketu - Mile 12 (Ojiodu *et al.*, 2023c)	322.99	1767.09	1623.133	4.078	69.811
Oshodi - Isolo (Ojiodu *et al.*, 2023a)	1031.73	1445.43	242.77	6.99	78.47
Ikeja (Ojiodu *et al.*, 2023b)	1043.73	2449.53	328.97	33.10	88.09
Central China/Arid Desert (Chiana) (Zhe *et al.*, 2021)	91.55	222.82	20.00	0.39	-
Shijiazhuang (China) (Kui *et al.*, 2019)	154.78	496.17	91.06	1.86	40.99
Xian(Chiana) (Li *et al.*, 2015)	97.4	169.2	46.6	0.72	29.3
Shanghai (Korea) (Li *et al.*, 2015)	295	735	197	1.23	84
Chengdu(Korea) (Li *et al.*, 2015)	375	1117	244	4.4	88.1
Guizhou(Korea) (Duan *et al.*, 2017)	67.81	185.98	129.80	0.62	61.07
Shihwa(Japan) (Jeong *et al.*, 2017)	612	1824	992	2.22	164
Delhi (India) (Suryawanshi *et al.*, 2016)	120.7	284.5	191.7	2.64	36.4
South Africa (Olowoyo *et al.*, 2016)	754.3	304.6	157.2	2.54	74.3

The levels of heavy metals in Ikorodu area was far greater than the recommended limits of the Federal Ministry of Environment (FME), European Communities (EC) and United Nations Environmental Programme (UNEP) permissible levels for heavy metals in the atmosphere (European Commission, 2006). The concentrations of heavy metals in all the sites was higher than the control value (Table 3). This may be due to the fact that the control site is an area with little or no anthropogenic activity.

Source apportionment

Using principal component analysis (PCA) to identify the potential sources of heavy metals in Ikorodu area

The Principal Component Analysis (PCA) was widely used to reduce large data sets to few components and here it makes it easier to understand the potential sources of Heavy metals in Ikorodu dust. It is used to classify variables into groups that can then be associated with factors that contributes to pollutant levels at receptors. The data acquired at Ikorodu sites were used to conduct PCA analysis. All KMO values for the individual items (0 > 0.70) were well above 0.5 and the Kaiser - Meyer Olkin KMO measured was 0.822 indicating that the data was sufficient for Exploratory Factor Analysis (EFA) (Table 2). The Bartlett's test of Sphericity $\chi^2_{(10)} = 174.562$, $p < 0.05$ showed that there was patterned relationships between the items. The Scree plot confirmed the findings of retaining two (2) factors. The results in Table 6. showed the factor loadings after rotation using a significant factor criterion of 0.50. Using the Eigen value greater than one rule, two factors were identified. The two factors were identified as those contributing to the measured values in Ikorodu area. The PCA analysis classified the dataset of heavy metals into two principal components (PCs) PC1 and PC2 which accounted for the variances of 75.061% of the total variation in the dataset collected from Ikorodu area of Lagos state. PC1: This factor 1 accounted for 39.635% of the total variance in the data. This factor was highly loaded with Pb and Cd. The sources of this heavy metals were from emissions from traffic/vehicles, industrial wastes, lubricating oil, diesel fuel, tire, and brake wear (Foti *et al.*, 2017; Men *et al.*, 2020; Heidari *et al.*, 2021). PC2: This factor 2 accounted for 36.426% of the total variance. This factor is loaded with Zn, Cu and Ni. These heavy metals were released through emissions from traffic/vehicles, industrial activities, combustion of fossil fuels, gasoline and diesel exhaust.

Table 6: The rotated component matrix for data of heavy metals in street dust of Ikorodu

Heavy metals	Principal components	
	PC1	**PC2**
Pb	**0.879**	0.412
Zn	0.005	**0.877**
Cu	-1.04	**0.887**
Cd	**0.984**	-0.080
Ni	0.256	**0.765**
Eigen values	1.827	1.964
% of Variance	39.635	36.426
% of Cumm. Variance	39.635	75.061

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

Correlation coefficient analysis

Table 7: Correlation analysis among the heavy metals in dust of Ikorodu (N = 77)

Metals	Pb	Zn	Cu	Cd	Ni
Pb	1				
Zn	0.344	1			
Cu	-0.056	0.886**	1		
Cd	0.887**	-0.072	-0.034	1	
Ni	0.408	0.986*	0.437**	0.159	1
Mean	95.31	235.52	32.89	4.06	8.67
SD	101.08	125.71	18.55	7.52	3.29

**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).

Pearson's significant correlation analysis was employed to statistically link the concentrations of heavy metals with the sources of Street dust. Pearson correlation coefficient, r, was used to measure the strength of the inter-relationship between the heavy metals (Lv, 2019). Table 7, Showed Pearson correlation coefficients, their significance and the total number of observations. There is a significant strong positive correlation amongst the heavy metals. The correlation for the five heavy metals in Ikorodu area of Lagos state were moderately correlated and significant, which indicates that fewer components are required to account for the variation. We can see the sample correlations among Zn, Pb, Cu, Cd, Ni ranges between -0.056 to 0.887 which shows that the variables were suitable for the Principal component analysis. There is strong positive correlation (0.887) between the heavy metals at 0.01 levels of significance (Enuneku *et al.*, 2017; Kara, 2020; Wang *et al.*, 2021). This results showed that Zn, Pb, Cu, Cd and Ni are from anthropogenic sources such as traffic/vehicular, industrial wastes, waste dumpsite/improper disposal of domestic wastes and sewage, industrial activities, combustion of fossil fuels, gasoline and diesel exhaust.

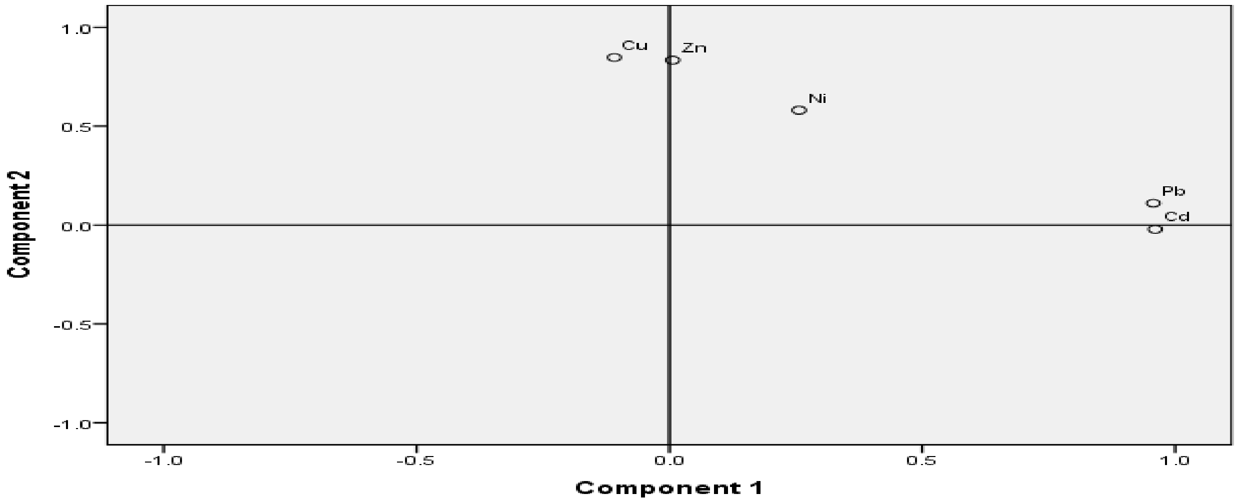

Figure 4: Bi-plot of the components

Cluster analysis

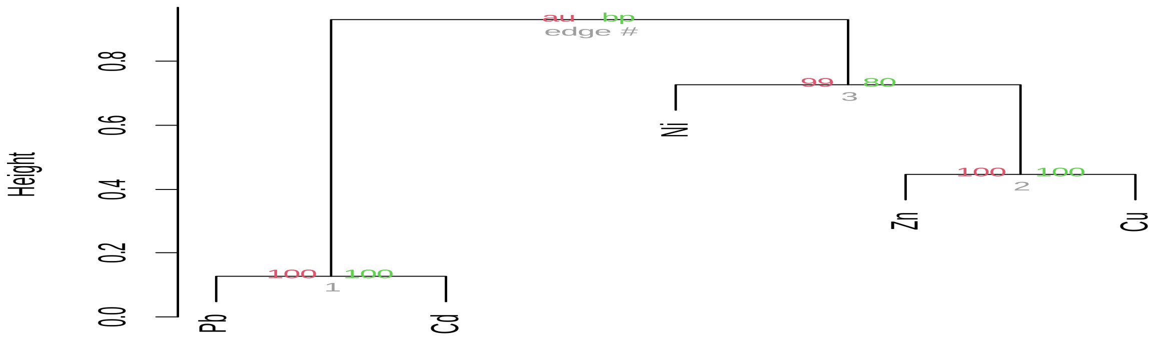

Figure 5: Cluster dendrogram

The bi-plot suggest that there were two clusters groups for the heavy metals in Ikorodu dust (Figure 4). We used hierarchical clustering because the datasets were small and continuous in nature and its' represented by dendrogram (Figure 5). There are two clusters 1(Pb and Cd) and Cluster 2 (Zn , Cu and Ni). The heavy metals in each cluster are from the same origin or Source i.e Traffic / vehiculest, industrial activities, industrial wastes, Waste dumpsite/ improper disposal of domestic wastes and sewage industrial activities, combustion of fossil fuels, gasoline and diesel exhaust. The results of the cluster analysis is in agreement with the results from the Principal component analysis Factor 1 PC1- Cluster 1 - Pb (0.879) and Cd (0.984), Factor 2 PC2 - Cluster 2 - Zn (0.877), Cu (0.887) and Ni (0.765) and Pearson's significant correlation analysis.

CONCLUSION

The high levels of Zn 79.4 , Pb 14.8 , Cu 0.9 , Ni 4.9 and Cd 0.01 % obtained in the dust samples from Ikorodu area could be attributed to anthropogenic activities such as traffic/vehicular emission, industrial activities, industrial wastes, Waste dumpsite/ improper disposal of domestic wastes and sewage, lubricating oil, diesel fuel and brake wear. The low concentration of Cadmium Cd suggest low contributing factors to their spread and as well as the dust inability to preferentially accumulate this metal. Therefore, there is need for constant environmental Monitoring of Ikorodu area dust due to the high concentration of heavy metal pollution which could be very hazardous to human and plants existence.

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CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

REFERENCES

Abadin, H., Ashizawa, A., Stevens, Y. W., Fernando, L., Gary, D., Gloria, S., Mario, C., Antonio, Q., Stephen, J. B. and Steven, G. (2007). *Toxicological Profile for Lead*. Agency for Toxic Substances and Disease Registry (US), Atlanta (GA).

Abbasi, S., Keshavarzi, B., Moore, F., Hooke, P. K., Kelly, F.J. and Dominguez, A. O. (2020). Elemental and magnetic Analyses, source identification and oxidative potential of airborne, passive, and street dust particles in Asaluyeh County, Iran. *The Sci. of the Total Environment*, 707 (10), 136132.

Adie, P. A., Torsabo, S. T., Uno, U. A. and Ajegi, J. (2014). *Funaria hygrometrica* Moss as bioindicator of atmospheric pollution of heavy metals in Makurdi and Environs, North Central Nigeria. *Research J. of Chem. Science*, 4(10), 10 - 17.

Aguilera, A., Armendariz, C., Quintana, P., Garcia - Oliva, F. and Bautista, F. (2019). Influence of land use and road type on the elemental composition of urban dust in a Mexican metropolitan area. *Polish J. of Environ. Studies*, 28, 1535 - 1547.

Amato, F., Alastuey, A., De La Rosa, J., Gonzalez Castanedo, Y., Sánchez de la Campa, A. M., Pandolfi, M., Lozano, A., Contreras González, J. and Querol, X. (2014). Trends of road dust emissions contributions on ambient air particulate levels at rural, urban and industrial sites in southern Spain. *Atmos. Chem. Phys., 14*, 3533 - 3544.

Bawuro, A., Voegborlo, R. and Adimado, A. (2018). Bioaccumulation of heavy metals in some tissues of fish in Lake Geriyo, Adamawa State, Nigeria. *J. of Env. and Public Health*, 1, 1-7.

Benhaddya, M. L., Boukhelkhal, A., Halis, Y. and Hadjel, M . (2016). Human health risks associated with metals from urban soil and road dust in an oilfield area of South eastern Algeria. *Arch. Environ. Contam. Toxicolology*, 70, 556 - 571.

Bhuiyan, M. A. H., Dampare, S. B., Islam, M. A. and Suzuki, S. (2015). Source apportionment and pollution evaluation of heavy metals in water and sediments of Buriganga River, Bangladesh, using multivariate analysis and pollution evaluation indices. *Environ. Monitoring Assessment*, 187, 4075.

Briffa, J., Sinagra, E. and Blundell, R. (2020). Heavy metal pollution in the environment and their toxicological effects on humans. *Heliyon*, 6.

Budai, P. and Clement, A. (2018). Spatial distribution patterns of four traffic-emitted heavy metals in urban Road dust and the resuspension of brake-emitted particles: Findings of a field study. *Transp. Res. D Transp. Environ*., 62, 179 - 185.

Buxton, S., Garman, E., Heim, K. E., Darden, T. L., Schlekat, C. E., Taylor, M. D. and Oller, A. R. (2019). Concise review of nickel human health toxicology and ecotoxicology. *Inorganics*, 7, 89.

Cao, Y., Chen, A., Radcliffe, J., Diletrich, K., Jones, R. L., Caldwelli, K. and Rogan, W. J. (2009). Postnatal cadmium exposure, neurodevelopment and blood pressure in children at 2, 5 and 7 years of age. *Env.. Health Perspect.*, 117, 1580 -1586.

Chopra, K., Pathak, C. and Prasad, G. (2009). Scenario of heavy metal contamination in agricultural soil and its management. *J. of Appl. and Nat. Sciences*, 1, 99 - 108.

Christoforidis, A.N. and Stamatis, N. (2009). Heavy metal contamination in street dust and roadside soil along the major national road in Kavala's region, Greece, *Geoderma.,* 151, 257 - 263.

Cui, Y. J. D., Chen, H., Gao, M., Maenhaut, W., He, J. and Wang, Y. (2019). Characteristics and sources of Hourly trace elements in airborne fine particles in urban Beijing, China. *J. of Geophy. Research*, 24, 11595 - 11613.

Duan, Z. B., Wang, J., Zhang, Y. X. and Xuan, B. (2017). Assessment of Heavy metals Contamination in Road Dust from Different Functional Areas in Guiyang, Southwest, China. *Inter. J. of Environ. Sci. Educ.*, 12, 427- 439.

Dytłow, S. and Górka - Kostrubiec, B. (2021). Concentration of heavy metals in street dust: An implication of using different geochemical background data in estimating the level of heavy metal pollution. *Environ. Geochem. Health*, 43, 521 - 535.

Ekpo, B. O., Uno, U. A., Adie, A. P. and Ibok, U. J. (2012). Comparative Study of Levels of Trace Metals in Moss Species in Some Cities of the Niger Delta Region of Niria. *Inter. J. of Appl. Science and Technology*, 2(3), 1- 9.

Enuneku, A., Biose, E. and Ezemon ye, L. (2017). Levels, distribution, characterization and ecological risk assessment of heavy metals in road side soils and earthworms from urban high traffic areas in Benin metropolis, Southern Nigeria. *J. of Environ., Chem. Engr.*, 5(3), 2773.

European Commission 2006. Regulation (EC) No 1881/2006. JO L, 364, 5 -24.

Faroon, O., Ashizawa, A., Wright, S., Tucker, P., Jenkins, K., Ingerman, L. and Rudisill, C. (2012). *Toxicological Profile for Cadmium*. Agency for Toxic Substances and Disease Registry (US), Atlanta (GA).

Foti, L., Dubs, F., Gignoux, J., Lata, J., Lerch, T. Z., Mathieu, J., Nold, F., Nunan, N., Raynaud, X., Abaddie, L. and Barot. S. (2017). Trace element concentrations along a gradient of urban pressure in forest and lawn soils of the Paris region (France). *The Sci. the Total Env*., 598, 938-948.

Han, Y.M., PX, D. U., Cao, J. J. and Posmentier, E. S. (2006). Multivariate analysis of heavy metal contamination in urban dusts of Xi'an, Central China. *The Sci. of the Total Env.*, 355, 176 - 186.

Heidari, M., Darijani, T. and Alipour, V. (2021). Heavy metal pollution of road dust in a city and its highly polluted suburb; Quantitative source apportionment and source - specific ecological and health Risk assessment. *Chemosphere*, 273, 129656.

Hussain, K., Rahman, M., Prakash, A. and Hoque, R. R. (2015). Street dust bound PAHs, carbon and heavy metals in Guwahati city - Seasonality, toxicity and sources. *Sustainable Cities Soc*., 19, 17 - 25.

Hwang, H.M., Fiala, M. J., Park, D. and Wade, T. L . (2016). Review of pollutants in urban road dust and stormwater runoff: Part 1. Heavy metals released from vehicles. *Inter. J. of Urban Science*, 20, 334 - 360.

Jahandari, A. (2020). Pollution status and human health risk assessments of selected heavy metals in urban dust of 16 cities in Iran. *Environ. Sci. Pollut. Research*, 27, 23094 - 23107.

Jeong, H.Y., Lee, J. H., Kim, K. T., Kim, E. S. and Ra, K. T. (2019). Identification on Metal Pollution Sources in Road Dust of Industrial Complex Using Magnetic Property around Shihwa Lake Basin. *J. of Korean Soc. Mar. Environ. Energy*, 22, 18 - 33.

Kara, M. (2020). Assessment of sources and pollution state of trace and toxic elements in street dust in a metropolitan city. *Environ. Geochem Health*, 42(10), 3213.

Karbassi, A.R., Nabi - Bidhendi Gh, R. and Bayati, I. (2005). Environmental geochemistry of heavy metals in a sediment core off Bushehr, Persian Gulf, Iran. *J. of Environ. Health Sci. Engineering*, 2, 225 - 260.

Keshavarzi, B., Abbasi, S., Moore, F., Mehravar, S., Sorooshian, A., Soltani, N. and Najmeddin, A. (2018). Contamination level, source identification and risk assessment of potentially toxic elements (PTEs) and polycyclic aromatic hydrocarbons (PAHs) in street dust of an important commercial center in Iran. *Environ. Management*, 62(4), 803 - 818.

Kui, C. and Chang, L. (2019). Street dust heavy metal pollution source apportionment and sustainable management in a typical city - Shijiazhuang, China. *Inter. J. Environ. Res. Public Health*, 2625, 1-16.

Li, H. H., Chen, L. J., Yu, L., Guo , Z., Shan, C., Lin, J., Gu, Y., Yang, Z., Yang, Y., Shao, J., Zhu, X. and Cheng, Z. (2017). Pollution characteristics and risk assessment of human exposure to oral bioaccessibility of heavy metals via urban street dusts from different functional areas in Chengdu, China. *The Sci. of the Total Environment*, 586, 1076 - 1084.

Li, Y.Y., Li, Z.P., Xiong, H.L., Chen, Y.C. and Dai, Y. (2015). Health risk assessment of street dust and heavy Metal pollution in Chongqing. *J. of Southwest Univ. (Nat. Sci. Ed.)*, 37(2), 18 - 23.

Li, K. J., Zhu, X., Yu, W. X. and Yu, Y. N. (2020). Particle size, spatial variations and pollution source apportionment of street dust from a typical Industrial district in Wuhan, China. *Appl. Ecology and Env. Res.*, 18(2), 3331- 3347.

Liu, E., Yan, T., Birch, G. and Zhu, Y. (2014). Pollution and health risk of potentially toxic metals in urban road dust in Nanjing, a mega-city of China. *The Sci. of the Total Environment*, 476, 522 - 531.

Liu, J., Liang, J.,Yuan, X., Dong, H., Zeng, G., Wu, H., Wang, H., Liu, J., Hua, S., Zhang, J., Yu, Z., He, X. and He, Y. (2015). An integrated model for assessing heavy metal exposure risk to migratory birds in wetland ecosystem: A case study in Dongting Lake Wetland, China. *Chemosphere*, 135, 14 -19.

Liu, M., Cheng, S. B., Ou, D. N., Hou, L. J., Gao, L., Wang, L., Xie, Y. S., Yang, Y. and Xu, S.Y. (2007). Characterization, identification of road dust PAHs in central Shanghai areas, China. *Atmos. Environ*. 41, 8785 - 8795.

Lorenzi, D., Entwistle, J. A., Cave, M. and Dean, J. R. (2011). Determination of polycyclic aromatic hydrocarbons in urban street dust; implications for human health. *Chemosphere*, 83, 970 - 977.

Lu, X., Wang, L., Li, L. Y., Lei, K., Huang, L. and Many, D. (2010). Multivariate statistical analysis of heavy metals in street dust of Baoji, N. W. China. *J. Hazard Mater.*, 173, 744-749.

Lu, X., Wu, X., Wang, Y., Chen, H., Gao, P. and Fu, Y. (2014). Risk assessment of toxic metals in street dust from a medium - sized industrial city of China. *Ecotoxicol. Env.*. Saf, 106, 154 - 163.

Lv, J. (2019). Multivariate receptor models and robust geostatistics to estimate source apportionment of heavy metals in soils. *Environ. Pollution,* 244, 72 - 83.

Men, C., Liu, R., Xu, F., Wang, Q., Guo, L. and Shen, Z. (2018). Pollution characteristics, risk assessment and source apportionment of heavy metals in road dust in Beijing, China. *The Sci. of the Total Environment*, 612, 38 - 147.

Men, C., Liu, R., Wang, Q., Guo, L., Miao, Y. and Shen, Z. (2019). Uncertainty analysis in source apportionment of heavy metals in road dust based on positive matrix factorization model and geographic information system. *The Sci. of the Total Environment*, 652, 27-39.

Men, C., Liu, R., Xu, L., Wang, Q., Guo, L., Miao, Y. and Shen, Z. (2020). Source - specific ecological risk analysis and critical source identification of heavy metals in road Dust in Beijing China. *J. of Hazard Materials*, 388.

Mohsen, S., Loretta, Y. L. and Mahdiyeh, S. (2012). Heavy metals and polycyclic aromatic hydrocarbons: Pollution and ecological risk assessment in street dust of Tehran. *J. of Hazard. Materials*, 227 - 228, 9 -17.

Moses, K. S., Whiting, V. A., Bratton, R. G., Taylor, J. R. and O'hara, M. T. (2009). Inorganic nutrients and contaminants in subsistence species of Alaska: Linking wildlife and human health. *Inter. J. of Circumpol. Health*, 68, 53-74.

Ojiodu, C. C., Damazio, O. A. and Oshin, T. T. (2023a). Assessment and source apportionment of heavy - metals (Zn, Pb, Cu, Ni, Cd) on street dust of Oshodi - Isolo Area, Lagos State, Southwestern Nigeria. *Nigerian J. of Environ. Sci. and Technology (NIJEST)*, 7(2), 203 - 216.

Ojiodu, C. C. and Elemike, E. E. (2017). Biomonitoring of Atmospheric heavy metals in Owode - Onirin, Ikorodu, Lagos, Using Moss *Barbular indica* (Hook.) Spreng. *J. of Chemical Society of Nigeria*, 42(2), 96 - 100.

Ojiodu, C. C., Eruola, A. O., Chinweoke, N. L., Haruna, A. D. and Jesse, W. A. (2022a). Assessment of heavy metals (Zn, Pb, Cu, Ni, Cd) on street dust: A case study of Oshodi-Isolo Area, Lagos - State, Southwestern – Nigeria. *Inter. J. of Sci. and Soc.*, 8(1), 73 - 82.

Ojiodu, C. C., Eruola, A. O., Chinweoke, N. L., Haruna, A. D. and Jesse W. A. (2022b). Heavy metals presence in street dust of Ikeja Area of Lagos - State, Southwestern- Nigeria, *Inter. J. of Science and Society*, 8(1), 121 -132.

Ojiodu, C. C., Eruola, A. O., Damazio, O. A. and Oshin, T. T. (2023b). Characteristic Distribution and Source Apportionment of Heavy Metals (Zn, Pb, Cu, Ni and Cd) on Street Dust of Ikeja Area of Lagos State, Southwestern Nigeria. *Nig. J. of Env.. Sci. and Techn. (NIJEST)*, 7(2), 217 - 231.

Ojiodu, C. C., Moses, D. U., Damazio, O. A. and Oshin, T. T. (2023c). Appraising heavy - metals distribution in Street Dust of Ketu - Mile 12 Area of Lagos - State, South-Western Nigeria. *Nig. J. of Env.. Sci. and Techn.*, 7(2), 277 - 290.

Ojiodu, C. C., and Olumayede, E. G. (2018). Biomonitoring of heavy metals using *Polytrichum commune* as a bioindicator in a Macroenvironment, Lagos - State, Southwestern – Nigeria. *FUW Trends in Sci. & Tech. Journal*, 3(1), 287- 291.

Ojiodu, C. C., Olumayede, E. G. and Okuo, J. M. (2018). The level of heavy metals in the atmosphere of a microenvironment, Lagos state, southwestern - Nigeria using Moss plant (*Dicranium scorparium*) as Bioindicator. *Sci. World J.*, 13(4), 69 - 74.

Olowoyo, J. O., Mugivhisa, L. L. and Magoloi, Z. G. (2016). Composition of trace metals in dust samples collected from selected high schools in Pretoria, South Africa. *Appli. Environ. Soil Sci.*, pp. 1 - 9.

Pan, H., Lu, X. and Lei, K. (2017). A comprehensive analysis of heavy metals in urban road dust of Xi'an, China: Contamination, source apportionment and spatial distribution. *The Sci. of the Total Environment*, 609, 1361 - 1369.

Praveena, S. M.(2019). Characterization and risk analysis of metals associated with urban dust in Rawang (Malaysia). *Arch. Environ. Contam. Toxicology*, 75, 415 - 423.

Qin - Qin, L., Yi - Ting, G. and Jing-sheng, L. (2023). Review on main sources and impacts of Urban Ultrafine particles: Traffic emission, nucleation and Climate modulation. *Atmos. Environ*., 19, 1- 17.

Querol, X., Viana, M., Alastuey, A., Amato, F., Moreno, T., Castillo, S., Pey, J., De la Rosa, J., De La Campa, A. S., Artíñano, B. and Salvador, P. (2007). Source origin of trace elements in PM from regional background, urban and industrial sites of Spain. *Atmos. Environ.*, 41, 7219 - 7231.

Rahman, M. S., Khan, M. D. H., Jolly, Y. N., Kabir, J., Akter, S. and Salam, A. (2019). Assessing risk to human health for heavy metal contamination through street dust in the Southeast Asian Megacity: Dhaka, Bangladesh. *The Sci. of the Total Env*., 660, 1610 - 1622.

Rai, P., Furger, M., Slowik, J. G., Zhong, H., Tong, Y., Wang, L., Duan, J., Gu, Y., Qi, L., Huang, R. J. and Cao, J. (2021). Characteristics and sources of hourly elements in PM10 and PM2.5 during winter time in Beijing. *Environ. Pollution*, 278, 116865.

Ramírez, O., de la Campa, A. S., Amato, F., Catacolí, R. A., Rojas, N. Y. and de la Rosa, J. (2018). Chemical composition and source apportionment of PM10 at an urban background site in a high - altitude Latin American megacity (Bogota, Colombia). *Environ. Pollution*, 233, 142 - 155.

Reyes, B. A., Bautista, F., Goguitchaichvili, A., Contreras, J. M., Owen, P. Q., Carvallo, C. and Battu, J. (2013). Rock - magnetic properties of top soils and urban dust from Morelia (>800,000 inhabitants), Mexico: Implications for anthropogenic pollution monitoring in Mexico's medium size cities. *Geofis. Int.*, 52, 121 - 133.

Roney, N., Osier, M., Paikoff, S. J., Smith, C. V. , Williams, M. and De Rosa, C. T. (2006). ATSDR evaluation of the health effects of zinc and relevance to public health. *Toxicology Industrial Health*, 22, 423 - 493.

Sahakyan, L., Maghakyan, N., Belyaeva, O., Tepanosyan, G., Kafyan, M. and Saghatelyan, A. (2016). Heavy metals in urban dust: Contamination and health risk assessment: A case study from Gyumri, Armenia, Arab. *J. of Geoscience*. 9:142.

Salwan, A. A., Safaa, A. K., Salam, H. E. and Nadhir, A. (2020). Bioaccumulation and health risk assessment of severe metal pollution of street dust from various urban regions in Baghdad, Iraq. *E3S Web of Conferences*, 158, 1 - 6.

Saghatelyan, A., Sahakyan, L., Belyaeva, O. and Maghakyan, N. (2014). Studying atmospheric dust and heavy metals on urban sites through synchronous use of different methods. *J. of Atmos. Pollution*, pp. 12 - 16.

Schweizer, C., Edwards, R. D., Bayer-Oglesby, L., Gauderman, W. J., Ilacqua, V., Juhani Jantunen, M., Hak Kan, L., Mark, N. and Nino, K. (2007). Indoor time -microenvironment-activity patterns in seven regions of Europe. *J. of Exp. Sci. and Env. Epidemiol.*, 17(2), 170-181.

Shabbaj, I. I., Alghamdi, M. A., Shamy, M., Hassan, S. K., Alsharif, M. M. and Khoder, M. I. (2018). Risk Assessment and Implication of Human Exposure to Road Dust Heavy Metals in Jeddah, Saudi Arabia. *Inter. J. of Environ. Res. Public Health*, pp. 15, 36.

Shinggu, D. Y., Ogugbuaja, V.O., Barminas, J. T. and Toma, I. (2007). Analysis of Street Dust for Heavy metal Pollutants in Mubi, Adamawa State, Nigeria. *Int. J. of Phy. Sci*., 2(1), 290-293.

Soltani, N., Keshavarzi, B., Moore, F., Tavakol, T., Lahijanzadeh, A. R., Jaafarzadeh, N. and Kermani, M. (2015). Ecological and human health hazards of heavy metals and polycyclic aromatic hydrocarbons (PAHs) in road dust of Isfahan metropolis, Iran. *The Sci. of the Total Environment*, 505, 712 - 723.

Suryawanshi, P. V., Rajaram, B. S., Bhanarkar, A. D. and Chalapati Rao, C. V. (2016). Determining heavy metal contamination of road dust in Delhi, India. *Atmósfera.*, 29, 221 - 234.

Tanner, P., Lingma, H. and Yu, P. K. N. (2008). Fingerprinting metals in urban street dust of Beijing, Shanghai and Hong Kong. *Environ. Sci. Technology*, 42, 7111 - 7117.

Taylor, A. A., Tsuji, J. S. , Garry, M. R., Mckardle, M. E., Goodfellow, W. E., Adams, W. J. and Menzie, C. A. (2020). Critical review of exposure and effects: Implications for setting regulatory health criteria for ingested copper. *Environ. Management*, 65, 131-159.

Trujillo - Gonzalez, J. M., Torres - Mora, M. A., Keesstra, S., Brevik, E. C. and Jimenez-Ballesta, R. (2016). Heavy metal accumulation related to population density in road dust samples taken from urban sites under different land uses. *The Sci. Total Env.*, 553, 636 - 642.

Valotto G., Rampazzo, G., Visin, F., Gonella, F., Cattaruzza, E., Glisenti, A., Formenton, G. and Tieppo, P. (2015). Environmental and traffic - related parameters affecting road dust composition: A multi- technique approach applied to Venice area (Italy). *Atmos. Environ*., 122(8), 596 - 608.

Wang, H., Shen, C., Kang, Y., Deng, Q. and Lin, X. (2020). Spatial distribution of pollution characteristics and human health risk assessment of exposure to heavy elements in road dust from different functional areas of Zhengzhou, China. *Environ. Sci. Pollution Research*, 27(21), 26650.

Wang, Q., Lu, X. and Pan, H. (2016). Analysis of heavy metals in the re-suspended road dusts from different functional areas in Xi'an, China. *Environ. Sci. Pollution Research*, 23, 19838 - 19846.

Wei, B., Jiang, F., Li, X and Mu, S. (2009). Spatial distribution and contamination assessment of heavy metals in urban road dusts from Urumqi, NW China. *Microchem., J.* 93, 147 - 152.

Xiao, Q., Zong, Y., Malik, Z. and Lu, S. (2020). Source identification and risk assessment of heavy metals in road dust of steel industrial city (Anshan), Liaoning, Northeast China. *Hum. Ecolog. Risk Assess.* 26, 1359 - 1378.

Xu, Z., Mi, W. B., Mi, N., Fan, X. G., Zhou, Y. and Tian, Y. (2020). Characteristics and sources of heavy metal pollution in desert steppe soil related to transportation and industrial activities. *Environ. Sci. Pollution Research*, 27(31), 1 - 14.

Yadav, I. C., Devi, N. L., Singh, V. K., Li, J. and Zhang, G. (2019). Spatial distribution, source analysis, and health risk assessment of heavy metals contamination in house dust and surface soil from four major cities of Nepal. *Chemosphere*, 218, 1100 - 1113.

Yu, Y., Ma, J., Song, N., Wang, X., Wei, T., Yang, Z. and Li, Y. (2016). Comparison of metal pollution and health risks of urban dust in Beijing in 2007 and 2012. *Env. Monitor. Assessment*, 188, 1 - 11.

Zhang, C., Qiao, Q. and Appel, E. B. (2012). Discriminating sources of anthropogenic heavy metals in urban street dusts using magnetic and chemical methods. *J. of Geochem. Exploration*, pp. 60 - 75, 119 - 120.

Zhe, X., Wenbao, M., Nan, M, I., Xingang, F., Ying, T., Yao, Z. and Ya-nan, Z. (2021). Heavy metal pollution characteristics and health risk assessment of dust fall related to industrial activities in desert steppes. *Peer J.*, 9: 1-26.