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The Distribution and Sources of Heavy Metals in Fine Particulate Matter in an Indoor Micro Environment of a Residential Area of Lagos state, Nigeria

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Abstract: *Clean air is very vital for the continual existence of man and all other higher forms of life on Earth. Unfortunately, anthropogenic activities such as industrialization and urbanization have significantly impaired the atmospheric air composition. Particulate matter (PM) comprises of different particles but, trace metals and trace organic compounds are the major components of PM that raise the most health concern. In general, PM and its content have enormous economic and social negative adverse impacts on man and his environment. This study aims at collecting base-line information of total suspended particulates (TSP) in an indoor micro environment in a residential area of Lagos state which might be necessary to develop existing air quality criteria and air quality standards. Samples were collected from July, 2016 to June, 2017 using a portable high volume sampler (Hi-Q CF – 901). The weight of samples collected were determined gravimetrically and thereafter, analyzed for elemental concentrations using Atomic Absorption Spectroscopic (AAS) method. The elemental concentrations were subjected to Principal Component Analysis (PCA) for source identification and Analysis of Variance (ANOVA) for temporal variation. The results show a high base-line concentrations range of 833.33-1944.45 µgm-3and 1111.11-2777.78 µgm-3 during the wet and dry season of the sampling period respectively. The result of the PCA identified road dust, vehicular emission and waste burning as the predominant sources of emission to the environment. The ANOVA result shows that there was no significant temporal variation in most of the analysed metals. Conclusively, results obtained show that, pollutants concentration in most of the sites were higher than safe limits proposed by regulatory bodies.*

Keywords: *Indoor, Air pollution, Heavy metals, Source identification, Temporal variation*

1. INTRODUCTION

Air pollution is a now a major issue both in developing and developed countries globally as a result of its adverse impacts on human health, visibility degradation and global climate change. [1, 2, 3, 4].Air pollution can be grouped into two categories: outdoor air pollution (OAP) and indoor air pollution (IAP) [5]. The indoor air pollution refers to air pollution in the indoor micro environment and can occur from a wide variety of sources depending on the type of activities and processes taking place [6]. Another source of indoor air pollution is the outdoor air. The most important environment that relates to human health is the indoor environment since, people spend as much as 90% of their time indoors [7]. Consequently, indoor air quality (IAQ) has gained great attention in recent years as it is considered one of the top five environmental risks to the public's health. The Environmental Protection Agency (EPA) defines IAQ as "the air quality within and around buildings and structures, especially as it relates to the health and comfort of building occupants" [8]. Air quality testing in homes across the United States estimated that 96% of homes had at least one problem with IAQ; approximately 85% had elevated concentrations of particulates and bioaerosols and approximately 71% were filled with odors and potentially harmful chemicals and gases [9].

Studies have revealed that, air pollutants are about two to five times higher indoors compared to outdoors and can even be 100 times higher than outdoor levels [10, 11]. It can even be worse in overcrowded, poorly ventilated, old homes and poor prevailing metrological factors [12]. Hence, indoor pollution is presumed to be more harmful than outdoor pollution. Global data shows that, IAP is far more lethal than OAP. Indoor air contaminants can cause acute or chronic health problems [13, 14,15]. Previous research has associated acute health problems such as headache, nausea and respiratory infections to the quality of the indoor air [16]. It has been estimated that about half a million women and children die yearly from indoor air pollution in India [17]. According to World Health Organization (WHO), indoor pollution resulting from cooking stove, caused the death of 1.6 million people in 2006; of the 1.6 million deaths, 396,000 deaths occurred in sub - Sahara Africa with highest incidents in Nigeria [18. 19]. Another WHO report posited that 78% of African population use charcoal and firewood burning (biomass fuel) for cooking and that, a third of infant deaths associated with IAP occurred in Africa [20]. Also, a recent comparative risk study by the organizationshow that, 28% of the overall disease and deaths is caused by indoor air particulate matter in developing countries.

Knowing and controlling common indoor air pollutants can help reduce the risk of indoor health concerns [8]. Also, eliminating the source of the pollution amongst others can help to control IAQ [21]. This study focuses on base data collection of TSP, elemental content determination and source identification of pollutants in the indoor micro environment ofa residential area in Lagos State, Nigeria.

2. MATERIALS AND METHODS

2.1. Sampling Site Description

The TSPsamples from which the analyzed metals in this study were extracted and quantified, were collected from three locations in Akoka, a residential area within the Lagos metropolis.Prominent in this area are: residential homes, banks, small-scale businesses, tertiary institutions, artisans and more to be mentioned. Man-made activities in the above mentionedplaces are capable of releasing pollutants into the atmosphere.

Site 1 is a food vendor that uses charcoal as the cooking fuel and with alot of cooking activities. Site 2 is a home located along a busy street around a busy bus-stop. It uses kerosene as the cooking fuel. Site 3 is a restaurant situated between two banks. Also, situated close by, is a campus shuttle, business centres and other man-made activities capable of generating pollutants.This site uses liquefied petroleum gas (LPG) as a cooking fuel. The sampling sites are as shown on figure 1.

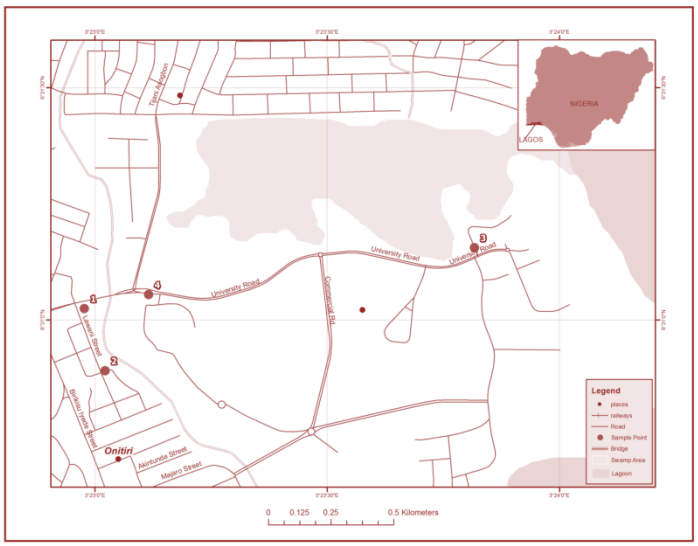

Figure1. *Map of Akoka showing the sampling sites*

2.2. Sample Collection

TSP sample was collected on a pre-weighed filter using a portable gravimetric air sampler (Hi-Q CF – 901) at a flow rate of 2.5 L/minfor 8 hours between 8:00 am and 4: pm and at a height of about 1.6 m

on each sampling occasion. Sampling was carried out from July 2016 to June 2017; this period covers the wet and dry season of the sampling period. For each sampling, the filter and cassette was humidity conditioned (equilibrated) in a charged desiccator for 24 hours and weighed before and after sampling. After sampling, the loaded filter was stored in sealed polythene bag and taken to laboratory for sample preparation and elemental analysis by Atomic Absorption Spectroscopy (AAS).

2.3. Sample Preparation

The loaded filter paper was carefully placed inside a 100 ml beaker. 10 ml of nitricacidwas added and heated at 150^0C in a fume cupboard. The sample was intermittently spiked with 5 ml perchloric acid after an hour and was heated for three hours until a clear solution was observed. The digest was cooled, filtered into 100 ml standard volumetric flask and diluted with distilled water to the ml mark in the 100 ml volumetric flask. A blank sample was prepared in the same manner. Elemental analysis was then carried out on the final digest and the blank using Perkin Elmer A Analyst 400 atomic absorption spectrophotometer. The blank concentration was duly subtracted from the obtained concentration. The alkali and alkali-earth metals were analyzed using Sherwood Model 410 Flame Photometer.

2.4.Principal Component Analysis (PCA)

Multivariate factor analysis was used to identify a probable number of contributing source factors to metals emission at the sampling sites [22, 23]. The elemental concentrations of the TSP samples were subjected to PCA with varimax rotation and only factors with eigen values ≥ 1 were considered significant and retained [24].

2.5. Analysis of Variance (ANOVA)

In order to determine the seasonal variation of the elemental concentrations in the various sampling sites, the concentrations of the analyzed metals for the two seasons were subjected to ANOVA.

3. RESULTS AND DISCUSSION

The mass concentrations obtained in the indoor micro environments during the study period is depicted in Table 1.

Table1. *Mass Concentration of Total Suspended Particulates (TSP) in $\mu g/m^3$*

	Wet Season			Dry season		
	Minimum	**Maximum**	**Mean±S.D**	**Minimum**	**Maximum**	**Mean±S.D**
Site 1	833.33	2500.00	1945.44±96.23	2500.00	3333.33	2777.78±48.11
Site 2	833.33	1666.67	1388.89±48.11	416.67	2500.00	1527.78±120.28
Site 3	416.67	1666.67	833.34±72.17	833.33	1666.67	1111.11±48.11
Gross mean mass concentration 1389.22				**Gross mean mass concentration** 1805.56		

The mean mass concentration obtained in the indoor micro environment in the study area ranged from 833.34 to 1945.44 $\mu gm^{-3}$with a gross mean mass concentration of 1389.22 μgm^{-3} during the wet season and 1111.11 to 2777.78 $\mu gm^{-3}$with a gross mean mass concentration of 1805.56 μgm^{-3} during the dry season of the sampling period. The highest and lowest mean concentration was obtained in site 1 and site 3 respectivelyin both seasons (Table 3.1a). The mean concentration in all the sites clearly violate the statutory limit of 230 μgm^{-3} stipulated by the World Health Organization [25] and 150-250 μgm^{-3} by Federal Ministry of Health [26]. These high concentrations obtained is a signature of high human activities and the variation in concentrations,is mostly likely connected with variations in human activities in the various sites.

Table2. *Comparison of Indoor-Outdoor Total Suspended Particulate Matter Results (μgm^{-3}) of this Study with others*

S/N	Site/Location	Indoor concentration	References
1	Urban/Lagos	833.33-2777.78	Current Study
2	Urban/Riyadh	62-473	[27]
3	Urban/Kosice	59.03-114.58	[28]

4	Urban/Benin City	243.05-451.39	[4]
5	Rural/Iyowa	425.92-1444.00	[29]
6	Rural/China	2000	[30]
7	Urban/Saudi Arabia	1845.90	[31]
8	Urban/Zagreb	90.00	[32]
9	Urban/Bomby	118.00	[32]
10	Urban/Toronto	68.00	[32]
	WHO	230	[25]
	FME	150-250	[26]

The concentrations of TSP recorded in this study and in some other studies (Table 3) are quite above the limits stipulated by regulatory bodies [25, 26] and this is a signature of anthropogenic contributions that requires air regulatory enforcement

3.1. Elemental Concentration

One of the most toxic constituents of atmospheric particulates is heavy metals (HMs) and so, environmental contamination and exposure to HMs is a serious growing problem across the globe as their occurrence in air contributes to substantial health effects [33]. Unfortunately, exposure cannot be totally averted in today's society as the society depends on them for proper functioning. As a matter of fact, human exposure to HMs has risen drastically in the past 5 decades owning to an exponential increase in their uses in industrial and agricultural processes.Several occupations involve exposure to HMs daily; over 50 professions entail exposure to Hg alone [34].

The mean elemental concentrations of HMs analysed in the indoor micro environments during the wet and dry seasons of the sampling period are presented in Table 3and Table 4 respectively.

Table3. *Mean Elemental Concentration (μgm^{-3}) of Total Suspended Particulate Matter during the Wet Season*

Elements	Site 1	Site 2	Site 3
	Mean±S.D	**Mean±S.D**	**Mean±S.D**
Pb	1.06±0.30	1.14±0.23	0.27±0.19
Cd	0.09±0.13	0.16±0.05	0.84±0.07
Cu	0.05±0.01	0.08±0.02	0.05±0.06
Ni	1.17±0.22	1.32±0.35	1.27±0.13
Fe	1.78±0.18	2.09±0.28	2.01±0.26

Table4. *Mean Elemental Concentration (μgm^{-3}) of Total Suspended Particulate Matter during the Dry Season*

Elements	Site 1	Site 2	Site 3
	Mean±S.D	**Mean±S.D**	**Mean±S.D**
Pb	1.12±0.26	1.26±0.07	0.46±0.33
Cd	0.16±0.16	0.38±0.19	0.80±0.13
Cu	0.09±0.11	0.10±0.02	0.13±0.10
Ni	1.21±0.44	1.56±0.35	1.29±0.83
Fe	2.12±1.60	2.29±0.65	2.94±0.85

Apart from Cu, the mean concentration of the analyzed HMs in the various site were high. This can be attributed to vehicular emission, road dust, waste burning amongst others. The highest mean concentration of the HMs was observed in site 2. This is probably due to the location of the site, emission sources, dispersion conditions, occupants behavior amidst other factors. The highest level of Pb recorded in this site may not be unconnected with the age of the building and nature of paint used. It has been reported that emulsion and gloss types of paints currently manufacture and sold in Nigeria contained substantial levels of Pb[35]. Another reason for this elevated level of Pb detectedin this site and other sites in this study could beas a result of emissions from automobile exhaust and non exhaust since,all the sites are near possible automobile source of emission. Ambient lead concentrations typically peak near busy roadways. High traffic density increases the availability of Pb in the environment. This implies that, Pb is still being released or re- suspended by vehicle traffic because, it has long residence time[36].

The concentrations of the HMs measured during the wet season, were relatively lower than that measured during the dry season in the various sites. The low concentration of metals observed in the wet season might be attributed to metrological factors such as: (i)lower air temperature (ii) higher

humidity, (ii)higher wind speed and(iii) increase in cloud covers and consequently, increase in the number of rainfall days experienced during the wet season. These factors help in minimizing the concentration of accumulated aerosol, trace metals and gaseous materials in air. At high humidity particulates are trapped in water molecules and later washed down via wet deposition. Also, the greater the wind speed, the greater the turbulence and the more rapid and complete the dispersion of contaminants in the air [37].

3.2. Principal Component Analysis (PCA)

The probable sources of metals emission in the study area were determined from the result of the PCA. During the wet season, two major factors were extracted which explained more than 76% of the cumulative variance. The elements in a particular factor loading, gives an indication of the possible source of emission. Factor 1 (PC1) which comprises of Cu, Ni, Fe may be attributed to road dust source. Factor 2 (PC2) loaded primarily by Pb, Cd and Cu. This factor may be attributed to waste burning. During the dry season, Factor 1 (PC1) loaded heavily on Cd, Cu, Ni. This factor may be attributed to waste burning. Factor 2 (PC2) loaded primarily by Cd and Fe. This is most likely related to road dust. Factor 3 (PC3) which loaded primarily by Pb and Ni.may be attributed to vehicular emissions.

3.2.1. Temporal variations of elemental concentration

In order to determine the temporal variation of the elemental concentrations in the various sampling sites, the concentrations of the analyzed metals for the two seasons were subjected to ANOVA. The result of the ANOVAis as shown in Table 5.

Table5. *Temporal variations of Elemental Concentrations*

	Wet season	Dry season	P
Site 1			
Pb	1.06 ± 0.30^{a}	1.12 ± 0.26^{a}	0.796
Cd	0.09 ± 0.13^{a}	0.16 ± 0.16^{a}	0.524
Cu	0.05 ± 0.01^{a}	0.09 ± 0.11^{a}	0.761
Ni	1.17 ± 0.22^{a}	1.21 ± 0.44^{a}	0.918
Fe	1.78 ± 0.18^{a}	2.12 ± 0.11^{a}	0.357
Site 2			
Pb	1.14 ± 0.23^{a}	1.26 ± 0.07^{b}	0.039
Cd	0.16 ± 0.05^{a}	0.38 ± 0.19^{a}	0.121
Cu	0.08 ± 0.02^{a}	0.10 ± 0.02^{a}	0.331
Ni	1.32 ± 0.35^{a}	1.56 ± 0.35^{a}	0.391
Fe	2.09 ± 0.28^{a}	2.29 ± 0.65^{a}	0.666
Site 3			
Pb	0.27 ± 0.19^{b}	0.46 ± 0.33^{b}	0.109
Cd	0.84 ± 0.07^{b}	0.80 ± 0.13^{b}	0.625
Cu	0.05 ± 0.06^{a}	0.13 ± 0.10^{a}	0.229
Ni	1.27 ± 0.13^{a}	1.29 ± 0.83^{a}	0.977
Fe	2.01 ± 0.26^{a}	2.94 ± 0.85^{a}	0.133

Means with different superscript are statistically different

The result of ANOVA shows thatapart from Pb that showed significant variation in site 2 ($p<0.05$) during the dry season, there was no significant temporal variations in the concentrations of the analysedmetals in the various sites. The significant temporal variation observed in Pb concentration in site 1,is probably an indication that anthropogenic source(s) of emission of the metal during the dry season is more prevalent than the wet season. Other factors responsible for spatial and temporal variation which could also be responsible for the trend in this area include: emission strength, emission rate, emission conditions and atmospheric dispersion conditions [29].

4. CONCLUSION

A high base-line data of TSP and heavy metal content in the indoor micro environment of the study area was obtained during the study period. These values violate both the WHO and FMEV standard of 230 μgm^{-3} and 150-230μgm^{-3}respectively and this can have adverse health effects especially on children, the elderly and those with pre-existing respiratory issues. Unless effectively controlled and

managed, pollution which is undesirable but the necessary evil of all developments will continue to pose serious challenges to man and his environment most especially in developing countries.

The study identified vehicular emission, road dust and waste burning as the predominant sources of emission in these indoor micro environments. The study also showed that, the temporal variability in the measured data was not apparent except in Pb in site 2.

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