QUANTIFICATION OF TOTAL SUSPENDED PARTICULATE (TSP) AND ITS ELEMENTAL CONTENT IN DIFFERENT MICRO ENVIRONMENTS OF A RESIDENTAL AREA IN LAGOS STATE, NIGERIA

ABSTRACT

The need for comprehensive periodic air quality measurements to assess the extent of airborne particulate matter and trace metals exposure in residential areas in Lagos State in view of the urbanization and different energy cooking source cannot be overemphasized. Total Suspended Particulates (TSP) was collected from July 2016 to April 2017 by gravimetric sampling technique in different indoor-outdoor micro environments of a residential area in Lagos and was analyzed by Atomic Absorption Spectroscopic (AAS) method. High base-line concentrations were obtained with an indoor range of 833.33-1944.45µgm^{-3} and outdoor range of 1111.11-1944.45µgm^{-3} during the wet season. During the dry season, it ranged from 1111.11-2777.78µgm^{-3} in the indoors and 1388.89-2222.22µgm^{-3} in the outdoors. Elemental concentrations were subjected to enrichment factor analysis (EF) and principal component analysis (PCA) for source identification. EF analysis was used to assess the relative contributions of natural and anthropogenic metals inputs to the air in the area while, PCA identified road dust, combustion activities and marine as the predominant sources of pollutants emission to the environment. To further elucidate the relationship among pollutants in the sampling sites, correlations analysis, cluster analysis and ANOVA were carried out. The results of the correlations analysis and cluster analysis confirmed the results of the EF and PCA. The results of ANOVA showed that, there was no spatial variation in the elemental concentration of most of the metals (P>0.05).

Conclusively, results obtained showed that, pollutants concentration in most of the sites were higher than safe limits proposed by regulatory limits.

Keywords: Total Suspended Particulate Matter (TSP), Indoor- Outdoor air pollution, cooking fuel

and elemental characterization.

1. INTRODUCTION

Atmospheric pollution has generally gained great national and global interest in the recent years due to its large societal burden and various adverse effects (Onabowale and Owoade, 2015). Air pollution can be grouped into two categories: outdoor air pollution (OAP) and indoor air pollution (IAP) (United Nations, 2011). Outdoor air enters and leaves the indoor micro environment by infiltration, natural and mechanical ventilation. When air pollutants from the outdoor air enter, they can either be diluted or accumulated depending on the ventilation condition. The indoor environment can be the home, office, school, workplace or public building. Even time spent within the car or in public transport can be considered as being in an 'indoor' environment (Simoni*et al*., 2003). Indoor Air Quality (IAQ) has gained great attention in recent years; chiefly due to the ample of time we spend indoors in modern times. People living in urban cities spend 87% indoors and only a mere 6% outdoors (Onabowale and Owoade, 2015). Studies have shown that, indoor sources significantly contribute to personal exposure concentrations experienced in indoor microenvironments. In addition, behaviour of people and ventilation characteristics of homes in different latitudes may significantly affect the concentrations of pollutants in indoor environments and in personal exposures. High temperature and humidity levels can also increase concentration of some pollutants (Ediagbonya *et al*., 2013).

Global data shows that, IAP is far more lethal than OAP. It has been estimated that about half a million women and children die each year from indoor air pollution in India (Smith, 2000). In 2004, less than 300 deaths per million people arising from OAP were reported while approximately 2,200 deaths per million people arising from IAP were reported (Omole*et al*., 2014). According to the World Health Organization, an estimated 7 million people were killed by diseases related to indoor and outdoor air pollution alone in 2012. The organization also reported that, 1.6 million people died from cooking stove fumes. Of the 1.6 million deaths, 396,000 deaths occurred in sub - Sahara Africa, with highest incidents occurring in Nigeria (WHO, 2006; Margulis*et al*., 2006). Another WHO report posited that 78% of African population used biomass burning to cook and that a third of infant deaths associated with IAP occurred in Africa (WHO, 2007). According to a recent comparative risk study by the World Health Organization (WHO), 28% of the overall disease and deaths is caused by indoor air particulates in developing countries. This may be attributed to the time people in urban areas spend indoors. Apart from death, inhalation of particulate matter in the indoor environment can cause a range of adverse health effects (Onabowale and Owoade, 2015).

The concentrations of total suspended particulate matter in Lagos ambient air have been investigated (Oluyemi and Asubiobjo, 2001). However, there is scanty information on TSP with respect to the different energy cooking source in the indoor micro environment.This study is therefore, necessary considering the potential negative health implications some cooking fuels can pose.

2. MATERIALS AND METHODS

2.1 SITE DESCRIPTION

The study was carried out in Akoka, a residential area in Lagos, Nigeria. The area is surrounded by the Lagos Lagoon and is densely populated with moderate traffic volume and other activities. Prominent in this area are food vendors, business centres, small-scale businesses, artisans, filling stations, banks, tertiary institutions amongst others. Activities in these afore-mentioned are possible sources of pollutants in the environment.

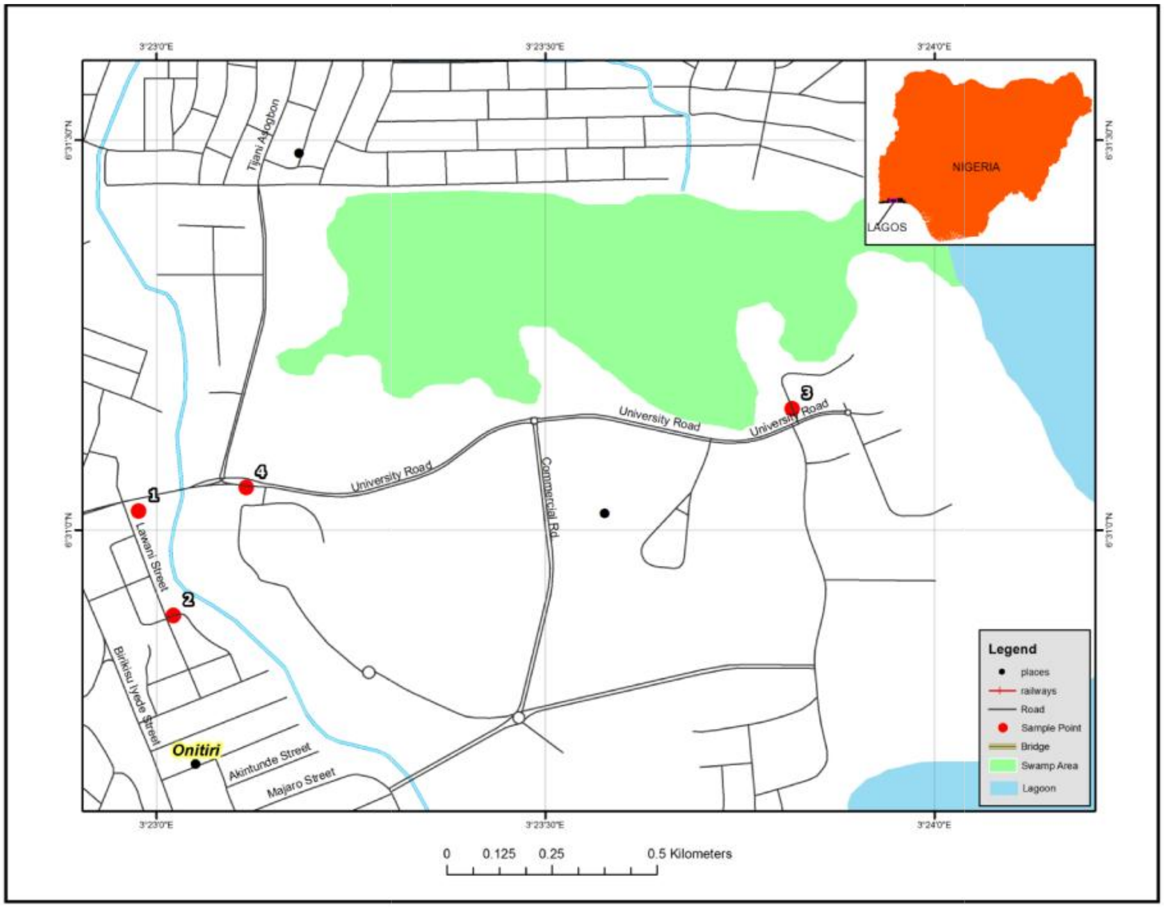

Figure 1: Map of Akoka Showing the Various Sampling Site

Table 1: Description of Sampling Sites Assessed

S/N	Site Code	Coordinates	Fuel Type	Description
1	AKO.CI AKO.CO	6°31'1.529"N 3°22'58.458"E	Charcoal	It is a food vendor with a lot of cooking activities and uses charcoal as the cooking fuel. It is close to Unilag main gate.
2	AKO.KI AKO.KO	6°30'53.792"N 3°23'1.085"E	Kerosene	It is a home located along a busy street close to AbuleOja bus-stop. It uses kerosene as the cooking fuel.
3	AKO.GI AKO.GO	6°31'9.265"N 3°23'48.746"E	Gas	It is a restaurant in UnilagAkoka campus. It is situated between two banks. Also, close to it, is a campus shuttle, suya joints and business centres.

4	AKO.VI AKO.VO	6°31'3.061"N 3°23'6.778"E	Gasoline, diesel	This site was created at the Unilag main gate. A short distance from the gate is a campus shuttle, restaurants and business centres.

AKO.CI and AKO.CO = Akokacharcoal indoor and outdoor AKO.KI and AKO.KO = Akoka kerosene indoor and outdoor AKO.GI and AKO.GO = Akoka gas indoor and outdoor AKO.VO = Akoka vehicular outdoor

2.2 SAMPLE COLLECTION

Sample was systematically collected directly by the use of a gravimetric high volume air sampler. The particulates were collected from the ambient air on the pre weighed whatmann cellulose filter paper using a portable high volume gravimetric sampler (Hi-Q CF – 901). 2.5L/min volume air was pumped through the filter paper for eight hours on each occasion. The sampling height in the course of this work was 1.6 m. The sampler was closely monitored throughout the duration of sampling to ensure accurate sampling collection timing, prevent battery failure and vandalism. 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 filters were stored in sealed polythene bags 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 100ml beaker. 10ml of HNO_3 was added and heated at 150^{0}C in a fume cupboard. The sample was intermittently spiked with 5ml perchloric acid after an hour and was heated for three hours until a clear solution was observed. The digest was cooled, filtered into 50 ml standard volumetric flask and diluted with distilled water to the ml mark in the 50 ml volumetric flask. Elemental analysis was then carried out on the final digest using Perkin Elmer A Analyst 400 atomic absorption spectrophotometer.

3. RESULTS AND DISCUSSION

High concentrations of TSP were obtained with an indoor range of 833.33-1944.45µgm^{-3} and outdoor range of 1111.11-1944.45µgm^{-3} during the wet season. During the dry season, it ranged from 1111.11-2777.78 in the indoors and 1388.89-2222.22µgm^{-3} in the outdoors.Thesevalues are about 3 to 11 fold the 250µgm^{-3} stipulated by the Federal Ministry of Environment (FMNEV) and World Health Organization (WHO) statutory limits of 250µgm^{-3} and 150 to 230 µgm^{-3} respectively (WHO, 2005) thus, they clearly violate the statutory limits.The high level of TSP in the air is probably from both natural and anthropogenic sources with the latter being more dominant.

Table 2: Comparison of Indoor-Outdoor Total Suspended Particulate Matter Results (µgm^{-3}) of this Study with Others

S/N	Site/Location	Indoor concentration	Outdoor concentration	References
1	**Urban/Lagos**	**833.33-2777.78**	**1111.11-2222.2**	**Current Study**
2	Urban/Benin City	Nil	583-20,166.67	Okuo*et al*.,(2011)
3	Urban/Warri	Nil	922.00-2333.00	Okuo*et al*.,(2011)
4	Urban/Benin City	243.05-451.39	451.39-625.00	Ediagbonya*et al*., (2013)
5	Rural/Iyowa	425.92-1444.00	240.74-555.55	Ukpebor*et al*., (2012)
6	Rural/China	2000	Nil	Mumford *et al*., (1987)
7	Urban/Saudi Arabia	1845.90	2494.40	Mahmoud *et al*., (2014)
8	Urban/Zagreb	90.00	152.00	Fugas*et al*., (2014)
9	Urban/Bomby	118.00	117.00	Fugas*et al*., (2014)
10	Urban/Toronto	68.00	60.00	Fugas*et al*., (2014)

The high levels of pollutants measured in this study and other studies (Table 2) is a signature of anthropogenic activities andis an indication that, the indoor-outdoor micro environments ofmany urban and rural areas are highly polluted and therefore calls for urgent environment pollution control.

3.1 ELEMENTAL CONCENTRATION AND ENRICHMENT FACTOR

When there is high concentration of heavy metals in airborne particulate matter, it becomes a thing of serious environmental concern because of the implications it poses to man and its environment. It therefore becomes necessary to monitor their concentration through air quality studies.

The mean elemental concentrations together with the mean enrichment factors calculated for the indoor-outdoor micro environmentsduring the wet and dry seasons of the sampling period are presented in Table 3-6.

Table 3: Mean Elemental Concentration and Enrichment Factor of Indoor Total Suspended Particulate Matter during the Wet Season

	AKO.CI		AKO.KI		AKO.GI	
	Mean±S.D	EF	Mean±S.D	EF	Mean±S.D	EF
Pb	1.06±0.30	1400.24	1.14±0.23	1287.2712144.0641.28436.36	0.27±0.19	317.01
Cd	0.09±0.13	7964.01	0.16±0.05	1.00 1.98 11.132.45	0.84±0.07	65969.89
Cu	0.05±0.01	29.46	0.08±0.02		0.05±0.06	26.09
Ni	1.17±0.22	455.82	1.32±0.35		1.27±0.13	439.35
Fe	1.78±0.18	1.00	2.09±0.28		2.01±0.26	1.00
Ca	1.65±0.18	4.02	3.93±0.34		2.62±0.26	2.78
Na	4.35±1.12	11.98	4.74±0.67		4.67±0.32	11.42
K	12.29±4.47	12.25	2.89±0.15		1.97±0.08	1.74

Table 4: Mean Elemental Concentration and Enrichment Factor of Outdoor Total Suspended Particulate Matter during the Wet Season

	AKO.CO		AKO.KO		AKO.GO		AKO. VO	
	Mean±S.D	EF	Mean±S.D	EF	Mean±S.D	EF	Mean±S.D	EF
PbC	1.00±0.570.	1344.84	0.89±0.43	1309.917	0.38±0.01	567.60	1.37±0.16	1559.74
dCu	06±0.09	5583.865	0.08±0.18	557.3947	0.82±0.44	81404.60	0.12±0.02	9199.856
Ni	0.09±0.02	5.87443.	0.07±0.01	.92	0.06±0.13	42.39	0.12±0.01	2.58
Fe	1.02±0.48	92 1.00	1.37±0.16	593.18	1.13±0.45	497.76	1.49±0.18	498.54
CaN	1.75±0.52	2.19	1.61±0.19	1.00 2.96	1.58±0.15	1.00 3.12	2.08±0.17	1.00 2.11
aK	1.80±0.36	13.68	3.94±2.09	13.17	2.30±0.23	15.91	2.05±0.14	14.40
	4.88±0.91	7.31	4.30±0.16	226	5.11±1.02	5.58	6.08±0.23	1.62
	7.21±2.18		2.05±0.20		4.97±1.29		1.90±0.15	

Table 5: Mean Elemental Concentration and Enrichment Factor of Indoor Total Suspended Particulate Matter during the Dry Season

	AKO.CI		AKO.KI		AKO.GI	
	Mean±S.D	EF	Mean±S.D	EF	Mean±S.D	EF
Pb	1.12±0.26	1246.79	1.26±0.07	1298.52	0.46±0.33	369.25
Cd Cu	0.16±0.16	11874.24	0.38±0.19	26107.85	0.80±0.13	42812.01
Ni	0.09±0.11	44.53	0.10±0.02	472.85	0.13±0.10	46.38
Fe	1.21±0.44	396.17	1.56±0.35	1.00	1.29±0.83	304.56
CaNa	2.12±1.60	1.00	2.29±0.65	1.00	2.94±0.85	1.00 2.11
K	2.33±0.18	2.35	4.54±0.45	4.23	2.91±0.87	10.71 1.49
	5.26±0.57	12.20	5.06±0.35	10.86	5.62±1.09	
	14.07±3.65	11.78	3.12±0.68	2.50	2.47±0.49	

Table 6:Mean Elemental Concentration and Enrichment Factor of Outdoor Total Suspended Particulate Matter during the Dry Season

	AKO.CO		AKO.KO		AKO.GO		AKO.VO	
	Mean±S.D	EF	Mean±S.D	EF	Mean±S.D	EF	Mean±S.D	EF
PbCd	1.03±0.19	1321.09	1.07±0.07	1256.32	0.66±0.36	819.79	1.53±0.29	1611.96
Cu	0.23±0.18	19666.01	0.19±0.13	14872.38	0.91±0.05	75354.77	0.18±0.13	12642.92
Ni	0.12±0.09	68.41	0.10±0.09	52.18	0.09±0.05	49.68	0.20±0.12	93.65
Fe	1.09±0.08	445.14	1.47±0.44	507.63	1.24±0.17	453.00	1.63±0.24	505.10
Ca	1.84±0.18	1.00	2.01±1.18	1.00	1.90±0.10	1.00	2.24±0.75	1.00
Na K	2.31±1.13	2.68	4.08±0.70	4.34	2.56±0.85	2.88	2.15±0.67	2.09
	4.97±0.98	13.28	4.51±1.92	11.03	5.18±2.29	13.40	6.31±0.54	13.85
	8.94±1.39	8.62	2.35±0.72	2.07	5.15±1.27	4.81	2.26±0.40	1.79

3.1.1 Elemental Concentration

Generally, it was observed that, the concentrations of the metals analyzed were higher indoors than outdoors. The increased indoor pollutants are in agreement with the studies of Environmental Protection Agency. EPA studies have shown that levels of air pollutants indoors may be anywhere from 2 to 5 times greater than outdoors and in some cases, more than 100 times greater (Pau, 2008).Also, according to Chen and Zhao (2011), in combined indoor and outdoor air quality studies, more than 2/3 authors found indoor air pollutant concentration higher than outdoor pollutant concentrations.This is probably due to a higher dispersion rate in the outdoor micro environment compared to the corresponding indoor micro environment.

It was also observed that, the concentrations of the metals measured during the wet season were relatively lower than that measured during the dry season in the various sites and this might be attributed to metrological factors such as: (i) lower air temperature (ii) higher humidity, (iii) higher wind speed and (iv) increase in cloud covers and consequently, increase in the number of rainfall days experienced during the wet season. A lower temperature and a higher humidity cause trapping of particulates in water molecules in the atmosphere (Okuo*et al*., 2017). These trapped particulates are later washed down via rainfall or droplets. Also, the greater the wind speed, the greater the turbulence and the more rapid and complete the dispersion of contaminants in the air (Guttikunda and Gurjar, 2012).

A similar study by Nasir*et al*., (2015) reported indoor-outdoor relationships of trace metals in PM in an urban and two rural areas of Pakistan. The concentrations of most of the metals in the indoor micro environment were higher than the outdoor micro environment in their study. This trend was also observed in this study. The reason for the observed lower concentrations in the outdoor micro environments of both studies is probably due to a higher dispersion rate.

3.1.2 Enrichment Factor (EF)

In order to discriminate the natural sources from the anthropogenic sources of atmospheric metals emission, enrichment factors (EFs) were calculated as:

$$EF = \frac{\left(\frac{E}{R}\right)_{sample}}{\left(\frac{E}{R}\right)_{crustal}} \qquad 1$$

Where E is the element of interest and R, the reference material

$\left(\frac{E}{R}\right)_{sample}$ is the ratio of the element of interest to the reference material in the sample

$\left(\frac{E}{R}\right)_{crustal}$ is the ratio of the element of interest to the reference material in the crustal material

The EF for Na a marker element for marine, was >10 in all the sites in both seasons. This implies severe enrichment in the various sites. The high EF of Na should be due to the pronounced effect of sea breeze in the region as Lagos is situated on the coast of the Atlantic Ocean. The EF of Ca and K was less than 3 in virtually all the sites. This is an indication that the main source of emission of these metals is natural. The EF of Cu, Pb, Cd and Ni were ≥ 25 in all the sites in the two seasons. The high enrichment of these metals suggests that, their dominant source

	Indoor			
	AKO.CI	AKO.KI	AKO.GI	P
Pb	1.06 ± 0.30^{a}	1.14 ± 0.23^{a}	0.27 ± 0.19^{b}	0.001
Cd	0.09 ± 0.13^{a}	0.16 ± 0.05^{a}	0.84 ± 0.07^{b}	0.000
Cu	0.05 ± 0.01^{a}	0.08 ± 0.02^{a}	0.05 ± 0.06^{a}	0.453
Ni	1.17 ± 0.22^{a}	1.32 ± 0.35^{a}	1.27 ± 0.13^{a}	0.834
Fe	1.78 ± 0.18^{a}	2.09 ± 0.28^{a}	2.01 ± 0.26^{a}	0.569
Ca	1.65 ± 0.55^{a}	3.94 ± 0.34^{a}	2.62 ± 0.26^{a}	0.062
Na	4.35 ± 1.12^{a}	4.74 ± 0.67^{a}	4.67 ± 0.32^{a}	0.805

K	12.29±4.47^{a}	2.89±0.15^{b}	1.97±0.08^{b}		0.006
		Outdoor			
	AKO.CO	AKO.KO	AKO.GO	AKO.VO	
Pb	1.00±0.57^{a}	0.89±0.43^{a}	0.38±0.01^{b}	1.37±0.16^{a}	0.000
Cd	0.06±0.09^{a}	0.08±0.18^{a}	0.82±0.44^{b}	0.12±0.02^{a}	0.000
Cu	0.09±0.02^{ab}	0.07±0.01^{b}	0.06±0.13^{b}	0.12±0.01^{a}	0.004
Ni	1.02±0.48^{a}	1.37±0.16^{a}	1.13±0.45^{a}	1.49±0.18^{a}	0.332
Fe	1.75±0.52^{a}	1.61±0.10^{a}	1.58±0.15^{a}	2.08±0.17^{a}	0.208
Ca	1.80±0.36^{a}	3.93±2.09^{a}	2.30±0.23^{a}	2.05±0.14^{a}	0.282
Na	4.88±0.91^{a}	4.30±0.16^{a}	5.11±1.02^{a}	6.08±0.23^{a}	0.073
K	7.21±2.18^{a}	2.05±0.20^{b}	4.97±1.29^{ab}	1.90±0.15^{b}	0.001

s are anthropogenic and a variety of pollution emissions such as vehicular exhaust/oil combustion, waste burning, smoking, paints, amongst others, might have contributed to their loading in the ambient air.

3.2 MULTIVARIATE ANALYSIS

The mean elemental concentrations of TSP measured in the various sampling sites were subjected to analysis of variance (ANOVA), inter- metallic correlation, principal component analysis (PCA) and cluster analysis using SPSS statistical package. This was done to elucidate relationships among the sampling sites and to identify the sources contributing to the metals level in the area.

3.2.1Analysis of Variance (ANOVA)

It was used to compare the mean concentrations of the metals in the various sampling sites so as to determine whether, they were significantly different or not. Table 7 and 8 shows the spatial variations of the metals in the indoor and outdoor microenvironments for both seasons.

Table 7: Analysis of Variance (ANOVA) for the Wet Season

		Indoor			
	AKO.CI	AKO.KI	AKO.GI		
					P
Pb	1.06 ± 0.30^{a}	1.14 ± 0.23^{a}	0.27 ± 0.19^{b}		0.001
Cd	0.09 ± 0.13^{a}	0.16 ± 0.05^{a}	0.84 ± 0.07^{b}		0.000
Cu	0.05 ± 0.01^{a}	0.08 ± 0.02^{a}	0.05 ± 0.06^{a}		0.453
Ni	1.17 ± 0.22^{a}	1.32 ± 0.35^{a}	1.27 ± 0.13^{a}		0.834
Fe	1.78 ± 0.18^{a}	2.09 ± 0.28^{a}	2.01 ± 0.26^{a}		0.569
Ca	1.65 ± 0.55^{a}	3.94 ± 0.34^{a}	2.62 ± 0.26^{a}		0.062
Na	4.35 ± 1.12^{a}	4.74 ± 0.67^{a}	4.67 ± 0.32^{a}		0.805
K	12.29 ± 4.47^{a}	2.89 ± 0.15^{b}	1.97 ± 0.08^{b}		0.006
		Outdoor			
	AKO.CO	AKO.KO	AKO.GO	AKO.VO	
Pb	1.00 ± 0.57^{a}	0.89 ± 0.43^{a}	0.38 ± 0.01^{b}	1.37 ± 0.16^{a}	0.000
Cd	0.06 ± 0.09^{a}	0.08 ± 0.18^{a}	0.82 ± 0.44^{b}	0.12 ± 0.02^{a}	0.000
Cu	0.09 ± 0.02^{ab}	0.07 ± 0.01^{b}	0.06 ± 0.13^{b}	0.12 ± 0.01^{a}	0.004
Ni	1.02 ± 0.48^{a}	1.37 ± 0.16^{a}	1.13 ± 0.45^{a}	1.49 ± 0.18^{a}	0.332
Fe	1.75 ± 0.52^{a}	1.61 ± 0.10^{a}	1.58 ± 0.15^{a}	2.08 ± 0.17^{a}	0.208
Ca	1.80 ± 0.36^{a}	3.93 ± 2.09^{a}	2.30 ± 0.23^{a}	2.05 ± 0.14^{a}	0.282
Na	4.88 ± 0.91^{a}	4.30 ± 0.16^{a}	5.11 ± 1.02^{a}	6.08 ± 0.23^{a}	0.073
K	7.21 ± 2.18^{a}	2.05 ± 0.20^{b}	4.97 ± 1.29^{ab}	1.90 ± 0.15^{b}	0.001

Table 8: Analysis of Variance (ANOVA) for Dry Season

		Indoor			
	AKO.CI	AKO.KI	AKO.GI		
					P
Pb	1.12±0.26^{a}	1.26±0.07^{a}	0.46±0.33^{b}		0.015
Cd	0.16±0.16^{a}	0.38±0.19^{a}	0.80±0.13^{b}		0.007
Cu	0.09±0.11^{a}	0.10±0.02^{a}	0.13±0.10^{a}		0.453
Ni	1.21±0.44^{a}	1.56±0.35^{a}	1.29±0.83^{a}		0.834
Fe	2.12±0.11^{a}	2.29±0.65^{a}	2.94±0.85^{a}		0.569
Ca	2.33±1.60^{a}	4.54±0.45^{a}	2.91±0.87^{a}		0.062
Na	5.26±0.57^{a}	5.06±0.35^{a}	5.62±1.09^{a}		0.805
K	14.07±3.65^{a}	3.23±0.52^{b}	2.47±0.49^{b}		0.036
		Outdoor			
	AKO.CO	AKO.KO	AKO.GO	AKO.VO	
Pb	1.03±0.19^{ab}	1.07±0.07^{ab}	0.66±0.36^{b}	1.53±0.29^{a}	0.010
Cd	0.23±0.18^{a}	0.19±0.13^{a}	0.91±0.05^{b}	0.18±0.13^{a}	0.000
Cu	0.12±0.09^{a}	0.10±0.07^{a}	0.09±0.05^{a}	0.20±0.12^{a}	0.437
Ni	1.09±0.08^{a}	1.47±0.44^{a}	1.24±0.17^{a}	1.63±0.24^{a}	0.178
Fe	1.84±0.18a	2.01±1.18a	1.90±0.10a	2.24±0.75^{a}	0.735
Ca	2.31±1.13^{a}	4.08±0.70^{a}	2.56±0.85^{a}	2.19±0.67^{a}	0.087
Na	4.97±0.98^{a}	4.51±1.92^{a}	5.18±2.29^{a}	6.31±0.54^{a}	0.583
K	8.94±1.39^{a}	2.35±0.72^{b}	5.15±1.27^{b}	2.26±0.40^{b}	0.000
			AKO.GI		P

		Indoor			
	AKO.CI				
		AKO.KI			
Pb	1.12±0.26^{a}	1.26±0.07^{a}	0.46±0.33^{b}		0.015
Cd	0.16±0.16^{a}	0.38±0.19^{a}	0.80±0.13^{b}		0.007
Cu	0.09±0.11^{a}	0.10±0.02^{a}	0.13±0.10^{a}		0.453
Ni	1.21±0.44^{a}	1.56±0.35^{a}	1.29±0.83^{a}		0.834
Fe	2.12±0.11^{a}	2.29±0.65^{a}	2.94±0.85^{a}		0.569
Ca	2.33±1.60^{a}	4.54±0.45^{a}	2.91±0.87^{a}		0.062
Na	5.26±0.57^{a}	5.06±0.35^{a}	5.62±1.09^{a}		0.805
K	14.07±3.65^{a}	3.23±0.52^{b}	2.47±0.49^{b}		0.036
		Outdoor			
	AKO.CO	AKO.KO	AKO.GO	AKO.VO	
Pb	1.03±0.19^{ab}	1.07±0.07^{ab}	0.66±0.36^{b}	1.53±0.29^{a}	0.010
Cd	0.23±0.18^{a}	0.19±0.13^{a}	0.91±0.05^{b}	0.18±0.13^{a}	0.000
Cu	0.12±0.09^{a}	0.10±0.07^{a}	0.09±0.05^{a}	0.20±0.12^{a}	0.437
Ni	1.09±0.08^{a}	1.47±0.44^{a}	1.24±0.17^{a}	1.63±0.24^{a}	0.178
Fe	1.84±0.18a	2.01±1.18a	1.90±0.10a	2.24±0.75^{a}	0.735
Ca	2.31±1.13^{a}	4.08±0.70^{a}	2.56±0.85^{a}	2.19±0.67^{a}	0.087
Na	4.97±0.98^{a}	4.51±1.92^{a}	5.18±2.29^{a}	6.31±0.54^{a}	0.583
K	8.94±1.39^{a}	2.35±0.72^{b}	5.15±1.27^{b}	2.26±0.40^{b}	0.000

The results of the ANOVA as shown in Table 7 and 8, show that apart from Pb, Cd and K that showed significant variation in the indoor micro environment and Pb, Cd, Cu and K in the outdoor micro environment ($p<0.05$), there were no significant variation of the metals distribution in the various sampling sites. During the dry season, apart from Pb, Cd and K that showed significant variation in both the indoor and outdoor micro environment ($p<0.05$), it was observed that variation of the metals distribution in the various sampling sites were not significant. Factors responsible for spatial and ambient concentrations of air pollutants which could also be responsible for the trend in this area include: emission strength, emission rate, emission conditions and atmospheric dispersion conditions (Ukbebor*et al.,* 2012).

3.2.2 Seasonal Variations of Elemental Concentration

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 and are presented in Table 9 and 10.

Table 9: Seasonal Variations of Elemental Concentration in the Indoors

	Wet Season	Dry Season	P
AKO.CI			
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
Ca	1.65±0.55^{a}	2.33±1.60^{a}	0.523
Na	4.35±1.12^{a}	5.26±0.57^{a}	0.278
K	12.29±4.47^{a}	14.07±3.65^{a}	0.105
AKO.KI			
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
Ca	3.94±0.34^{a}	4.54±0.45^{a}	0.471
Na	4.74±0.67^{a}	5.06±0.35^{a}	0.509
K	2.89±0.15^{b}	3.23±0.52^{b}	0.596
AKO.GI			
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
Ca	2.62±0.26^{a}	2.91±0.87^{a}	0.608
Na	4.67±0.32^{a}	5.62±1.09^{a}	0.223
K	1.97±0.08^{b}	2.47±0.49^{b}	0.155

Apart from Pb that showed significant variation in site AKO.KI ($p<0.05$), there was no significant variations in the concentrations of the metals in the indoor micro environment sampling sites during the wet and dry seasons of the sampling period. The seasonal significant variation observed in Pb concentration in site AKO.KI is probably an indication that, anthropogenic source(s) of emission during the dry season is more prevalent than the wet season.

As mentioned earlier, metrological factors is yet another reason for the observed seasonal variations.

Table 10: Seasonal Variations of Elemental Concentrations in the Outdoors

	Wet Season	Dry Season	P
AKO.CO			
Pb	1.00 ± 0.57^{a}	1.03 ± 0.19^{ab}	0.894
Cd	0.06 ± 0.09^{a}	0.23 ± 0.18^{a}	0.191
Cu	0.09 ± 0.02^{ab}	0.12 ± 0.09^{a}	0.631
Ni	1.02 ± 0.48^{a}	1.18 ± 0.23^{a}	0.918
Fe	1.75 ± 0.52^{a}	1.84±0.18a	0.797
Ca	1.80 ± 0.36^{a}	2.31 ± 1.13^{a}	0.509
Na	4.88 ± 0.91^{a}	4.97 ± 0.98^{a}	0.910
K	7.21 ± 2.18^{a}	8.94 ± 1.39^{b}	0.002
AKO.KO			
Pb	0.89 ± 0.43^{a}	1.07 ± 0.07^{ab}	0.093
Cd	0.08 ± 0.18^{a}	0.19 ± 0.13^{b}	0.000
Cu	0.07 ± 0.01^{a}	0.10 ± 0.07^{a}	0.516
Ni	1.37 ± 0.16^{a}	1.47 ± 0.44^{a}	0.600
Fe	1.61 ± 0.10^{a}	2.01±1.18a	0.586
Ca	3.93 ± 2.09^{a}	4.08 ± 0.70^{b}	0.015
Na	4.30 ± 0.16^{a}	4.51 ± 1.92^{a}	0.858
K	2.05 ± 0.20^{b}	2.35 ± 0.72^{b}	0.521
AKO.GO			
Pb	0.38 ± 0.01^{b}	0.66 ± 0.36^{a}	0.049
Cd	0.82 ± 0.44^{b}	0.91 ± 0.05^{b}	0.224
Cu	0.06 ± 0.13^{a}	0.09 ± 0.05^{a}	0.414
Ni	1.13 ± 0.45^{a}	1.24 ± 0.17^{a}	0.415
Fe	1.58 ± 0.15^{a}	1.90 ± 0.10^{a}	0.120
Ca	2.30 ± 0.23^{a}	2.56 ± 0.85^{a}	0.839
Na	5.11 ± 1.02^{a}	5.18 ± 2.29^{a}	0.963
K	4.97 ± 1.29^{a}	5.15 ± 1.27^{b}	0.028
AKO.VO			
Pb	1.37 ± 0.16^{a}	1.53 ± 0.29^{a}	0.460
Cd	0.12 ± 0.02^{a}	0.18 ± 0.13^{a}	0.465
Cu	0.12 ± 0.01^{a}	0.20 ± 0.12^{a}	0.336
Ni	1.49 ± 0.18^{a}	1.63 ± 0.24^{a}	0.468
Fe	2.08 ± 0.17^{a}	2.24 ± 0.75^{a}	0.731
Ca	2.05 ± 0.14^{a}	2.19 ± 0.67^{a}	0.747
Na	6.08 ± 0.23^{a}	6.31 ± 0.54^{a}	0.536
K	1.90 ± 0.15^{b}	2.26 ± 0.40^{b}	0.216

In the outdoor micro environment of site AKO.CO, apart from K that is significantly different ($p<0.05$), there was no seasonal variations ($p>0.05$) in the analyzed metals. Metrological factors and a higher rate of emission during the dry season, is probably a reason for the observed increase in the concentration of K in the season. In site AKO.KO there was no significant variations in the concentrations of the metals except in Cd and Ca. The reason for the variation observed in these two metals is as mentioned in the case of K. In site AKO.GO, seasonal variation was observed only in Pb and K. Again, the reason is as stated above.

There was no significant difference in the concentrations of most of the metals analyzed for the two seasons. This seasonal pattern is similar to the seasonal pattern observed for metals in TSP at Guangzhou and Foshan (Xiao*et al*., 2015).

3.2.3 Correlation Analysis

The possible sources around the sampling sites were qualitatively identified from the correlation matrix by analyzing the correlation between elements. Correlations among metals indicate a common source of origin as shown in Table 11 and 12.

Table 11: Inter-metallic Correlations of Indoor-Outdoor Samples

	Pb	Cd	Cu	Ni	Fe	Ca	Na	K
Indoor					.			
Pb	1	-.928**.	..526	.129	.075	-.609	.164	.690*
Cd		1	-.419	.074	.177	.759*	.127	-.497
Cu			1	.636	.139	-.141	.586	.538
Ni				1	.253	.544	.509	.478
Fe					1	.473	.712*	.625
Ca						1	.294	.042
Na							1	.441
K								1
Outdoor								
Pb	1	-.839**.	.650*	518	652*	-.246	383	-.247
Cd		1	-.481	-.288	-.306	.347	.123	.255
Cu			1	0.192	.444	-.412	.542	-.388
Ni				1	.808**.	.541	.404	.300
Fe					1	.268	.614*	.294
Ca						1	.092	.386
Na							1	-.128
K								1

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

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

The results of inter-elemental correlation matrix and during the wet season showed that, there was strong correlation between Pb-Cd (-0.928), Pb-K (0.690), Cd-Ca (0.759) and Fe-Na (0.712) in the indoors, Pb-Cd (-0.839), Pb-Cu (0.650), Pb-Fe (0.652), Fe-Ni (0.808) and Fe-Na (0.614) in the outdoors. The strong correlation of these metals suggests they may have a common origin. The correlations between Pb, Cd,K andCa suggests road dust source (i.e., sum of soil dust and automobile source type). While that between Fe and Na may be attributed to crustal dust. In the outdoor samples, there was a strong correlation between Pb-Cd (-0.839), Pb-Cu (0.650), Pb-Fe (0.652), Fe-Ni (0.808) and Fe-Na (0.614). The strong correlation between Pb, Cd, Cu, Ni and Fe strongly suggests vehicular emission as a prominent anthropogenic source of emission in this area. Emissions from vehicle exhaust and wear abrasion are both important sources of these metals. Again, previous studies have pointed out that, in addition to road dust, wear debris from brake linings and tyres as well as diesel engine emissions are main sources of Fe in areas near traffic emissions (Amato *et al*., 2009). This therefore confirms the traffic volume in the area.

Table 12Inter-metallic Correlations of Indoor-Outdoor Samples

	Pb	Cd	Cu	Ni	Fe	Ca	Na	K
Indoor								
Pb	1	-0.509	0.100	0.560	0.328	0.491	0.103	0.433
Cd		1	0.476	0.350	.-0.072	0.257	0.536	-0.591
Cu			1	0.659	0.580	0.636	0.783*	-0.018
Ni				1	0.249	0.673*	0.800**	-0.021
Fe					1	0.269	0.303	0.568
Ca						1	0.308	0.326
Na							1	0.096
K								1
Outdoor								
Pb	1	-0.655**	0.719**	0.585*	0.303	-0.222	0.683*	0.103
Cd		1	-0.269	-0.210	0.292	0.596*	-0.139	-0.198
Cu			1	0.698*	0.586*	0.177	0.756*	0.001
Ni				1	0.626*	0.085	0.776**	-0.332
Fe					1	0.388	0.805**	0.051
Ca						1	0.216	-0.159
Na							1	0.093
K								1

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

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

During the dry season, the result of the inter-metallic matrix showed that in the indoors, there was strong correlation between Na-Cu (0.783), Ni-Ca (0.673) and (0.800). These relationships suggest road dust. While in the outdoors, a strong correlations between Pb-Cd (-0.655), Pb-Cu (0.719), Pb- Ni (0.585), Pb-Na (0.683), Cu-Ni (0.698), Cu-Fe (0.586), Ni-Fe (0.626), Ni-Na (0.776), Fe-Na (0.805), Cd-Ca (0.596) and Cu-Na (0.756) was observed. The correlation between Pb-Cd, Pb-Cu, Pb-Ni, Cu-Ni, Cu-Fe suggests vehicular source emission type since these metals are mainly emitted either from fuel, tyre wear/tear or corrosion of car steel parts. While the correlation between Ni-Fe, Ni-Na and Cd-Ca suggests road dust source (i.e., sum of soil dust and automobile source type) as a major source of emission in the sites. The correlation between Fe and Na may be attributed to crustal dust.

3.2.4 Principal Component Analysis

In order to identify the source(s) contributing to the metals emissions at the sampling sites, the obtained data were further subjected to PCA.To determine the number of factors to retain in the results, the values of variance after rotation were examined and only factors with eigenvalues ≥ 1 were considered significant as shown in Table13-16.

Table 13: Rotated Factor Loading for TSP in the Indoor SitesDuring the Wet season

Variables	Factor 1	Factor 2	Communality
Pb	0.219	0.949	0.948
Cd	0.070	-0.979	0.964
Cu	0.627	0.525	0.668
Ni	0.784	-0.031	0.616
Fe	0.768	-0.151	0.612
Ca	0.521	-0.787	0.890
Na	0.848	-0.013	0.720
K	0.721	0.522	0.792
Eigen Values	3.394	2.815	
%Variance	42.429	35.192Biomass/waste	
Possible sources	Marine Road dust	BurningCrustal dust	

In the indoor micro environment, two major factors were identified. Factor 1 (PC1)loads heavily on Cu, Ni, Fe, Ca, Na and K. This source may be attributed to the combination of marine and road dust. Factor 2 (PC2) is loaded primarily by Pb, Cd, Ca, Cu and K. This is likely from anthropogenic activities and may be attributed to biomass/waste burning and construction.

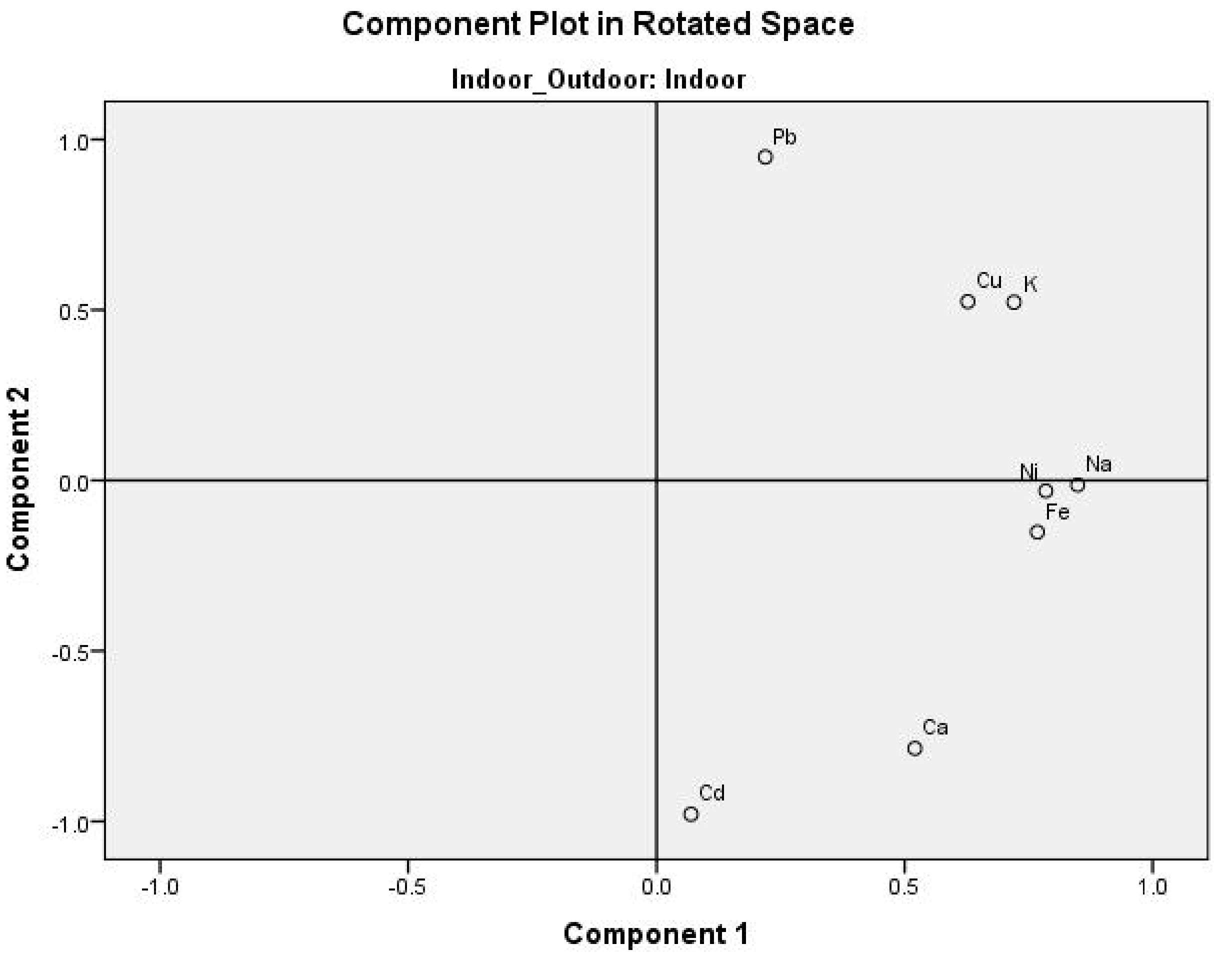

Figure 2: Indoor Samples Component Plot in Rotated Space during the Wet Season

Table 14: Rotated Factor Loading For TSP in the Outdoor Sites during the Wet Season

Variables	Factor 1	Factor 2	Factor 3	Communality
Pb	0.893	-0.055	0.390	0.953
Cd	-0.970	0.160	0.098	0.976
Cu	0.501	-0.404	0.645	0.830
Ni	0.457	0.717	0.418	0.898
Fe	0.492	0.523	0.632	0.916
Ca	-0.273	0.813	0.090	0.744
Na	-0.029	0.039	0.974	0.952
K	-0.113	0.765	-0.199	0.638
Eigen Values	3.414	2.322	29.031	
% Variance	42.669	29.031	14.616	
Possible sources	Waste burning	Construction activities Biomass burning	Vehicular Marine	

Factor 1 (PC1) loads heavily on Pb, Cd and Cu. This is may be attributed to waste burning. Factor 2 (PC2) is loaded primarily by Ni, Fe, Ca and K and may be related to construction activities and biomass burning. Factor 3 (PC3) loads heavily on Cu, Fe and Na. This factor represents a combination of vehicular and marine. Cu and Fe is marker element for brake/tyre/car parts wear and tear and thus can serve as indicators of traffic re-suspension (Amato *et al*., 2009).

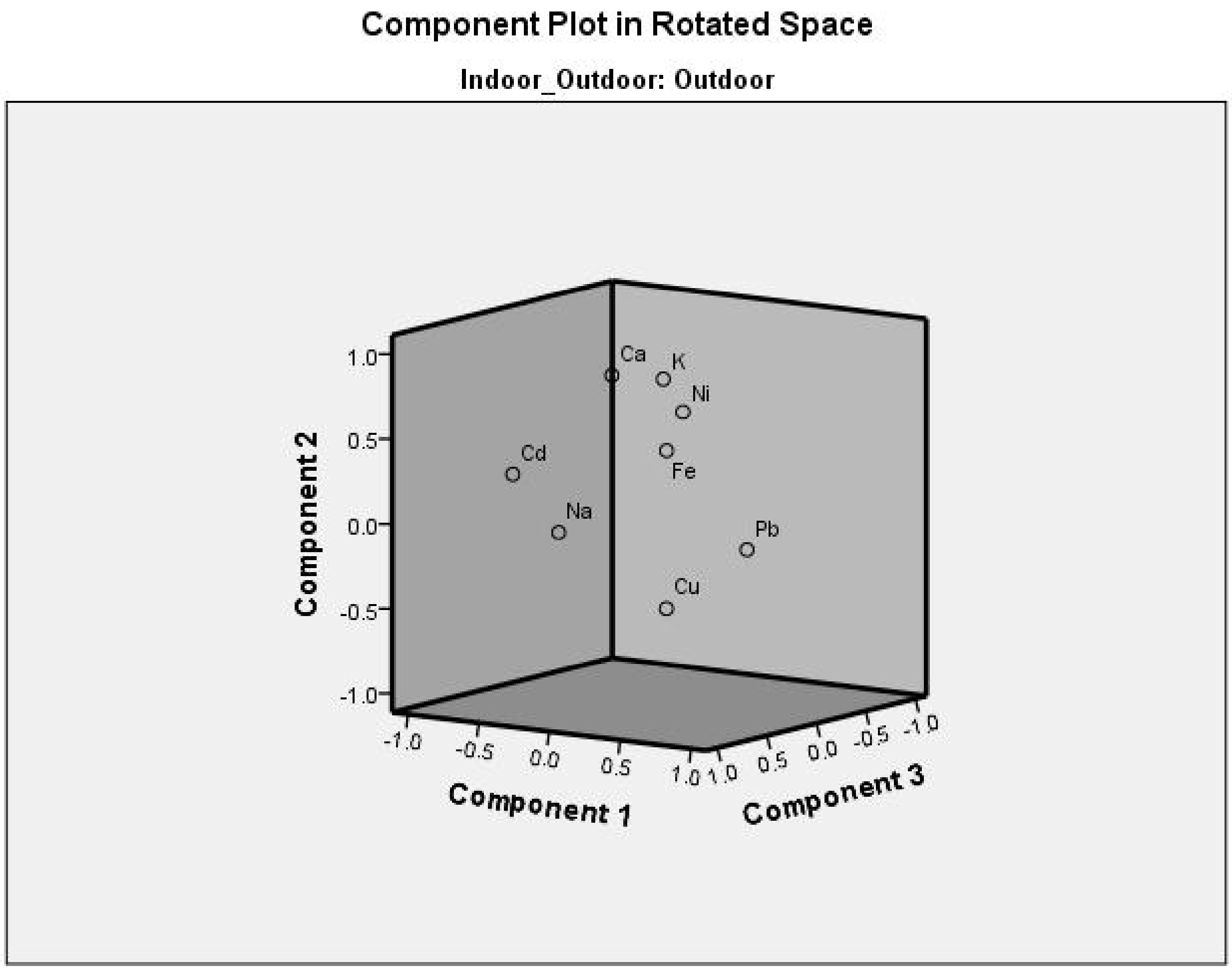

Figure 3: Outdoor Samples Component Plot in Rotated Space during the Wet Season

Table 15: Rotated Factor Loading For TSP in the Indoor Sites during the Wet season

Variables	Factor 1	Factor 2	Factor 3	Communality
Pb	-0.146	0.447	0.866	0.970
Cd	0.738	-0.579	-0.195	0.918
Cu	0.896	0.109	0.274	0.889
Ni	0 .632	0.004	0.68	0.873
Fe	0.455	0.725	0.134	0.751
Ca	0.390	-0.224	0.811	0.860
Na	0.887	0.108	0.158	0.824
K	-0.078	0.968	-0.040	0.944
Eigen Values	3.723	2.107	1.116	
% Variance	44.539	26.343	13.949	
Possible Sources	Waste burning Marine	Road dust Biomass burning	Vehicular Construction activities	

Factor 1 (PC1) loads heavily on Cd, Cu, Ni and Na. This factor may be attributed to the combination of waste burning and marine. Factor 2 (PC2) is loaded primarily by Cd, Fe and K. This is most likely related to road dust and biomass burning. Factor 3 (PC3) loads heavily on Pb, Ni and Ca. This factor may be attributed to vehicular and construction activities.

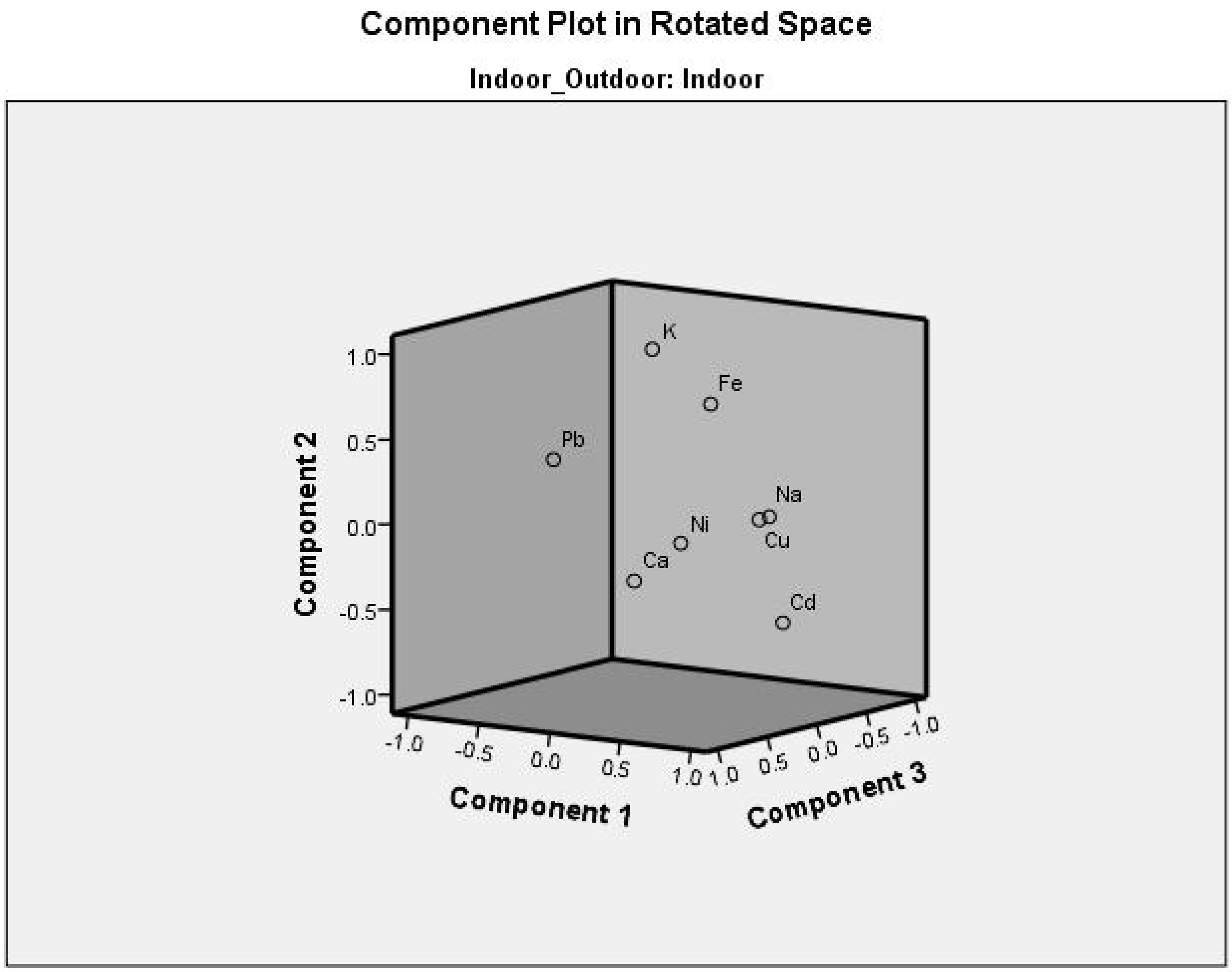

Figure 4:Indoor Samples Component Plot in Rotated Space during the Dry

Table 16: Results of the Rotated Factor Loading for TSP in the Outdoor Sites during the Dry Season

Variables	Factor 1	Factor 2	Factor 3	Communality
Pb	0.759	-0.548	0.060	0.879
Cd	-0.215	0.921	0-.083	0.901
Cu	0.888	-0.084	0-.009	0.795
Ni	0.853	-0.064	0-.391	0.885
Fe	0.790	0.475	0.118	0.864
Ca	0.202	0.820	-0.066	0.718
Na	0.952	0.074	0.107	0.924
K	0.004	0-.119	0.983	0.980
Eigen Values	3.723	2.107	1.116	
% Variance	46.539	26.343	13.949	
Possible sources	Road dust Marine	Waste burning Crustal dust	Biomass burning	

Factor 1 (PC1) loads heavily on Pb, Cu, Ni, Fe and Na. This may be attributed to road dust and sea spray (marine). Factor 2 (PC2) is loaded primarily by Pb, Cd and Ca. This may be related to waste burning and construction activities. Factor 3 (PC3) loads heavily on K. This factor is probably related to biomass burning.

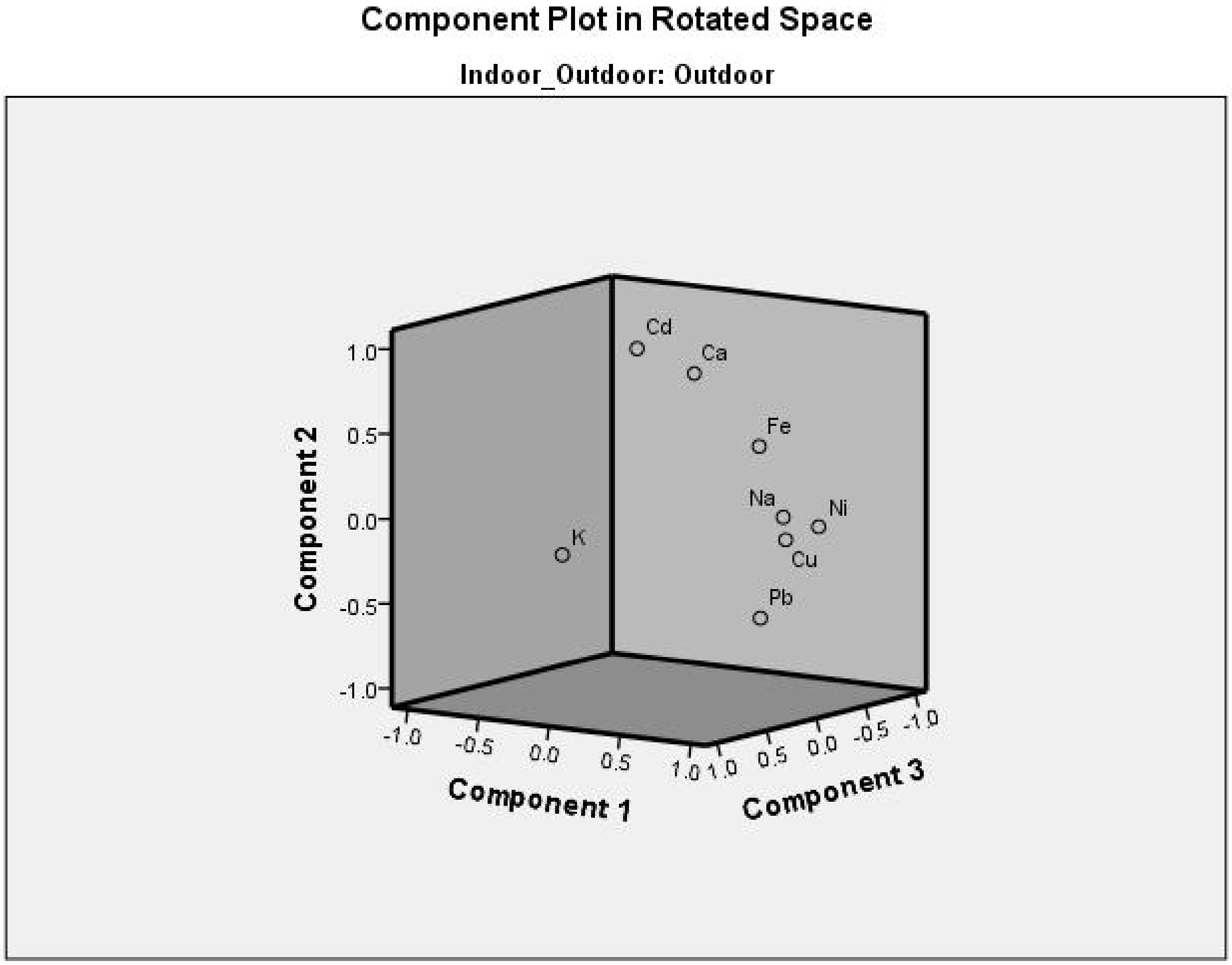

Figure 5: Outdoor Samples Component Plot in Rotated Space during the Dry Season

3.2.5 Cluster Analysis

The result of the cluster analysis carried out with the aid of cluster package using Euclidean distance and complete linkage farthest neighbors as a measure of correlation was able to confirm the sources as identified by the PCA analysis.

During the wet season, the result showed significant clustering of Cd, Cu, Pb and Ni; Fe, Ca and K and Na in the indoor micro environment. While a significant clustering of Pb Cd and Cu; Ni, Fe, Ca and K and Na was observed in the outdoor micro environment. Cluster 1, 2 and 3 may be relevant to vehicles or waste combustion, crustal dust and marine respectively in both indoor and outdoor micro environment. During the dry season, the indoor result showed significant clustering of Cd, Cu, Pb, and Ni; Ca and Na; Fe and K. While; a significant clustering Pb, Ni, Cd and Cu; Fe and Ca; Na and k was observed. Cluster 1, 2 and 3 may be relevant to vehicles or waste combustion and crustal dust in the indoors. And in the outdoors, cluster 1, 2 and 3 may be relevant to vehicles or waste combustion, crustal dust and marine.

CONCLUSION

The results of this study identified road dust, marine and combustion activities as the major sources of PM and metals in this area. It also revealed that, the concentration of these pollutants in most of the sites were higher than safe limits proposed by regulatory bodies and this can have significant implications on the vulnerable groups (elderly, children, pregnant women) and public health in general. Of the three cooking fuels in this study, charcoal generated the highest TSP while, gas stove generated the least.The use of clean cooking fuel in homes should therefore be adopted where possible.

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