Article

Heavy metal in inhalable and respirable particles in urban atmosphere

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Abstract

Human activities in Sapele are veritable sources of particulate pollution which are exuded into the atmosphere. These activities include bush burning which is one of the pre-planting activities, transportation, gas flaring, incineration of wastes refuse disposal and the use of wood as a source of fuel. The objective of this study is to determine the concentration of the trace metal in particulate matter captured in glass fibre filter paper. High volume sampler was used to collect the respirable and inhalable suspended particulate matter at ten different sites located in Sapele, from December 2010 to April 2011. The foam and the glass fibre filter were analysed for nine (Mn, Ni, Cr, Cd, Zn, Cu, Co, Fe, and Pb) respectively by Flame Atomic Absorption Spectrophotometer (FAAS). The concentration of the respirable particle ranged from 104.17 to 145.83μg/m^3 while the inhalable concentration ranged from 166.67 to 812.50μg/m^3. From the analysis the element Cd was moderately enriched.

Keywords respirable particles; inhalable particles; atomic absorption spectroscopy; factor analysis.

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1 Introduction

The airborne dust may have variety of sources. The chemical composition of all the emission sources varies strongly. In order to trace down the pollution sources and to evaluate the degree of anthropogenic contribution, the study of the chemical composition is imperative.

The greatest air pollution in Nigeria environment is atmospheric dust (Ediagbonya et al., 2013a, b). Few authors have determined the elemental composition of air borne particulate in Nigerian cities (Ediagbonya et al., 2013a, b; Okuo et al., 2005; Ogunsola et al., 1994; Ndiokware, 1984). Elemental concentrations in airborne particulate have been reported in other parts of the world (Ediagbonya et al., 2013; Akeredolu et al., 1994; Dams, 1975; Finkelman, 1994; Benson et al.,1988; Sinha and Banhopadhyay, 1997; Kato, 1996).

The rapidly growing population and the carefree attitude towards pollution control, indiscriminately burning and dumping of waste have actually heightened the particulate beyond the National Standard (FEPA, 1991) and the WHO standard(WHO, 1987).

Particulate matter and their metabolites can cause adverse health effect by interacting with and impairing, molecules crucial to the biochemical or physiological processes of the human body (Bressan, 1974). The biological effects of inhaled particles are determined by the physical and chemical properties of the particles, the site of deposition and the mechanism by which the particles injure the lung (Baranki, 1993). Human health is commonly affected by the absorption of the respiratory portion of total suspended particulate, which contain trace elements. These associated problems maybe cough, Asthma, hearing disability, loss of vision, anaemia, renal failure and infertility (Ediagbonya and Tobin, 2013a; Cohen et al., 1979).

Atmospheric pollution by particulate matter also has adverse effects on forest and vegetation. The particles adhere unto the surfaces of the leaves and these block the stomata, making it impossible for processes such as absorption of gases, radiant energy and transpiration to take place (Bussoti and Ferretti, 1998). The effects of air pollution on vegetation has been reviewed and well documented by the vegetation objective working group of Canadian environment (Polonioki et al., 1997).

Another visible effect of particulate matter is the light scattering and intercepting properties of particles larger than 1 µm. Particles of 0.1 µm cause interference phenomena because they are about the same dimensions as the wavelengths of visible light, so their light-scattering properties are essentially significant (d`Almeida, et al., 1991; Seinfield,1986).

The objectives of this study are to analyse nine trace metals in the glass fibre filter and respirable foam as well as to identify those elements which are normally enriched in the atmosphere. Some of these metals are well known to cause chronic and acute poisoning of vital organ in the body, cancer, dermatitis and ulcers of the skin, pneumoconiosis, manganese poisoning and silicosis (NIOSH, 2002; IARC, 1997; Mohebbi and AbdRad, 2007).

These metals enter the atmosphere from both anthropogenic and biogenic sources. There is a paucity of data on inhalable and respirable particulate matter emitted by individual processed industries in Nigeria even though there is a very strong desire to obtain ambient air-quality information for different locations (Ediagbonya et al., 2013a, b). The reason for this paucity of information is due largely to lack of proper air quality-monitoring equipment which is highly prohibited in cost.

2 Materials and Methods

2.1 Study area

The town Sapele is situated in the south-south geopolitical region of Nigeria with a population of about 135,800. It was once an integral part of the old western region of Nigeria. This study area is located within the co-ordinates of latitude N005^{0} 50$^{'}$ 0$^{''}$-N005^{0}56’0$^{''}$ and longitude E005^{0}37$^{'}$0$^{''}$ – E005^{0}45$^{'}$0$^{''}$ .The study area has a total area of 165.25 square kilometers. Sapele is located near the junction of Jamieson and Ethiope rivers and about 80 mile (144 kilometers) from the sea, well closer into the timber yielding forest of the interior. Sapele is one of the first-rate wood industries in this region. However, it is a commercial city with four petroleum and allied industries. The climate is tropical with two distinct seasons, wet and dry. The major activities among the people of Sapele that generate particulate pollution are usually bush burning as a pre planting preparation, combustion of solid waste as a means of waste disposal, gas flaring, resuspension of dust from unpaved road, and the production of charcoal which involves the burning of wood in an open space from dawn till dusk in four different locations in the city. These charcoal are usually exported to other countries and sometime nearby cities.

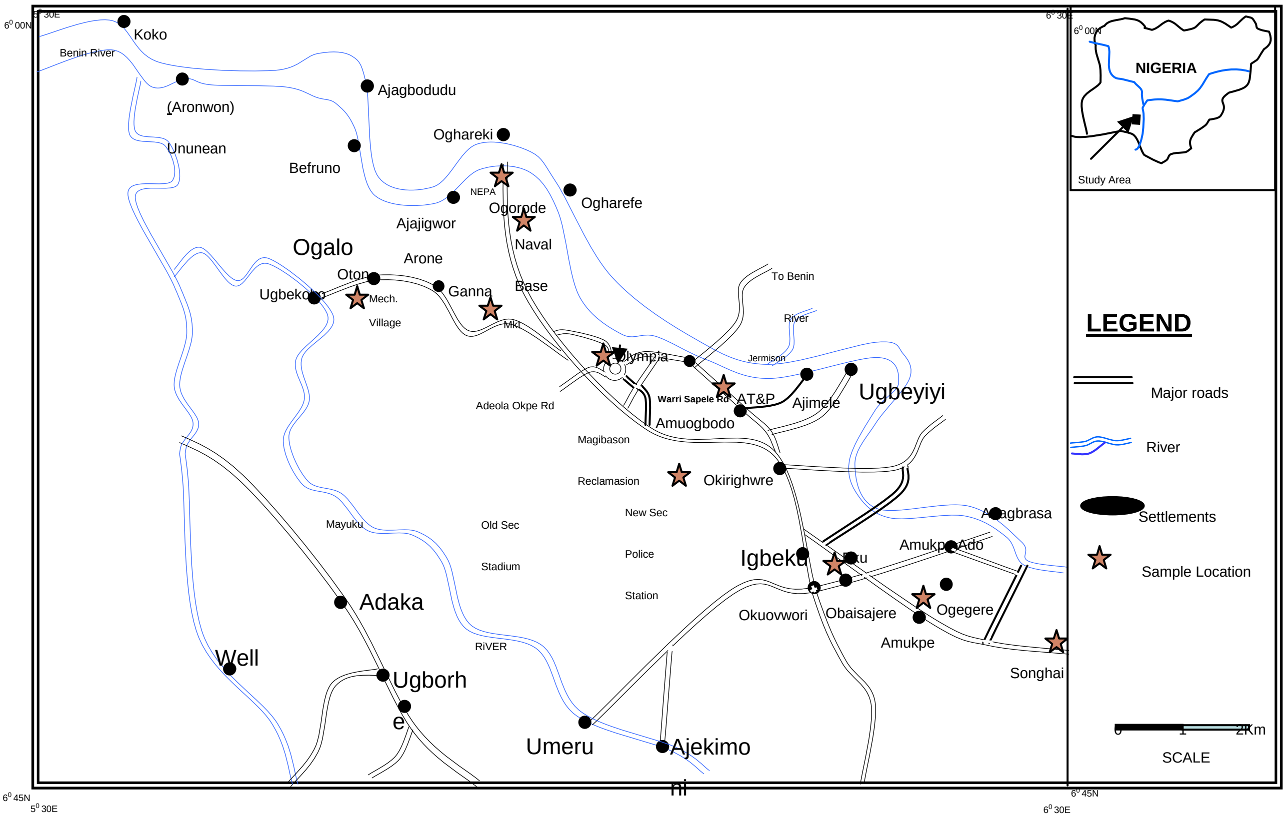

Fig. 1 Map of Sapele reflecting the various sampling locations.

Table 1 Site coordinates and description.

S/N	Site code	Co-ordinates	Site description
1	SP.MV	N05°51’53.5” E005°41’39.0”	The site was created at the mechanic village (shell Rd)
2	SP.SG	N05°51’025” E005°44^{1}.37.4”	This was created at the Songhai
3	SP.NOR	N05°51’06.3” E005 44’45.4”	The site was created at new Ogorode Road.
4	SP.RH	N05°51’.33.” E005°43’06.4”	The site was created at residential houses in Amoukpe area
5	SP.OJ	N05°53’24.8” E005°40’4.9”	The site was created at Olympia Junction
6	SP.SM	N05°54’05.9” E005°41’8·9”	The site was created at Sapele market
7	SP.IA	N05°55’16.8” E005°38’48.5”	The site was created at the industrial area
8	SP.NER	N05°52’28.6” E005°42’07.8”	This was created at New Eku Road
9	SP.SWR	N05°52’28.6” E005°42’07.8”	The site was created at Warri Sapele Road
10	SP.OK	N05°52’27.0” E005°43’40.7”	The site was created at Okirighwere

In line with the objectives of the study, ten monitoring sites were carefully selected to represent all the quarters of the city with high air pollution sources. These sites were created within the vicinities to reflect variation in traffic volume and human activities. Table 1 represents the monitoring sites and their co-ordinates. The monitoring sites were Geo-referenced by using GARMin GPS MAP 765 chart plotting receiver

2.2 Sample collection

SKC Air Check XR5000 high volume Gravimetric sampler model 210-5000 High volume Gravimetric sampler model 210-5000 serial No. 20537 with a Whatman glass fibre filter respirable foam were used to capture the particles. The particles were collected at a flow rate of 2.0l/m for eight hours and the sampler was placed between the heights of 1.5-2m of human. The Whatman glass fibres used were conditioned in a controlled room temperature for at least 24h before pre-and post weighing. The sampling was done from December 2009-April 2010.

2.3 Sample digestion

The trace metals Pb, Cd, Ni, Cu, Co, Fe, Zn, Cr and Mn were determined by AAS (Thermo electron corporation Atomic Absorption spectrometry, S. Series). A portion of the effective filter and the respirable foam were digested separately with 2Oml 1:1 HNO_3 in a beaker and covered with a watch glass which was concentrated to about 50 ml on a hot plate at 150-180^{OC} 10ml of 1:1 HNO_3 was added to repeat it. The extract was filtered through a 541 filter paper, the filter paper and the beaker was washed with 0.25M HNO_3. The filtrate was transferred and weighted into 50ml volumetric flask. The chemical and reagents used for analysis were analar grade.

2.4 Data analysis

The results got from this work were subjected to descriptive statistics and enrichment factor computation. In this work, Fe was chosen as the reference element during the computation of enrichment factor. Ediagbonya, Jian and Ukuo used Fe as a reference (Zheng et al., 2004; Okuo and Ndiokwere, 2005; Ediagbonya et al., 2013a)

$$\left(\frac{C_1}{C_{Fe}}\right)_{\text{Inhalable/Respirable}} \Big/ \left(\frac{C_1}{C_{Fe}}\right)_{crust} .$$

where C_1 the concentration of the element is considered in the TSP of the crust and C_{Fe} is the concentration of the reference element (Fe). The elemental concentration in the crust used in this study was taken from Wedephol (Wedephol, 1986).

3 Results and Discussion

3.1 Spatial distribution of chemical composition of particulate during dry season in Sapele

In addition to particulate matter mass limit values which are based on health impact, recent European union Standard target (As, Cd, Ni, Pb) limit for metals 6 ng/m^3 for As, 5 ng/m^3 for Cd, 20 ng/m^3 for Ni and 500 ng/m^3 for Pb. An enrichment factor close to 1 indicates that the relative concentration of a given element is identical to that which is present in the soil. An enrichment factor greater than 1 indicates that the element is more abundant in the air relative to that found in the soil, while values less than 1 suggests a depletion of the element in the air over that found in soil.In this present study,enrichment factor was used to assess the level of contamination and the possible anthropogenic impact. Also, according to Zhang and Liu (2002), enrichment factor valves between 0.5 and 1.5 indicate the metal is entirely from crustal material or natural processes,whereas enrichment factor values greater than 1.5 suggests that the sources are more likely to be anthropogenic. The results of this study show that Cadmium and Lead were significantly enriched. This high values of Cadmium and Lead suggest that Cadmium and Lead are from anthropogenic sources such as vehicular related emission and re suspended dust.The difference in magnitude could due to water soluble metal. Table 2 shows the total mean concentration of the trace metal composition of the various locations in urban area, and the Enrichment factor.

The total mean concentration values of the analysed trace metals in inhalable fraction are: Fe: 2.12mg/m^3, Zn: 0.0626mg/m^3, Cu: 0.0693mg/m^3, Mn: 0.1278mg/m^3, Cd: 0.311mg /m^3, Pb: 1.7635mg/m^3, Cr: 0.020mg/m^3, while Respirable fraction are: Fe: 2.24mg/m^3, Cu: 0.0884mg/m^3, Cd: 0.391mg/m^3, Cr: 0.0057mg/m^3, Zn: 0.0778mg/m^3, Mn: 0.0736mg/m^3, Pb: 1.6028mg/m^3. Ni and Co were below detection limit in both inhalable and respirable particles. The spatial distribution were insignificant (P>0.05).

From the data generated Cd was highly enriched, this is in accordance with Ediagbonya et al. (2013a), Zheng et al. (2004), and Okuo and Ndiokwere (2005) while Pb was moderately enriched.

Table 2 The descriptive statistics of inhalable suspended particulate matter (mg/m^3) and enrichment factor during dry season in sapele (urban area).

	Min	**Max**	**Mean**	**SD**	**Enrichment Factor**
Fe	0.23	4.56	2.12	1.64171	1
Zn	0.03	0.12	0.0626	0.02979	0.167
Cu	0.03	0.13	0.0693	0.03362	0.370
Mn	0.07	0.2	0.1278	0.04978	0.027
Cd	0.02	0.55	0.3105	0.15223	516.310
Pb	1.27	2.54	1.7635	0.43598	29.060
Cr	0.02	0.02	0.02	0.000	0.510
Ni	BDL	BDL	BDL	BDL	
Co	BDL	BDL	BDL	BDL	

BDL= Below Detection Limit

Table 3 The descriptive statistics of respirable suspended particulate matter (mg/m^3) and enrichment factor during dry season in sapele (urban area).

	Min	**Max**	**Mean**	**SD**	**Enrichment Factor**
Fe	0.68	4.63	2.2401	1.09568	1
Zn	0.03	0.24	0.0778	0.06332	0.237
Cu	0.04	0.2	0.0884	0.04623	0.0388
Mn	0.03	0.12	0.0736	0.03252	0.017
Cd	0.23	0.5	0.391	0.07082	616.340
Pb	1.13	2.54	1.6028	0.46378	16.960
Cr	0	0.02	0.0057	0.00898	0.519
Ni	BDL	BDL	BDL	BDL	
Co	BDL	BDL	BDL	BDL	

BDL= Below Detection Limit

3.2 Source identification of inhalable and respirable particulate matter

Factor analysis was carried out which includes correlation coefficient ,principal component analysis and cluster analysis of metal concentration in order to pin down possible source of the trace metal concentration.

Table 4 above shows the inter-elemental correlation between the trace metals. Elements positively correlated shows that an increase in one element gives rise to a corresponding increase in the other element; while negatively correlated elements shows that an increase in one element gives rise to a corresponding decrease in the other element. From the table above, an increase in Cu gives a corresponding increase in Mn, while an increase in Fe will result to a decrease in Cu.

Table 4 The correlation coefficient of inhalable trace metal.

Fe	1.00						
Zn	0.03	1.00					
Cu	-0.80	0.23	1.00				
Mn	-0.39	-0.40	0.54	1.00			
Cd	0.33	0.37	0.05	-0.07	1.00		
Pb	-0.49	0.30	0.44	0.03	-0.50	1.00	
Cr	0.12	-0.08	-0.39	-0.32	-0.13	-0.04	1.00

From the PCA with varimax rotation, three components were extracted which explained 81.07% of the total variance.

The rotated component matrix showed that from the three components extracted from PCA Mn loaded positively with the first component, while Fe and Cd loaded negatively with the second component with Pb positively loaded. For the third component Zn was loaded positively, these three components suggest three possible sources which are vehicular related emission, metal processing and incineration of refuse. The rotated component plot is shown in the Fig. 2.

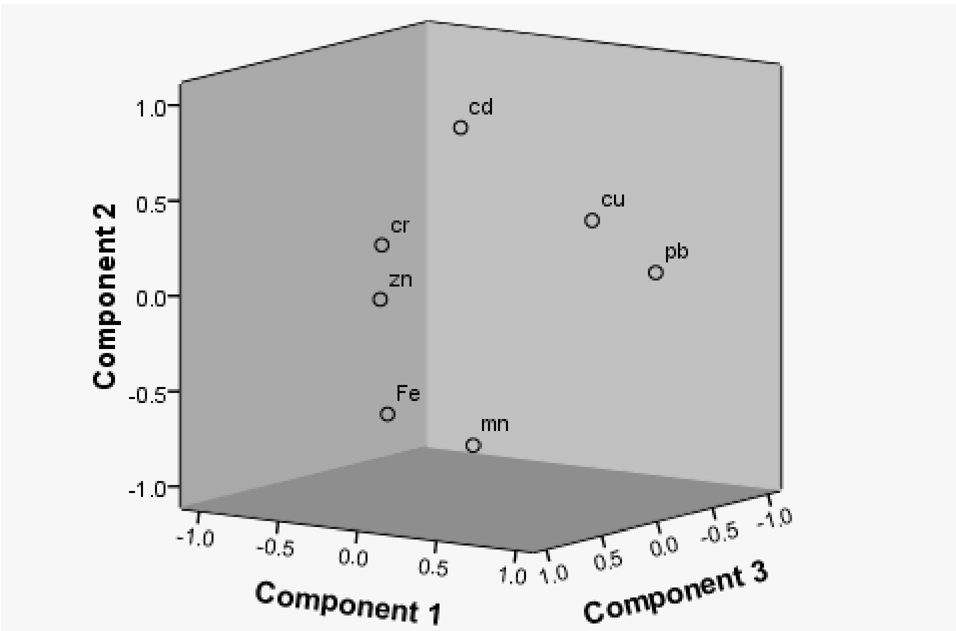

Fig. 2 Component plot in rotated space of inhalable in Sapele.

Table 5 Inter-elemental correlation matrix for respirable particulate matter.

Fe	1.00						
Zn	0.55	1.00					
Cu	-0.14	-0.39	1.00				
Pb	-0.76	-0.18	0.00	1.00			
Mn	-0.39	0.22	-0.50	0.59	1.00		
Cd	0.60	-0.04	-0.24	-0.84	-0.65	1.00	
Cr	0.44	-0.19	-0.41	-0.61	-0.49	0.93	1.00

Table 5 above shows the inter-elemental correlation between the trace metals. Elements positively correlated shows that an increase in one element gives rise to a corresponding increase in the other element; while negatively correlated elements shows that an increase in one element gives rise to a corresponding decrease in the other element.

From the PCA with varimax rotation, three components were extracted which explained 94.27% of the total variance.

Table 6 Rotated component matrix.

	Component		
	1	2	3
Fe	0.56	0.77	-0.09
Zn	-0.15	0.92	0.27
Cu	-0.21	-0.16	-0.96
Mn	-0.80	-0.43	0.23
Cd	-0.66	0.01	0.68
Pb	0.99	0.10	0.02
Cr	0.96	-0.12	0.24

The rotated component matrix from Table 6 showed that from the three components extracted from PCA, Pb, Mn and Cr (although Mn loaded negatively with this component) loaded highly with the first component suggesting vehicular related emission. Zn and Fe loaded highly with the second components suggesting metal processing, while in the third component Cd and Cu incineration of refuse. The rotated component plot is shown in the Fig. 3.

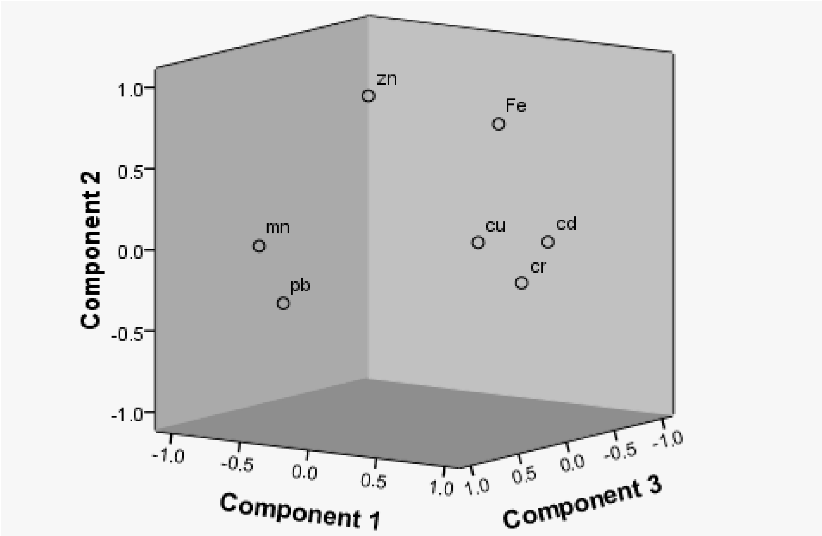

Fig. 3 Component plot in rotated space of respirable in Sapele.

3.3 Cluster analysis

Hierarchical cluster analysis in Fig. 4 and 5 for both inhalable and respirable further confirmed the three principal components. So, it is evident, that there are three major sources of these trace metals.

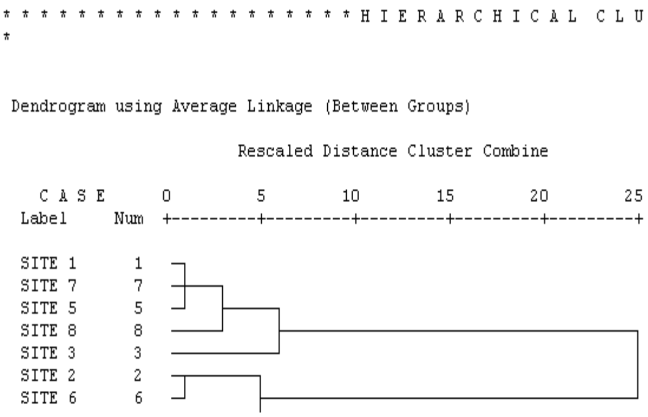

Fig. 4 Dendrogram showing sites cluster of inhalable particulate matter.

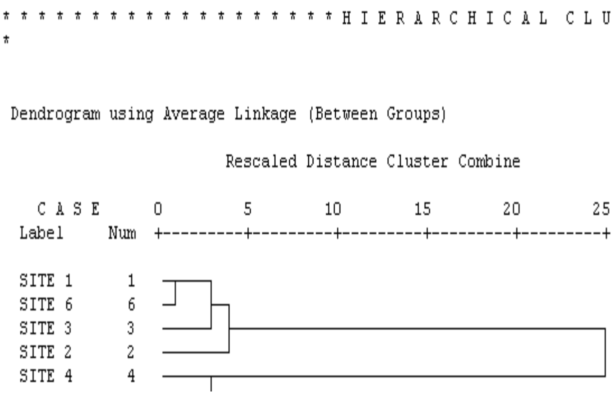

Fig. 5 Dendrogram showing sites cluster of respirable particulate matter.

4 Conclusion

Glass fibre filter and the respirable foam were used to capture the inhalable fraction and the respirable fraction simultaneously. AAS was used to analyses the various trace metals. The results got from this work were subjected to descriptive statistics and enrichment factor computation.In this work,Iron was chosen as the reference element during the computation of enrichment factor.The elemental concentration in the crust used in this study was taken from Wedephol 1968. Nickel and Cobalt were below detection limit

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