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ANALYSIS OF RESPIRABLE AND INHALABLE PARTICLE IN OBARETIN DURING DRY SEASON

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ABSTRACT
Application of effective abatement plan to curtail particulate matter is only conceivable when the emission sources have been uniquely identified and characterized. SKC high volume gravimetric sampler Model 210-5000, serial no 20537 and respirable foam were used to capture the respirable particle and the inhalable particle at five different locations in Obaretin between December 2008 to April 2009. The foam and the glass fibre filter were analyzed for trace metals (NI, Cr, Zn, Co, Fe, Mn, Cu Pb and Cd) by using Atomic Absorption Spectrophotometric, (AAS). From the analysed trace metals Ni and Co were below detection limit and the trace metal Cd was moderately enriched. The total mean concentration values of the analyzed trace metals for inhalable particle (Fe: 1.7022mg/m^3, Zn:0.0532mg/m^3, Cu:0.1370mg/m^3, Mn:0.0345mg/m^3, Cd:0.04452mg /m^3, Pb: 0.15226mg/m^3, Cr: 0.0070mg/m^3). Trace metals in respirable particles, the total mean concentration values of the analysed trace metals are: (Fe: 1.4536mg/m^3, Zn:0.0456mg/m^3, Cu:0.1206mg/m^3, Mn:0.1130mg/m^3, Cd:0.20984mg /m^3, Pb: 0.13560mg/m^3, Cr: 0.10000mg/m^3) Ni and Co were below detection limit. The spatial distribution were insignificant (P>0.05). The values obtained in this study violated the available WHO limit and fell within the purview of OSHA limit.
Keywords: Suspended Respirable Particle, Inhalable Particle, Atomic Absorption Spectroscopy, Rural Area, Enrichment Factor, Trace metal.

INTRODUCTION

Atmospheric environmental problems with trace metals in particulate matter have been investigated in Nigeria (Obioh *et al.*,2005; Abulude,2006). And other parts of the world (Mazzei *et al.*,2006; Macnhaut *et al.*,2007).

Airborne dust and trace elements in air tend to be transported by the wind and are mixed with the surrounding air until their concentration in their turbulent boundary layer is relatively uniform. Dispersion in the horizontal plane is generally unrestricted and occurs more rapidly than vertical mixing. The extents to which air pollutants become diluted after emission is largely controlled by factor determining the degree of turbulence in the boundary layer and include wind speed, solar radiation, cloud cover and land surface roughness (Ediagbonya *et al.*,2013). The ultra-fine particles have diameters less than 1.0μm. The international standard organization applies the thoracic concentration in the classification of particulate matter. In the system, the inhalable fraction comprises those particles that enter the respiratory system during breathing and it corresponds to the PM_{10} while the respirable fraction comprises those that reach the gas exchange region of the lungs and it corresponds to the $PM_{2.5}$ (Holman *et al.*, 1999; Quarg,1996; Ediagbonya *et al.*,2015; Ediagbonya *et al.*,2014b). The chemical composition of atmospheric particulate is quite diverse reflecting the complexity of the sources (Eltayeb *et al.*,1993).

Metals enter the atmosphere from both anthropogenic and biogenic sources. In coastal areas sodium gets into atmospheric particles as sodium chloride from sea spray. These metals enter the atmosphere from both anthropogenic and biogenic sources. The objectives of this study are to analyze the nine trace metals in the glass fiber filter, compare the values obtained with regulatory limit and compute enrichment factors.

MATERIALS AND METHODS

Sampling Site

Sampling was done in Obaretin in Ikpoba-Okha L.G.A Edo State in Niger Delta region of Nigeria. The various locations and coordinates; RHA (N06^{0}09′43.3″ E005^{O}38′49.2″) RHB (N06^O 09′46.9 ″E005^{O}38′44.7″) RHC (N06^{o}09″46.9″ E005^{O}38′48.1″) RHD (N06^O 09′40.0″ E005^{O}38′53.8″) RHE (N06^{O}09′35.8″E005^{O}38′30.4″)

Sample Collection

SKC Air Check XR5000 high volume Gravimetric sampler model 210-5000 High volume Gravimetric sampler model 210-5000 serial No. 20537 . The sampling was done from Dec. 2006-April 2009.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).The details of the data analysis had been reported (Ediagbonya *et al.*,2014a; Ediagbonya *et al.*, 2014b).

RESULTS AND DISCUSSION

From Table 3 inhalable particle (PM_{10}) mean concentration for Iron was 1.7022mg/m3. The concentration of Iron in Inhalable particle obtained in this study fell below the occupational health and safety administration limit (OSHA) for each element for 8hrs (5mg/m^3). In Nigeria the concentration of Iron in inhalable particle has not been reported but the result obtained in this study can be compared to other studies in other parts of world such as in China, Tanzania, Chile and Asian. The average concentration of Iron in the atmosphere of inhalable particle (PM_{10}) in other studies are 0.0005mg/m^3 (Ji-Hyun *et al.*, 2012) had mean concentration of 0.013875mg/m^3. From Table 4, the mean concentration of Iron in Respirable particle was 1.4576mg/m^3. The concentration of Iron in Respirable particle obtained in this study fell below the occupational health exposure value limit for each element for 8hrs (5mg/m^3). In Nigeria the concentration of Iron in Respirable particle has not been reported. The result obtained in this study can be compared to other studies in other parts of world. The mean concentration of Iron in Respirable particle ($PM_{2.5}$) reported by other countries 0.00005394mg/m^3, maximum and mean value for Han *et al.*, 2003 are: 0.0000035mg/m^3, 0.0023294mg/m^3 and 0.0003858mg/m^3. The concentration of Iron reported by Wu *et al.*, 2010 is 0.000737mg/m^3, according to Zhang *et al.*,2007, the Iron concentration was 0.0001866mg/m^3, Ji-Hyun *et al.*, 2012 had a concentration of 0.009586mg/m^3; Sabrina *et al.*,2014 had mean concentration of Iron in the Respirable particle 0.000401mg/m^3. From Table 3, the mean concentration of in inhalable particle (PM_{10}) was 0.0532mg/m^3. The concentration of Zinc in Inhalable particle obtained in this study fell below the occupational health and safety administration(OSHA) value limit for each element for 8hrs (5mg/m^3).WHO limit has not been reported. In Nigeria the concentration of Zinc in inhalable particle has been reported by Obioh *et al.*,2005 which ranged from 0.00011mg/m^3---0.00183mg/m^3, while the mean range value for Amato *et al.*,2009 are: 0.0894mg/m^3--0.0495mg/m^3; Atef *et al.*, 2015 reported Zinc concentration in inhalable particle (PM_{10}): 0.645mg/m3 as mean value and 0.00585mg/m3—0.1397mg/m^3 as the range, (Ji-Hyun *et al.*, 2012) had mean concentration of 0.000457mg/m^3, Sabrina *et al.*,0.0000253. From Table 4, the mean concentration of Zinc in Respirable particle was 0.0456mg/m^3. The concentration of Zinc in Respirable particle obtained in this study fell below the occupational health and safety administration(OSHA) value limit for each element for 8hrs (5mg/m^3). WHO limit has not been reported. In Nigeria the concentration of Zinc in Respirable particle has only been reported by Obioh *et al.*, 2005 with a range value of 0.00015mg/m^3---0.00266mg/m^3.

The result obtained in this study can be compared to other studies in other parts of world, the mean concentration of Zinc in Respirable particle ($PM_{2.5}$) the minimum, maximum and mean value for Han *et al.*, 2003 are: 0.0000032mg/m^3, 0.000196mg/m^3 and 0.0000278mg/m^3. The concentration of Zinc being reported by Wu *et al.*, 2010 is 0.0004997mg/m3; Sabrina *et al.*, 2014 had mean concentration of Zinc in the Respirable particle 0.0003503mg/m^3. From Table, the mean concentration of copper in inhalable particle was 0.137mg/m^3. The concentration of Copper in Inhalable particle obtained in this study violated the occupational health and safety administration (OSHA) value limit for each element for 8hrs (0.1mg/m^3). In Nigeria the concentration of Copper in inhalable particle has been reported by Obioh *et al.* 2005 which ranged from 0.00004mg/m^3---0.00046mg/m^3, but the result obtained in this study can be compared to other studies in other parts of world. The average concentration of Copper in the atmosphere of inhalable particle (PM_{10}) in other studies are 0.0000199mg/m^3, while the minimum and maximum value for Amato *et al.*, 2009 are 0.00018mg/m3 and 0.001392mg/m^3; Atef *et al.*, 2015 reported Copper concentration in inhalable particle (PM_{10}): 0.0063mg/m^3 as mean value and 0.00296mg/m^3—0.01133mg/m^3 as the minimum and maximum. (Ji-Hyun *et al.*, 2012) had mean concentration of 0.000033mg/m^3, 0.000175mg/m^3 and 0.0000494mg/m^3 in entrance while in exit the mean concentration was0.0001895mg/m3 and the minimum and maximum value are; 0.0000728mg/m^3 and 0.000471mg/m^3. Sabrina *et al.*,2014 had a concentration of 0.0000061mg/m^3. From Table 4, the mean concentration of Copper in Respirable particle was 0.1206mg/m^3. The concentration of Copper in Respirable particle obtained in this study fell within the purview of the occupational health and safety administration (OSHA) value limit for each element for 8hrs (0.1mg/m^3) but the maximum value is higher than the limit. In Nigeria the concentration of Copper in Respirable particle has only been reported by Obioh *et al.*,2005 with a range value of 0.00035mg/m^3---0.00132mg/m^3. The result obtained in this study can be compared to other studies in other parts of world. The mean concentration of Copper in Respirable particle($PM_{2.5}$) has reported by other authors: 0.0000115mg/m^3 ; while the mean value for Han *et al.*,2003 was: 0.0000073mg/m^3. The concentration of Copper in respirable particle as reported by Wu *et al.*, 2010 was 0.00002494mg/m^3, according to Sabrina *et al.*, 2014, the mean concentration of Copper in the Respirable particle was; 0.0000535mg/m^3. The reduction or decline in the concentration of the trace metals from one location to another and from one country to another could be adduced to the reduction in industrial and domestic emission. High level of lead exposure in men can damage the organs responsible for sperm production (Mahafeey *et al.*, 1982). From Table 3, the mean concentration of Lead in inhalable particle was 0.1523mg/m^3. The concentration of Lead in Inhalable particle obtained in this study violated the occupational health and safety administration (OSHA) value limit for each element for 8hrs (0.05mg/m^3), also higher than the WHO limit (0.0005mg/m^3). In Nigeria the concentration of Lead in inhalable particle had been reported by Obioh *et al.*,2005 which ranged from 0.00056mg/m^3---0.00659mg/m^3, but the result obtained in this study can be compared to other studies in other parts of world.

The average concentration of Lead in the atmosphere of inhalable particle(PM_{10}); while the mean range by Amato *et al.*, 2009 were: 0.001mg/m^3----0.00229mg/m^3; Atef *et al.*, 2015 reported Lead concentration in inhalable particle (PM_{10}): 0.00154mg/m^3 as mean value and 0.00108mg/m3—0.00206mg/m3 as the range, Ji-Hyun *et al.*,2012 had mean concentration of 0.000188mg/m^3.From Table 4, the mean concentration of Lead in Respirable particle was 0.136mg/m^3. The concentration of Lead in Respirable particle obtained in this study fell within the purview of the occupational health and safety administration (OSHA) value limit for each element for 8hrs (0.05mg/m^3) but higher than the WHO limit (0.0005mg/m^3). In Nigeria the concentration of Lead in Respirable particle had been reported by Obioh *et al.*, 2005 with a range value of 0.00004mg/m^3---0.00612mg/m^3. The result obtained in this study can be compared to other studies in other parts of world, the mean concentration of Lead in Respirable particle ($PM_{2.5}$): 0.0000189mg/m^3 (Ruojie *et al.*,2015); while the minimum, maximum and mean value for Han *et al.*, 2003 are: 0.0000018mg/m^3, 0.0001mg/m^3 and 0.0000204mg/m^3. The concentration of Lead reported by Wu *et al.*,2010 is 0.00001469mg/m^3, according to Zhang *et al.*, 2007, the Lead concentration ranged from 0.0000198mg/m^3----0.000035mg/m^3.Sabrina *et al.*,2014 had mean concentration of lead in the Respirable particle 0.0001312mg/^{3} . IARC has classified cadmium and cadmium compounds as Group 1 human carcinogens, having concluded that there was sufficient evidence that cadmium can produce lung cancers in humans and animals exposed by inhalation (IARC, 1993). From Table 3, the mean concentration of inhalable particle (PM_{10}) was 0.04452mg/m^3. The concentration of Cadmium in Inhalable particle obtained in this study fell within the purview of the occupational health and safety administration (OSHA) value limit for each element for 8hrs (0.005mg/m^3), also higher than the WHO limit (0.000005mg/m^3). In Nigeria the concentration of Cadmium in inhalable particle has not been reported but the result obtained in this study can be compared to other studies in other parts of world. The average concentration of Cadmium in the atmosphere of inhalable particle(PM_{10}) in other studies are, 0.0000001mg/m^3 cold, 0.000000mg/m^3) Amato *et al.*, 2009 had a range of 0.00046mg/m^3---0.0014mg/m^3; Atef *et al.*, 2015 reported mean Cadmium concentration in inhalable particle (PM_{10}) 0.00008mg/m^3. From Table 4, the mean concentration of Cadmium in Respirable particle was 0.02984mg/m^3. The concentration of Cadmium in Respirable particle obtained in this study fell below the limit of the occupational health and safety administration (OSHA) value limit for each element for 8hrs (0.005mg/m^3) but higher than the WHO limit (0.000005mg/m^3). In Nigeria the concentration of Cadmium in Respirable particle has not been reported. The result obtained in this study can be compared to other studies in other parts of world, the mean concentration of Cadmium in Respirable particle.

IARC has stated that for chromium and certain chromium compounds there is sufficient evidence of carcinogenicity in humans (Group 1) (IARC,1990). From table 3, the mean concentration of Chromium in inhalable particle (PM_{10}) was 0.007mg/m^3. The concentration of Chromium in Inhalable particle obtained in this study fell below the occupational exposure value limit for each element for 8hrs (0.5mg/m^3) but higher than the WHO limit (0.00000025mg/m^3). In Nigeria the concentration of Chromium in inhalable particle had been reported by Obioh *et al.*, 2005 which ranged from 0.00003mg/m^3---0.00133mg/m^3, but the result obtained in this study can be compared to other studies in other parts of world. The average concentration of Chromium in the atmosphere of inhalable particle (PM_{10}) while Amato *et al.*, 2009 had a range of :0.01234mg/m^3----0.05mg/m^3;Atef *et al.*, 2015 reported Chromium concentration in inhalable particle (PM_{10}) 0.00135mg/m^3 as mean value;0.0000018mg/m^3. From table 4, the mean concentration of Chromium in Respirable particle was 0.01mg/m^3. The concentration of Chronium in Respirable particle obtained in this study fell below the occupational health and safety administration (OSHA) value limit for each element for 8hrs (0.5mg/m^3) but higher than the WHO limit(0.00000025mg/m^3). In Nigeria the concentration of Chromium in Respirable particle had been reported by Obioh *et al.*, 2005 with a range value of 0.00005mg/m^3---0.00155mg/m^3. The result obtained in this study can be compared to other studies in other parts of world. The mean concentration of Chromium in Respirable particle ($PM_{2.5}$) mean value by Han *et al.*,2003; 0.0000061mg/m^3. The mean concentration of Chromium had reported by Sabrina *et al.*,2014; 0.0000047mg/m^3.

The toxicity of manganese varies according to the route of exposure. By ingestion, manganese has relatively low toxicity at typical exposure levels and is considered a nutritionally essential trace element. By inhalation, however, manganese has been known since the early nineteenth century to be toxic to workers. From Table 3, the mean concentration of Manganese in inhalable particle (PM_{10}) was 0.0345mg/m^3. The concentration of Manganese in Inhalable particle obtained in this study fell below the occupational health and safety administration (OSHA) value limit for each element for 8hrs (5mg/m^3) but higher than the WHO limit (0.00015mg/m^3). In Nigeria the concentration of Manganese in inhalable particle has not been reported but the result obtained in this study can be compared to other studies in other parts of world. The average concentration of Manganese in the atmosphere of inhalable particle (PM_{10}) in other studies while Amato *et al.*, 2009 had a range of 0.074mg/m^3----0.15mg/m^3; Atef *et al.*, 2015 reported Manganese concentration in inhalable particle (PM_{10}): 0.0088mg/m^3 as mean value. The mean concentration of Manganese in Respirable particle is 0.113mg/m^3. The concentration of Manganese in Respirable particle obtained in this study fell below the occupational health and safety administration (OSHA) value limit for each element for 8hrs (5mg/m^3) but higher than the WHO limit (0.00015mg/m^3). In Nigeria the concentration of Manganese in Respirable particle has not been reported. The result obtained in this study can be compared to other studies in other parts of world. The mean concentration of in Respirable particle ($PM_{2.5}$).

The mean concentration of Manganese reported by Sabrina *et al.*, 2014, 0.0000083mg/m^3; Ji-Hyun *et al.*, 2012 had a mean concentration of 0.000043mg/m^3; Wu *et al.*,2010 had a mean concentration of 0.000022mg/m^3.Ni and Co were below detection limit both in inhalable and respirable particle. The spatial distribution were insignificant (P>0.05). From the data in Table 3 and Table 4, the generated, Cd was highly enriched, while Pb was moderately enriched. Table 5 shows the correlation coefficient of the metal concentration in inhalable particles. While Table 6 shows the correlation coefficient of the metal concentration in respirable particles. Table 1 shows principal component analysis (PCA) for inhalable. The Table 1 shows the PCA with varimax rotation, three components were extracted which explained the entire (100%) total variance. The rotated component matrix showed that from the three components extracted from PCA, Pb and Cu loaded positively with the first component suggesting vehicular related emission, while Fe loaded negatively with Cd and positively with Pb, the second component suggested vehicular related emission and biomass burning. The third component Fe loaded positively with Mn suggesting re-suspended dust. The rotated component plot is showed in Fig1. Table 2 shows the PCA of respirable particle with varimax rotation. One component was extracted which explained the entire (100%) total variance. The rotated component matrix showed that the whole trace metals were from the same source which is vehicular related emission and biomass burning. Fig2. Shows the hierarchical cluster analysis for inhalable particle, this cluster confirmed two major clusters arrangement of the trace metal concentration and distribution at the five monitoring sites. Cluster comprises site 1 which is a unique cluster while the second cluster is subdivided into two parts made up of Site 2 and Site 4. This cluster analysis for inhalable particle also supports the three components analysis got from the principal component analysis.

Fig4 shows the hierarchical cluster analysis for respirable particle. This cluster confirmed one major clusters arrangement of the trace metal concentration and distribution at the five monitoring sites. Cluster comprises Site 2 and 4.Which also supports the one principal component obtained from the principal component analysis.

Table 1: The Rotated Component Matrix of Inhalable Fraction

	Component		
	1	2	3
Fe	-0.10	0.80	0.59
Zn	-0.94	0.13	-0.31
Cu	0.89	-0.24	-0.39
Mn	0.11	-0.06	0.99
Cd	0.12	-0.95	0.30
Pb	0.76	0.59	0.26

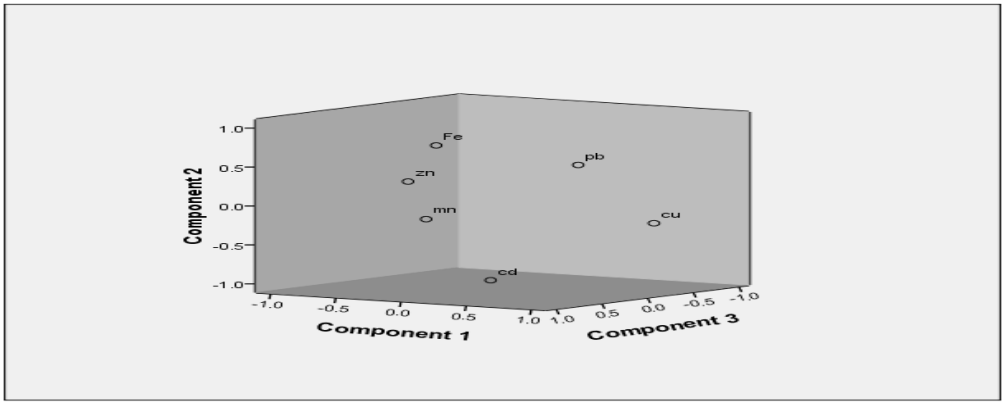

Fig 1: Rotated component plot for inhalable fraction

* H I E R A R C H I C A L C L U S T E R A N A L Y S I S *

Dendrogram using Average Linkage (Between Groups)

Rescaled Distance Cluster Combine

C A S E Label	Num	0	5	10	15	20	25
SITE 2	2						
SITE 4	4						
SITE 1	1						

Figure 2: Cluster analysis for inhalable fraction

Table 2: Rotated component plot for respirable fraction

	Component
	1
Fe	.998
Zn	.999
Cu	.999
Mn	.971
Cd	.544
Pb	-.999

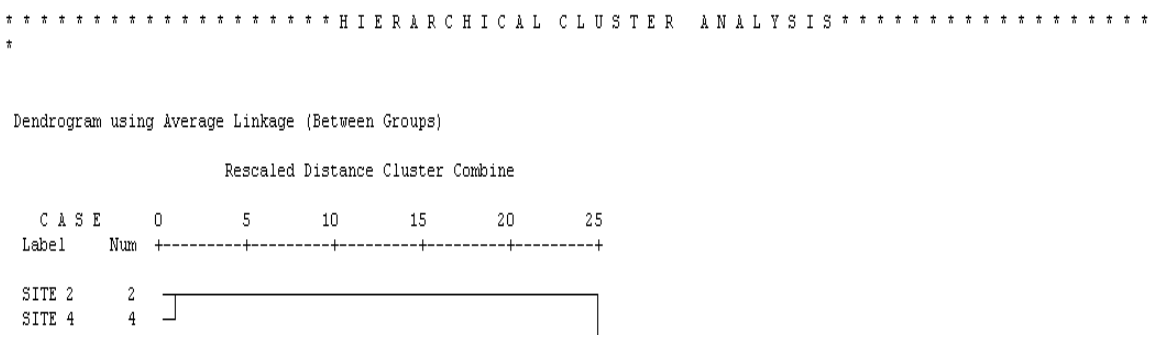

Figure 3: The cluster for analysis respirable fraction

Table 3: The descriptive statistics of inhalable suspended particulate matter (mg/m^3) and enrichment factor during dry season in obaretin

	Min	Max	Mean	SD	Enrichment Factor	Regulatory Limit(OSHA)	WHO
Fe	0.4600	2.1300	1.7022	0.7019	1.000	5mg/m3	----------
Zn	0.0300	0.0700	0.0532	0.0161	0.178	5mg/m3	…….
Cu	0.0900	0.1800	0.1370	0.0438	0.860	1mg/3	----------
Mn	0.0000	0.0700	0.0345	0.0398	0.004	5mg/m3	0.00015mg/m^3
Cd	0.03400	0.05000	0.04452	0.00621	822.300	0.005mg/m3	0.000005mg/m^3
Pb	0.12700	0.21100	0.15226	0.03777	18.730	0.05mg/m3	0.0005mg/m^3
Cr	0.0000	0.0200	0.0070	0.0121	0.589	0.5mg/m3	0.00000025mg/m^3
Ni	BDL	BDL	BDL	BDL			
Co	BDL	BDL	BDL	BDL			

BDL= Below Detection Limit

Table 4: The descriptive statistics of respirable suspended particulate matter (mg/m^3) and enrichment factor during dry season in obaretin

	Min	Max	Mean	SD	Enrichment Factor	Regulatory Limit(OSHA)	WHO
Fe	1.2500	1.7100	1.4576	0.2041	1.000	5mg/m3	-------
Zn	0.0300	0.0800	0.0456	0.0259	0.217	5mg/m3	---------
Cu	0.1000	0.1600	0.1206	0.0272	0.930	1mg/3	----------
Mn	0.0900	0.1500	0.1130	0.0318	0.040	5mg/m3	0.00015mg/m^3
Cd	0.00200	0.04100	0.02984	0.01701	883.800	0.005mg/m3	0.000005mg/m^3
Pb	0.08600	0.16900	0.13560	0.03478	21.350	0.05mg/m3	0.0005mg/m^3
Cr	0.0000	0.02000	0.01000	0.01414	0.072	0.5mg/m3	0.00000025mg/m^3
Ni	BDL	BDL	BDL				
Co	BDL	BDL	BDL				

BDL= Below Detection Limit

Table 5: Inter-elemental correlation Inhalable

Fe	*1*					
Zn	0.011	1				
Cu	-0.502	-0.751	1			
Mn	0.521	-0.418	-0.27	1		
Cd	-0.596	-0.325	0.214	0.371	1	
Pb	0.554	-0.725	0.441	0.303	-0.391	1

Table 6: Inter-elemental correlation Respirable

Fe	1					
Zn	1	1				
Cu	1	1	1			
Mn	0.985	0.982	0.982	1		
Cd	0.483	0.5	0.5	0.327	1	
Pb	-1	-1	-1	-0.982	-0.5	1

CONCLUSION

The trace metal values obtained in this study are comparable to other studies in other parts of the world. Three major sources were obtained from the inhalable fraction suggesting biomass burning, vehicular related emission and metal processing while in respirable fraction one major source was obtained from the component plot matrix suggesting biomass burning and vehicular related emission.

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