

Article

Spatial distribution of respirable and inhalable particulate matter concentration in sawmills of South-South Region of Nigeria

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Abstract

Dust particles in the air that can be respired into the nose or mouth during normal breathing are known as inhalable particle. Inhalation decreases gradually with increasing particle diameter. The respirable and inhalable sawdust were collected from nine different sawmills in Benin City from November 2009 to February 2010 using portable programmable SKC Air Check XR5000 High Volume Gravimetric Sampler Model 210-5000 Serial No. 20537 and I.O.M (Institute Occupational Medicine Edinburg) Multi dust sampler, Batch No. 221442/1. The objective of this study is to know the concentration of inhalable suspended particulate matter fraction and the respirable suspended particulate matter fraction in sawmill particulate. The mean concentration range of the respirable suspended particulate matter was 173.61-520.83 $\mu\text{g}/\text{m}^3$ and the inhalable suspended particulate matter was in a range of 555.56-2,013.98 $\mu\text{g}/\text{m}^3$. A strong positive correlation existed for inhalable suspended particulate matter and respirable suspended particulate matter. And the spatial variation was significant and remarkable.

Keywords respirable particle; inhalable particle; sawmill and South-South spatial variation; toxicity potential.

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1 Introduction

In Nigeria, information on environmental pollution by particulate matter and their impacts on human health are largely minuet where available, they are usually focused on larger industries and vehicular emissions (Akeredolu et al., 1994; Asubiojo et al., 1991; Ndiokwere, 1984; Oyedele et al., 1994).

Over 99% of inhaled particulate matter is rather exhaled or trapped in upper areas of the respiratory system and expelled. The balance enters the wind pipe and lungs where some particulate known as inhalable particulates cling to protective mucous and are removed, other mechanisms such as coughing, also filter out or

remove particles.

Collectively, these “Pulmonary Clearance” mechanisms protect the lungs from the majority of inhalable particles (Hatch, 1961; Hilding, 1965; Nadel, 1965).

Some of the smallest particles called respirable (PM_{2.5}) particulates lodge in the lung capillaries and alveoli causing the following effects slowing down the exchange of oxygen and carbon dioxide in the blood, causing shortness of breath and straining the heart, because it must work harder to compensate for oxygen loss. The people most sensitive to these conditions include those with heart problems or respiratory disease like emphysema, bronchitis and asthma. The elderly and children are very sensitive (Ediagbonya and Tobin, 2012).

The adverse health effects from particulate matter exposure are often not immediately noticed (Prajapati, 2012). Particulates can accumulate in the lungs after repeated long-term exposure causing respiratory distress and other health problems (Columbia Encyclopedia, 2006; Miroslav et al., 1999).

Some particles themselves may be poisonous if inhaled or absorbed and can damaged remote organs like the kidneys or liver, swallowed mucous laden with poisonous particulate matter may also damaged the gastrointestinal system. Irritating odours are often associated with particulates.

Epidemiological studies have long recognized increased mortality and morbidity in susceptible populations during high air pollution episodes (Stipharious et al., 1993; Chebbi et al., 1996).

The finding suggests a strong relationship between particulate matter and impairment of Cardiopulmonary function (Schauer et al., 2001)

Airborne particulate matter represents a complex mixture of organic and inorganic substances. It is also a mixture of solid, liquid or solid and liquid particles suspended in air (Yu et al., 2006; Yang et al., 2005; Dockery et al., 1997; Telesca and Lovallo, 2011).

Particulate matter of thoracic size may be emitted from a number of sources, some of them are natural (e.g. volcanoes and dust storms) and many others that are more widespread and more important to public health (e.g. power plants and industrial processes vehicular traffic or motor vehicle exhaust fossil fuel, biomass burning, industrial and municipal waste incinerators). The majority of these man-made source are concentrated in limited area, that is, urbanized area, where population are also concentrated (Proceeding of the symposium on Biological Test, 1983; Chauer et al., 2002; Mayol-Bracero et al., 2002; Pio et al. 2005; Ukpebor et al., 2004; He et al. 2001; Dan et al., 2004; Ediagbonya et al., 2013a).

Particulate matter is what most people see and feel when they experience “dirty air” particulate can Corrode metals and Masonry (Hudson, 1943; Report of Committee on Corrosion, 1952; Galagar et al., 1961; Whitby, 1933; Esterow, 1964; Winkler, 1965).

2 Materials and Method

2.1 Area of study

The study was conducted in Benin City the capital of Edo State (Fig. 1). This ancient City is located in the Southern part of Nigeria and has a population of about 1,147,188 (NPC 2005/2006). It is a commercial City with few petroleum and allied industries. Sawmills are found in every nook and cranny of the city. During production, very small pieces of wood that fall as powder when wood is cut with a saw are emitted into the atmosphere. From Monday to Saturday the workmen saw wood from 9:00am to 6:00pm. Sawmill factory is a major factory in Benin City of Edo State. However, the climate is tropical with two distinct seasons wet and dry.

2.2 Sampler and analytical procedure

SKC Air check XR5000 High volume Gravimetric sampler Model 210-5000 serial No. 20537 and the I.O.M multi fraction dust sampler (institute of occupational medicine).

The sampling device includes a sampling train which embodies an air mover, a flow measuring device, a sample collection mechanism. The air mover creates a flow of air that will allow the contaminants in the air to be captured in the sample collection mechanism for analysis. The collection mechanism consist of the cassette cover front plate, two-o-rings, cassette rear cassette front and the sampler body which is connected to the vacuum pump with a Teflon tube. The inbuilt flow meter has a rating of 1000ml/min to 5000ml/min of air samples. Before sampling, the unit was carefully calibrated against a standard meter to determine the quantity of air flows and all unloaded glass fiber filter and the foam were dried in the desiccators at room temperature.

The Respirable foam for I.O.M (institute of occupation medicine Edinburgh) multi fraction dust sampler with batch No. 221442/1 uses 25mm diameter filter for inhalable dust sampling it is a flexible sample head which can be with foam to give a respirable measurement.

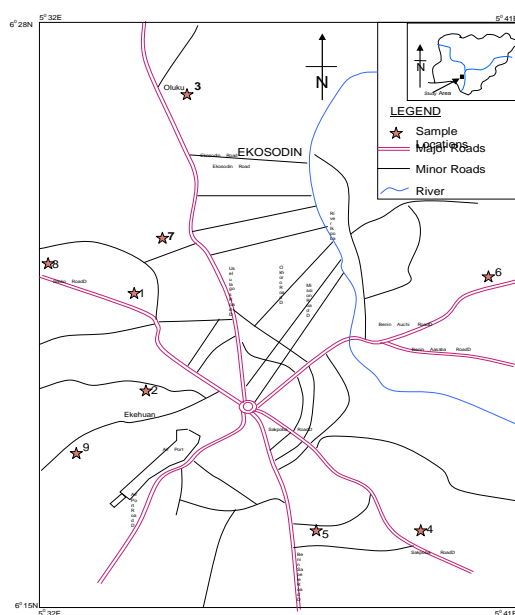


Fig. 1 Map of Benin City showing the sampled locations.

The filter and cassette rear was pre-weighed to determine the initial respirable dust, while the filter, foam and whole cassette together was pre-weighed to determine the initial inhalable. After sampling, the filter, foam, and the whole cassette together were re-weighed to determine the inhalable fractions. Then, the whole cassette was split, in order to weigh the cassette rear and filter only to determine the final weight of the respirable fractions the particles were collected at a flow rate of 2l/min for eight hours and the sampler was placed between height of 1.5-2m of man.

The difference between the final weight and the initial weight is the amount of respirable and inhalable dust collected. (Shaw, 1987; UNEP / WHO, 1994)

The Concentration in $\mu\text{g}/\text{m}^3$ was calculated by

$$\frac{\text{final weight (mg)} - \text{initial weight (mg)}}{\text{Flow rate (m}^3 / \text{min)} \times \text{Sampling Period (min)}} \times 1000$$

For a quantitative estimate of the possible impact of the airborne particulate on the health of those exposed, the toxicity potential (TP) of respirable and inhalable suspended particulate matter (REPM & ISPM) were calculated by dividing its concentration for each sampling site with the daily average USEPA National

Ambient Air Quality standard level concentration of 150 and 65 $\mu\text{g}/\text{m}^3$ for inhalable and respirable particle.

2.3 Data analysis

The data captured were subjected to statistical analysis using the Statistical Package for Social Sciences (SPSS version 16.0 for windows). The following statistics were done to achieve the aim of this work: descriptive statistics, Pearson correlation, one-sample t-test, one-way Analysis of Variance (ANOVA) and Cluster analysis.

3 Results and Discussion

After sampling, the mean concentration of the inhalable and respirable particulate matters of the nine (9) different sawmills were compared for spatial variation. The mean measurement of inhalable and respirable particulate matters in the nine locations of Sawmill in Benin is presented in Fig. 2. The ANOVA showed that there is a significant difference ($P < 0.05$) in the spatial distribution of both inhalable ($F = 17.10$, $df = 8$) and respirable ($F = 5.998$, $df = 8$) particulate matters. The highest mean concentration was observed in site 8 (2,013.89 $\mu\text{g}/\text{m}^3$) while the lowest mean was observed in site 3 (729.16 $\mu\text{g}/\text{m}^3$). Tables 1 and 2 also show the mean comparison of the different sites visited and the t-test was used to test the true means from the Standard from National Ambient Air Quality Standard for respirable and inhalable particulate matter. For Inhalable particulate matter, the data generated in all the sites significantly ($P < 0.05$) exceeded the Standard (150 $\mu\text{g}/\text{m}^3$); while for Respirable particulate matter, the data generated in all the sites also significantly ($P < 0.05$) exceeded the standard (65 $\mu\text{g}/\text{m}^3$), except for Uwasota sawmill and Federal Sawmill. For Inhalable, the Toxicity potential was in the range of 3-13, while the Toxicity potential for respirable was in the range of 2-9 as seen in Table 3. However, the concentration of inhalable and respirable particles obtained can also be compared to the one in rural area (Ediagbonya et al., 2013b).

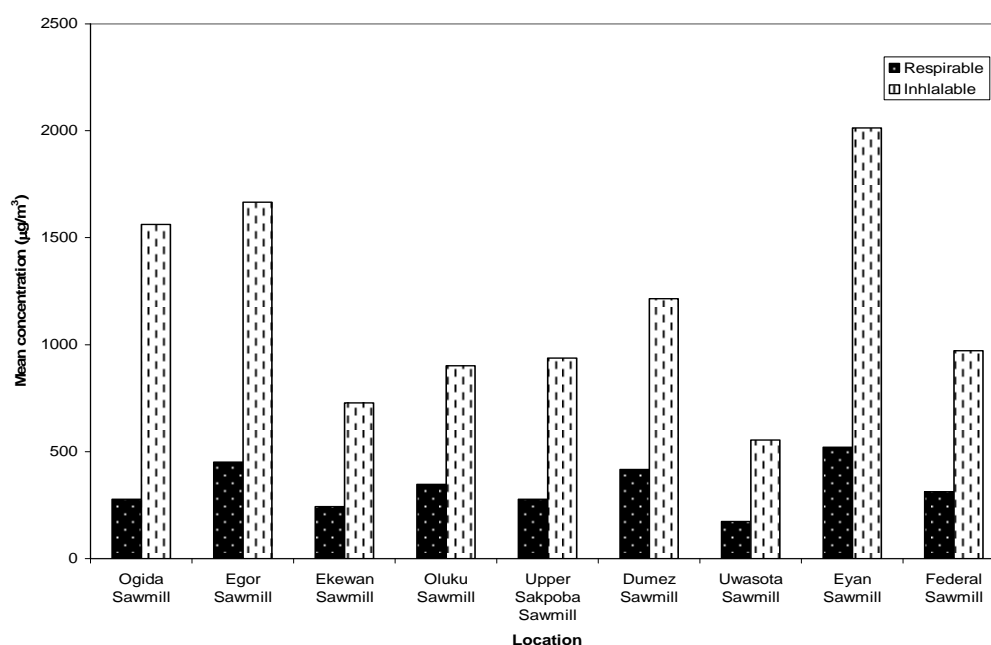


Fig. 2 Mean Concentration of Inhalable and Respirable at the nine (9) sampling locations.

Table 1 Mean comparison (Duncan Multiple Range Test) and t-test of inhalable particulate matter with standard.

Location	Inhalable	F	t	NAAQS
Uwasota Sawmill	555.56±159.12 ^a	17.10	4.42*	150 µg/m ³
Ekewan Sawmill	729.16±104.15 ^{ab}		9.63*	"
Oluku Sawmill	902.78±159.12 ^{ab}		8.19*	"
Upper Sakpoba Sawmill	937.50±312.50 ^{ab}		4.37*	"
Federal Sawmill	972.22±159.12 ^{ab}		8.95*	"
Dumez Sawmill	1215.30±216.84 ^{bc}		8.51*	"
Ogida Sawmill	1562.50±104.17 ^{cd}		23.47*	"
Egor Sawmill	1666.70±275.60 ^{cd}		9.53*	"
Eyan Sawmill	2013.90±216.84 ^d		14.89*	"

Note: Mean (±S.D) with different letters are significantly different (P<0.05). *Significant at P<0.05, when compared with NAAQS standard.

Table 2 Mean comparison (Duncan Multiple Range Test) and t-test of respirable particulate matter with standard

Location	Respirable	F	t	NAAQS
Uwasota Sawmill	173.61±60.14 ^a	5.998	3.13	65 µg/m ³
Ekewan Sawmill	243.05±60.14 ^{ab}		5.13*	"
Oluku Sawmill	347.22±60.14 ^{abc}		8.13*	"
Upper Sakpoba Sawmill	277.78±60.14 ^{ab}		6.13*	"
Federal Sawmill	312.50±104.17 ^{abc}		4.115	"
Dumez Sawmill	416.67±104.17 ^{bc}		5.85*	"
Ogida Sawmill	277.87±60.25 ^{ab}		6.12*	"
Egor Sawmill	451.40±60.13 ^{bc}		11.13*	"
Eyan Sawmill	520.83±104.17 ^c		7.58*	"

Note: Mean (±S.D) with different letters are significantly different (P<0.05). *Significant at P<0.05, when compared with NAAQS standard

There was a strong positive correlation ($r = 0.82$) between the inhalable fraction and the respirable fraction. From Fig. 2, we can see that 68.6% (R^2) of the mean inhalable accounted for the mean respirable, that is, we have a 68.6% confidence that there is a linear relationship between them.

Table 3 Toxicity potentials for the different location sites.

S/N.	SITES	Respirable	Inhalable
1.	Ogida Sawmill	4.27	10.08
2.	Egor Sawmill	6.94	10.75
3.	Ekewan Sawmill	3.74	4.70
4.	Oluku Sawmill	5.34	5.82
5.	Upper Sakpoba Sawmill	4.27	6.05
6.	Dumez Sawmill	6.41	7.84
7.	Uwasota Sawmill	2.67	3.58
8.	Eyan Sawmill	8.01	12.99
9.	Federal Sawmill	4.81	6.27

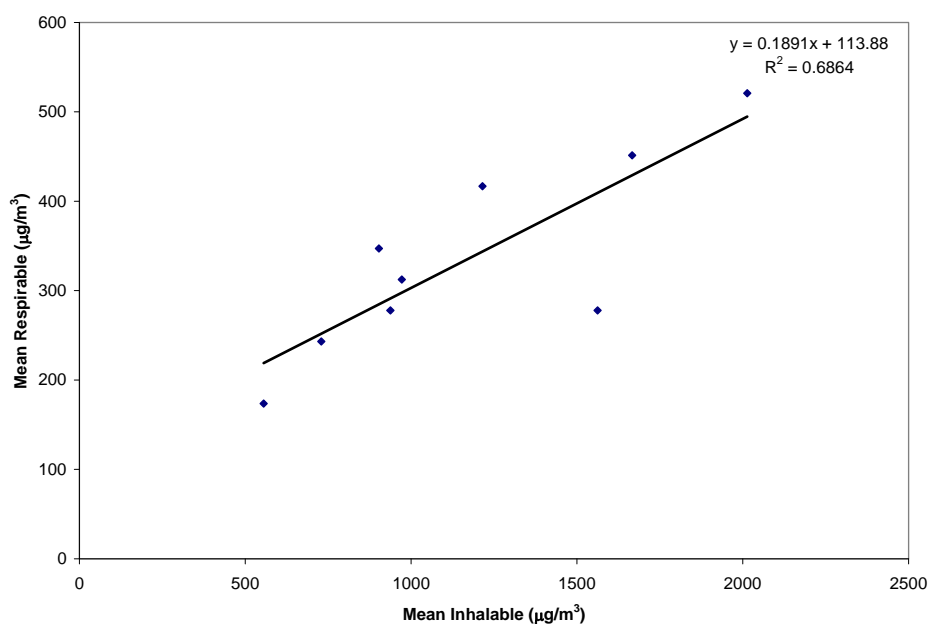


Fig. 3 Correlation of inhalable fraction with respirable fraction.

Table 4 Comparison of the respirable and inhalable suspended particulate matter result of this study with others.

Site/location	Rang/mean of respirable particle ($\mu\text{g}/\text{m}^3$)	Ranges of inhalable particle ($\mu\text{g}/\text{m}^3$)	Sources
Current study	173.61-520.83	555.56-2,013.98	Present study
Urban/China	106-145	67-203	L.Y. Chan et al (2002)
Urban/Hong Kong, China	-	44-112	Chan et al (2002)
London/ UK	39	-	Adams et al (2001)
Munch Germany		110-165.39	Praml and Schier (2002)
Birmingham, UK	33	-	Pfelfor et al (1999)
Urban/China	151-519	-	Lu and Wang (2007)
Urban/Seoul	86.9	215.1	Kim et al (2007)
Urban/Ile-Ife	11-238	18-599	IB.Obioh et al (2005)
Urban/ Belgrade	61	77	M.Tabic et al (2006)
Urban/Milan	66(W) 43 (S)	103(W) 68 (S)	G. maroazzan et al (2001)
Urban/Madrid	34	48	E. manoli et al (2002)
Urban/Berlin	30	38	X. Querol et al (2001)
Urban/Rome	-	60	P.enschow et al (2001)
Lucknow, India	-	370.3-450	Awasthi et al (1996)
Dehi, India	-	378 – 1714	Cropper et al (1997)
Urban/Mumbai, India	35-115.85	82 – 235	P. Kothai et al (2008)

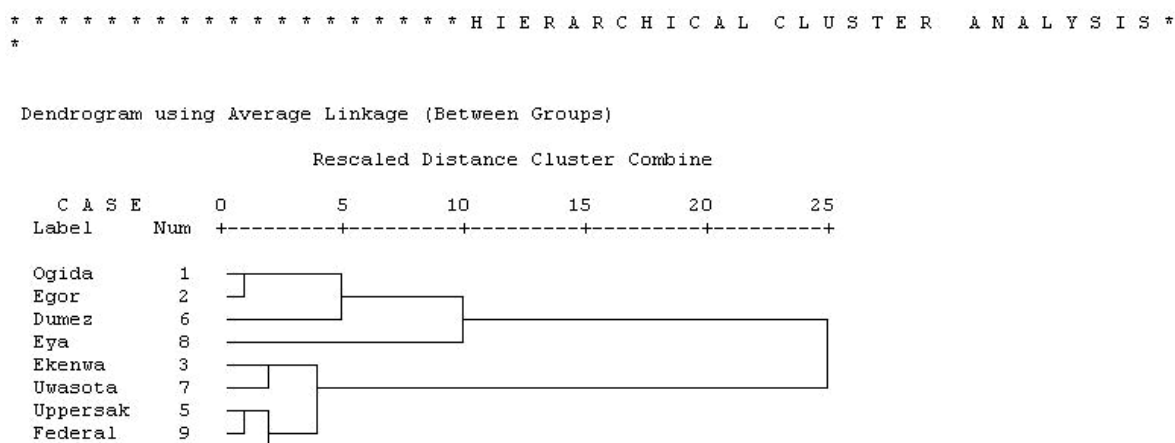


Fig. 4 Dendrogram showing clusters based on inhalable particulate matter.

The cluster analysis test of proximity of sawmills revealed 2 major clusters of the nine locations visited in terms of their Inhalable particulate matter concentration. Cluster 1 consists of Sawmills in Ogida, Egor, Dumez and Eya, while cluster 2 consists of sawmills in Ekenwan, Uwasota, Upper Sakponba and Federal as shown in Fig. 4.

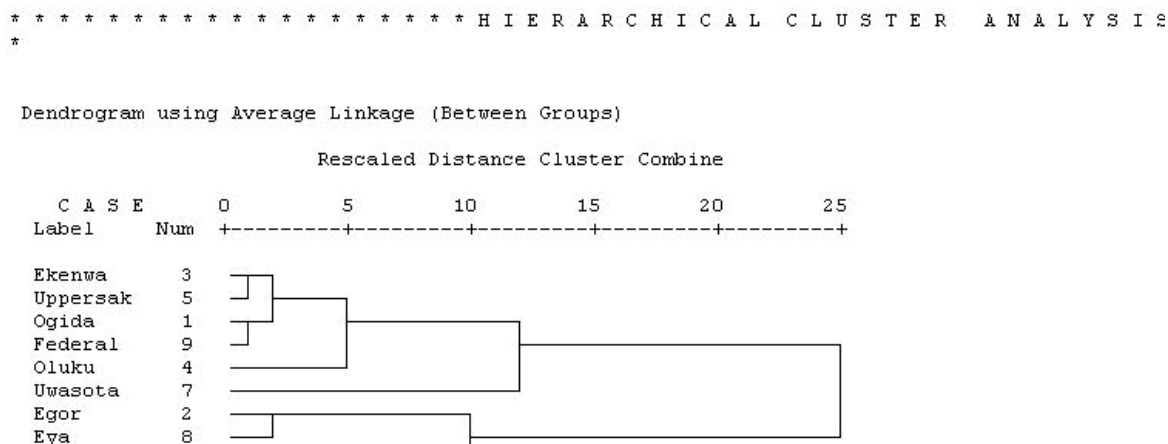


Fig. 5 Dendrogram showing clusters based on respirable particulate matter.

The cluster analysis test of proximity of sawmills revealed 2 major clusters of the nine locations visited in terms of their respirable particulate matter concentration. Cluster 1 consists of Sawmills in Ekenwan, Upper Sakponba, Ogida, Federal and Oluku, while cluster 2 consists of sawmills in Uwasota, Egor and Eya as shown in Fig. 5.

4 Conclusion

The respirable and the inhalable fraction were captured using a portable, programmable SKC Air Check Sampler and I.O.M. (Institute of Occupational Medicine Edinburgh). The spatial variation of inhalable and respirable fraction was significant and remarkable. In all the sites, the Respirable and Inhalable fraction clearly exceeded the limit set by the National Ambient Air Quality Standard implying high health implication to residents around these areas.

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