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An Assessment of Seasonal Variation of Air Pollution in Benin City, Southern Nigeria

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Abstract

This study determined the effects of seasonality on air pollution in a tropical city of Southern Nigeria. This was with a view to acquiring data that would be useful in policy formulation and planning for proper management of ailments that result from seasonal variation of air pollution in the study area. Sampling for the study covered a period of six months, between mid-October 2013 and mid-April 2014. Air pollutants, taken into consideration, include particulate matter ($PM_{0.3, 0.5, 1.0, 2.5, 5.0 \text{ and } 10\mu m}$) and carbon monoxide (CO). Particulate matter was measured using a hand-held particle counter, while CO was measured with a single gas monitor (T40 Rattler). Five sampling points were selected based on stratified sampling technique, which represented five land use types monitored in the study area. Sampling was carried out twice in a week in accordance with the guidelines of Central Pollution Control Board, Delhi India. Sampling height was two meters above ground level. The student T-test was used to determine significant differences in monthly mean concentration of air pollutants across dry and wet seasons. The results revealed the dry season with mean values of 248568.19, 64639.04, 11140.21, 2810.39, 665.84, 320.80 particle counts for $PM_{0.3, 0.5, 1.0, 2.5, 5.0 \text{ and } 10\mu m}$ and 3.01 ppm for CO concentration, was characterized by higher concentration of pollutants, while the rainy season with a mean values of 94728.24, 24745.69, 4338.29, 1158.11, 262.69, 131.36 particle counts for $PM_{0.3, 0.5, 1.0, 2.5, 5.0 \text{ and } 10\mu m}$ and 2.70 ppm for CO concentration was characterized with less concentration of pollutants. The study concludes that seasonality significantly influences the concentration of pollutants in the city.

Keywords

Seasonality, Air Pollutants, Concentration, Variation

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1. Introduction

Seasonality has always been a factor determining concentration of pollution in the lower atmosphere. Therefore introduction of contaminants such as SO_2, CO, NO_2, particulates and Chlorofluorocarbons (CFCs) at toxic levels by natural processes and human activities could practically affect the quality of air, and in turn, the quality of life of living things [1]. Protecting citizens of a community, especially children from the health effects of air pollution is one of the most fundamental goals of environmental health researches and programs. There is therefore need to emphasize the connection between air quality and seasonality, so as to monitor trends in pollution and plan ahead for health challenges, which are linked to seasonal fluctuations in pollutant concentration. Ailments such as asthma, impairments in respiratory system, cough, nose and eye irritation have been linked to high concentration of repairable particulate matter [2], while deaths by suffocation and CO poisoning have also been reported by the Nigerian media severally. Ukpebor *et al.* reported that the months of May and June, 2008 recorded about 22 deaths from CO poisoning [3]. There are two major seasons in Nigeria: the dry and rainy seasons. The present study therefore provides baseline levels of particulate matter and carbon II oxide pollutants in the atmosphere of a typical tropical southern city and evaluates the diurnal trend of these pollutants, in order to acquire data for comparison with regulatory standards, and generate data that would be useful in policy formulation and planning for the proper management of ailments which are seasonally influenced by air pollutants.

2. Study Area

The study area is the typical tropical city of Benin located in the Southern geopolitical region of Nigeria as shown in **Figure 1**. It is bounded by latitude 6˚30'N, 6˚06'N and longitudes 5˚30'E and 5˚45'E (Western and Eastern boundaries) and has an estimated land area of 500 square kilometres [4]. The city falls within the tropical equatorial zone characterized by dry and wet seasons, with a estimated annual rainfall of over 2000 mm and average temperature of 27˚C [5]. Wet season spans between the months of March and October, while the shorter dry season begins November and ends February. Averagely, rain falls all year round with double peak periods in the months of July and September, with a short temporal break in August. Benin City has a population of 3,218,332 [6] and comprises four local government areas, which include Ikpoba Okha, Oredo, Ovia North East and Egor local government areas.

3. Method of Data Collection and Analysis

The primary data includes air quality parameters collected from distributed sampling stations across the study area, coordinate values of which were captured with the use of GPS (Global Positioning System) device, marking sampling stations. Secondary data were sourced from previous literature related to the theme of the study. Stratified random sampling technique was used in selecting sites for administering air quality tests, for effective representation. Stratification of the study area was done based on the Australian Standard AS2922 [7]. Based on the AS2922 classification schemes, the siting of sampling units for the study satisfied the category "Neighbourhood Stations". Each neighbourhood station represented a land use class for which a sampling point was randomly selected. **Table 1** shows the inventory of five sampling points chosen for the study as well as the land use activity each represents. Sampling frequency for both Particulate Matter and Carbon II Oxide was carried out twice weekly for six (6) months, beginning from mid-October 2013 to mid-April 2014, producing a total of 52 sample counts per sampling point. The two major pollutants considered include Particulate Matter ($PM_{0.3}$, $PM_{0.5}$, $PM_{1.0}$, $PM_{2.5}$, PM_5 and $PM_{10μm}$) and Carbon II Oxide. The light scattering method was applied, by use of a CEM (Continuous Emission Monitoring) Particle Counter in detecting and counting air borne particles at a height of approximately two metres from ground level, while Carbon II Oxide concentrations were measured using a Single Gas Monitor called the T40 Rattler at same height. Readings for mean temperature and relative humidity were also derived from the field using an in-built temperature and humidity probe in the hand-held particle counter. The independent-samples T test was applied to determine significant differences in monthly variations of air parameter readings. The arithmetic mean was used in constricting a wide array of air quality data derived from the field.

4. Results and Discussion

The results obtained from the field assessment of air quality parameters ($PM_{0.3\text{-}10μm}$ and Carbon Monoxide) are

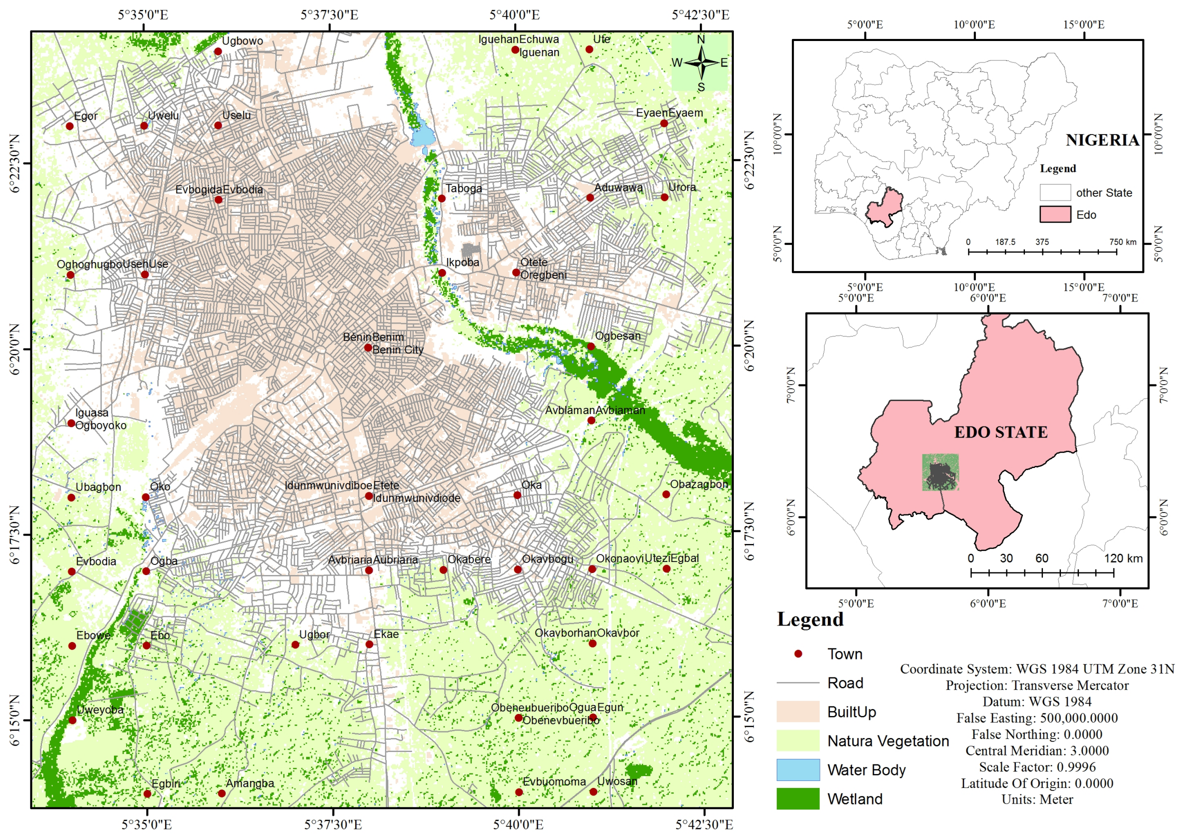

Figure 1. Benin City (Insert: Edo State, Insert: Nigeria).

Table 1. Names and location of sampling points.

Locations	Land Use Type	Coordinates	Altitude (meters)
University of Benin	Institutional	Lat 6˚23'47.8"N Long 5˚37'30.2"E	103
PPRH Plantation Ugbowo.	Agricultural	Lat 6˚24'15.3"N Long 5˚36'16.1'E	114
Ring Road	Commercial	Lat 6˚19'53.1'N Long 5˚37'26.5'E	84
Ikpoba Hill/Agbor Road	Indutrial	Lat 6˚20'52.4"N Long 5˚40'6.6'E	115
Akugbe/Eweka Road	Residential	Lat 6˚21'36.6'N Long 5˚37'55.3"E	90

presented in tables. The values in **Tables 2-7** represent monthly mean values of particle counts ($PM_{0.3,\ 0.5,\ 1.0,\ 2.5,\ 5.0\ \text{and}\ 10\mu m}$) for air pumped at the rate of 0.1 ft^3/minute for an averaging period of 10 minutes. While the values in **Table 8** represents monthly mean values of CO concentration in PPM, run for an averaging period of 15 minutes. **Table 9** shows the results of the independent-samples T test, which determined if there were significant differences in seasonal mean values of all air quality parameters. The results reveal significant differences in seasonal variations for all categories of particulate matter where $P = 0.00 < 0.05$. Nevertheless, results for CO concentration reveal no significant difference with respect to seasonality where $P = 0.07 > 0.05$ (5% significance level). Therefore, we can conclude that seasonality affects the quality of air for all land use types in the study area, especially for particulate matter concentration.

Seasonal and Spatial variations have been represented using line graphs in **Figures 2-8**. It is evident from the graphs that peak mean values for $PM_{(0.3,\ 0.5\ \text{and}\ 1.0)\mu m}$ were recorded in the dry season month of November, that for

Table 2. Monthy values of $PM_{0.3\mu m}$.

Land Use	Average Monthly Particle Counts (2013/2014)						
	October	November	December	January	February	March	April
Institutional	69321	176903	254900	237635	268376	88142	58588
Agricultural	61110	196718	243610	245347	265185	86144	58711
Commercial	132772	367649	303180	363114	275478	109394	94128
Industrial	187991	476602	306854	298763	270036	95172	82945
Residential	163232	273716	280665	271515	262195	102016	66642

Table 3. Monthly values of $PM_{0.5\mu m}$.

Land Use	Average Monthly Particle Counts (2013/2014)						
	October	November	December	January	February	March	April
Institutional	18699	38011	66951	56035	84932	23964	16666
Agricultural	14055	47926	65611	56369	83981	24132	17068
Commercial	36066	88617	78917	82198	83254	29817	26110
Industrial	44671	154306	79402	67065	81176	26725	23608
Residential	36739	60868	74243	61862	84394	28251	19076

Table 4. Monthly values of $PM_{1.0\mu m}$.

Land Use	Average Monthly Particle Counts (2013/2014)						
	October	November	December	January	February	March	April
Institutional	2407	5371	12351	8949	17892	4548	3148
Agricultural	2260	7215	12426	9210	17965	4650	3242
Commercial	7162	13227	14651	12374	16829	5763	4590
Industrial	7720	19253	14283	10521	16511	5295	4374
Residential	5528	8569	13882	10195	17826	5278	3630

Table 5. Monthly values of $PM_{2.5\mu m}$.

Land Use	Average Monthly Particle Counts (2013/2014)						
	October	November	December	January	February	March	April
Institutional	555	1162	3148	2089	5300	1148	771
Agricultural	492	1577	3286	2188	5380	1181	792
Commercial	2303	2878	4198	2709	4811	1500	1093
Industrial	2783	3108	3783	2447	4769	1375	1050
Residential	1136	1760	3731	2498	5578	1373	902

Table 7. Monthly values of $PM_{10.0\mu m}$.

Land Use	Average Monthly Particle Counts (2013/2014)						
	October	November	December	January	February	March	April
Institutional	61	128	325	216	629	109	82
Agricultural	57	169	362	234	660	118	83
Commercial	346	339	544	278	578	176	97
Industrial	307	316	462	261	592	148	102
Residential	131	184	481	292	611	156	96

Table 8. Monthly values of CO concentration.

Land Use	Average Monthly CO Concentration in PPM (2013/2014)						
	October	November	December	January	February	March	April
Institutional	2	0	3	3	3	2	2
Agricultural	1	0	2	3	2	2	2
Commercial	5	3	4	6	4	3	4
Industrial	5	2	4	5	4	4	4
Residential	0	1	3	4	3	3	3

Table 9. The independent sample T-Test result for seasonal variation.

Air Pollutant	F-value	Significance Value (P)
$PM_{0.3\mu m}$	17.616	0.000
$PM_{0.5\mu m}$	13.088	0.000
$PM_{1.0\mu m}$	16.440	0.000
$PM_{2.5\mu m}$	11.546	0.001
$PM_{5.0\mu m}$	9.060	0.003
$PM_{10\mu m}$	8.466	0.004
CO (PPM)	3.240	0.073

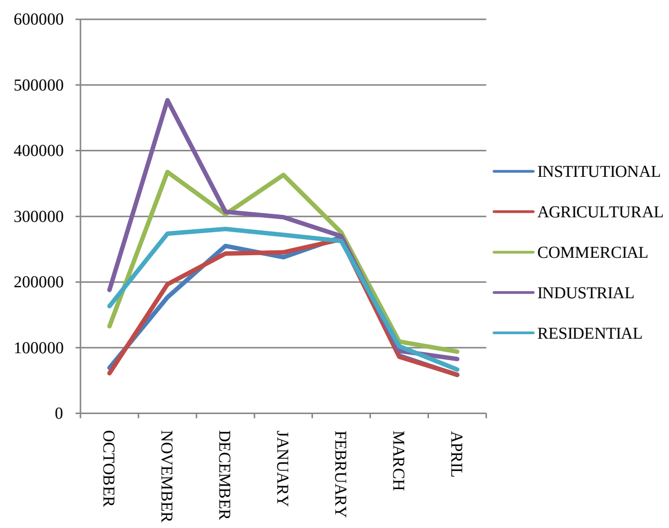

Figure 2. Mean particle counts for $PM_{0.3\mu m}$.

$PM_{(2.5,\ 5.0\ \text{and}\ 10.0)\mu m}$ occurred in the dry season month of February and lastly, that for CO occurred in the dry season month of January. Minimum mean values for particulate matter for all sizes sampled, occurred in the wet season month of April, while minimum mean value of CO was recorded in the dry season month of November.

Meteorological factors which influence the dispersion and dilution of pollutants include wind speed, atmospheric temperature and relative humidity. These explained seasonal differences in concentration of pollutants. This corroborates the postulation by Jacobson, that low wind speed, high temperature and low humidity reduce the rate of dispersion of air pollutants, thus increasing ground concentration of same pollutants and vice versa. Also, higher concentration of pollutants observed during the dry season could be a result of higher ambient

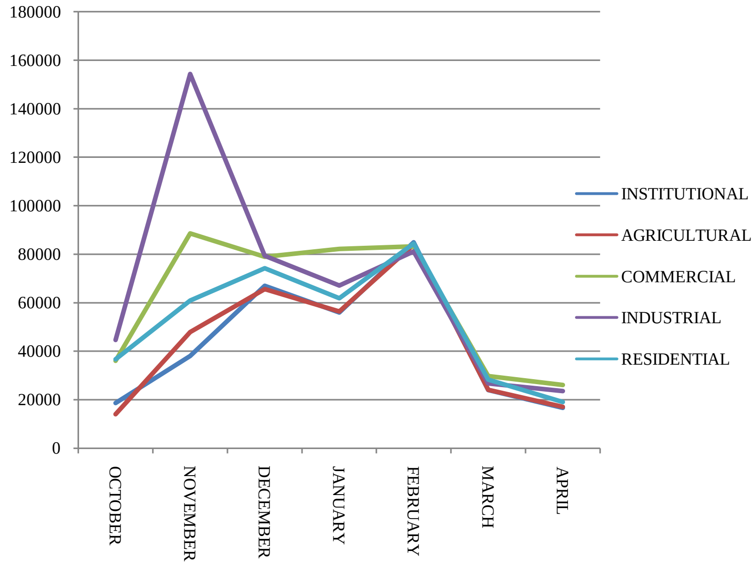

Figure 3. Mean particle counts for $PM_{0.5\mu m}$.

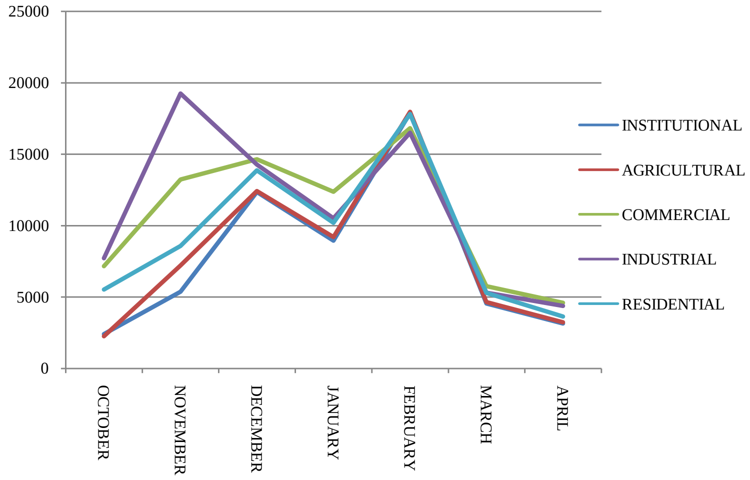

Figure 4. Mean particle counts for $PM_{1.0\mu m}$.

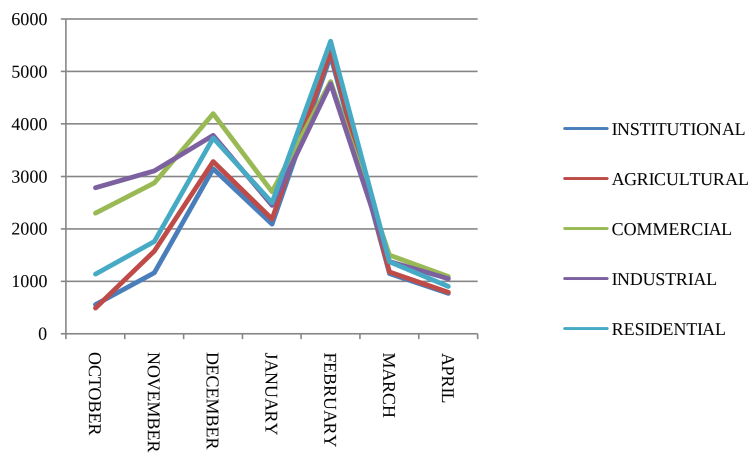

Figure 5. Mean particle counts for $PM_{2.5\mu m}$.

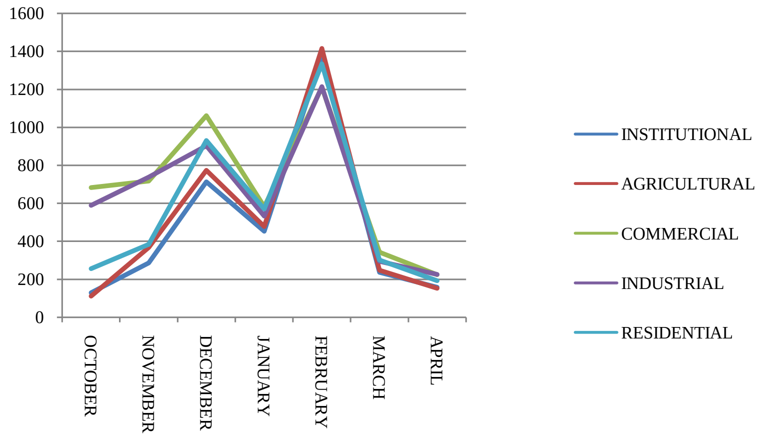

Figure 6. Mean particle counts for $PM_{5.0\mu m}$.

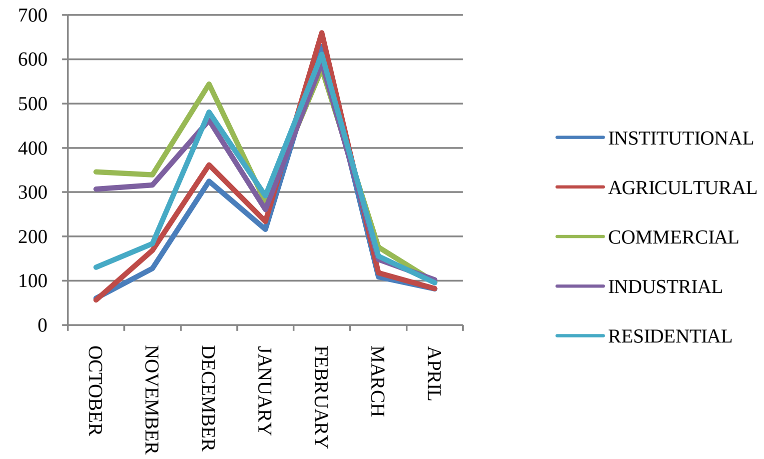

Figure 7. Mean particle counts for $PM_{10\mu m}$.

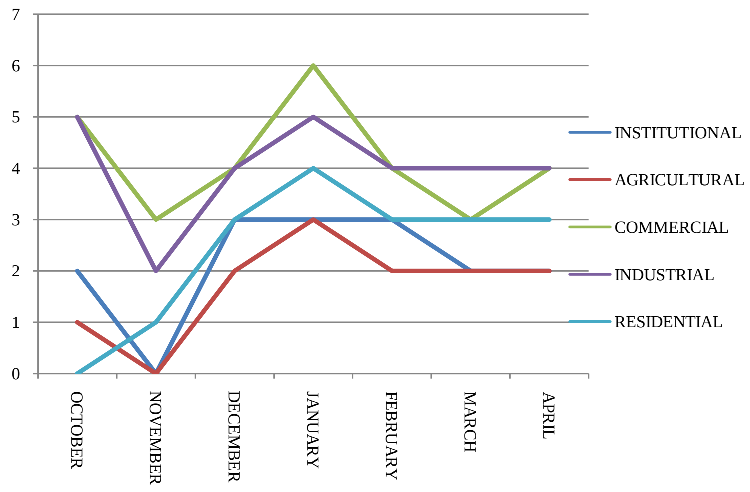

Figure 8. Mean co concentrations (PPM).

temperatures, leading to downward movement of pollutants and consequently high ground level concentrations. If temperature of pollutant gases is higher than the surrounding air, the plumes will tend to rise. On the other hand, if temperature of ambient air is higher, pollutant gases become concentrated at ground level [8]. Therefore atmospheric temperature is thus an important factor for the dispersion of pollutant gases, as the larger the difference between cool ambient air and plumes, the higher the plume rises, so also the rate of dispersion or spread of pollutants from its source before it reaches ground level. Relative humidity is also another meteorological factor that explains the concentration of pollutants at a point. Rene revealed that relative humidity is generally higher during the wet season. High relative humidity results to lower atmospheric temperature, and consequently high rate of plume ascent, and vice versa [9]. In Nigeria, dry seasons are characterized by high temperatures and low humidity, while the reverse is the case for wet seasons. This explains why higher readings were recorded for almost all pollutants during the dry season months, when compared with lower readings recorded during the rainy season months. Wind speed is generally low in Benin City, when compared with some other regions of the world. For instance, a study on variations in CO levels in Benin City recorded a wind speed range of 0.0 - 1.5 ms^{-1} at all sampling sites [10]. Low wind speed reduces the ability of the atmosphere to disperse high dose of emitted CO and particulate matter.

Table 10 describes 9 classes of environments ranging from class 1 (representing the cleaner class) to class 9, (representing the dirtier class). Note that 1meter^3 of sampled air = 35.315ft^3 of sampled air

Therefore deriving mean values of particle counts for 35.315ft^3 of air from 0.1ft^3 of sampled air is calculated as;

$$\text{Particle count per } 35.315\ \text{ft}^3 \text{of pumped air} = \frac{\text{particle count per } 0.1\ \text{ft}^3 \text{of air pumped} \times 35.315}{0.1} \quad (1)$$

By comparing them with mean values derived from the field in **Table 11** and **Table 12**, we notice that all land use types in the study area fall into the categories of the classes 6, 8 and 9, which represent "moderately dirty", "dirty" and "very dirty" environments. For Carbon Monoxide, the regulatory limit of 90 ppm for 15 minutes was not exceeded. Nevertheless it is needful to understand that current air quality standards are to a large extent based on the concept of an 'effect threshold', below which significant health effects are not likely to occur. However, no such threshold is exclusively guaranteed. Therefore, even if the limit is not exceeded, significant health impacts may result. In other words, reductions in pollutant concentration below current standards are expected to result in health benefits, but do not guarantee a zero adverse health effect. Moreover, air quality guidelines designed to protect the general population in the area may be insufficient to protect babies, children, elderly, fragile and other susceptible group of individuals.

5. Implication of the Study

Results from this study have shown that concentrations of pollutants are generally higher in the dry season,

Table 10. Classess of 'cleaner' and 'dirtier' environments based on particle count concentration.

Critical Environment Classification (ISO 14644-1)	Concentration (particles/meter³) > or = Size Shown			
	{Sum} $PM_{(0.1,\ 0.2\ \&\ 0.3)\mu m}$	$PM_{0.5\ \mu m}$	$PM_{1.0\mu m}$	$PM_{5.0\mu m}$
1	12			
2	134	4		
3	1,339	35	8	
4	13,390	352	8	
5	133,900	3,520	832	29
6	1,339,000	35,200	8,320	293
7		352,000	83,200	2,930
8		3,520,000	832,000	29,300
9		35,200,000	8,320,000	293,000

Source [11].

Table 11. Particle counts per 35.315ft3 of air volume sampled in the rainy season.

Sampling Location	Mean Values of Particle Counts per 35.315ft3 of Pumped Air					
	$PM_{0.3\mu m}$	$PM_{0.5\mu m}$	$PM_{1.0\mu m}$	$PM_{2.5\mu m}$	$PM_{5.0\mu m}$	$PM_{10\mu m}$
Uniben (Institutional)	26,493,313	7,267,121	1,282,641	316,776	66,392	31,784
Environmental Class	8	6	6	-	9	-
PPRH (Agricultural)	25,492,133	6,951,051	1,297120	319,248	66,039	32,843
Environmental Class	8	6	6	-	9	-
Ring Road (Commercial)	38,989,173	10,664,071	2,029,553	554,092	137,022	68,158
Environmental Class	8	6	6	-	9	-
Ikpoba/Agbor Road(Industrial)	40,052,860	10,605,448	1,975,894	568,572	121,130	60,742
Environmental Class	8	6	6	-	9	-
Akugbe/ Eweka (Residential)	37,439,197	9,728,929	1,713,484	416,364	91,113	46,616
Environmental Class	8	6	6	-	9	-

Source: Field Work, Benin City 2013/2014.

Table 12. Particle counts Per 35.315ft3 of air volume sampled in the dry season.

Sampling Location	Mean Values of Particle Counts per 35.315ft3 of Pumped Air					
	$PM_{0.3\mu m}$	$PM_{0.5\mu m}$	$PM_{1.0\mu m}$	$PM_{2.5\mu m}$	$PM_{5.0\mu m}$	$PM_{10\mu m}$
Uniben (Institutional)	84,061,354	21,184,762	3,756,103	964,200	228,488	105,239
Environmental Class	8	6	6	-	9	-
PPRH (Agricultural)	83,744,578	21,829,261	3,946,098	1,027,313	246,499	115,833
Environmental Class	8	6	6	-	9	-
Ring Road (Commercial)	117,246,860	29,278,607	4,938,096	1,247,679	302,650	147,970
Environmental Class	8	6	6	-	9	-
Ikpoba/Agbor Road (Industrial)	118,940,567	32,824,939	5,162347	1,192,941	283,226	136,669
Environmental Class	8	6	6	-	9	-
Akugbe/Eweka (Residential)	96,422,310	24,379,710	4,303,132	1,133,612	268,747	132,784
Environmental Class	8	6	6	-	9	-

Source: Field Work, Benin City 2013/2014.

while low wind speed in the city has been observed to be responsible for poor dilution and dispersion of contaminants. This validates previous study [3]. Higher concentration of pollutants during dry seasons implies that certain social and policy changes should be put in place to curb associated health risks involved. Automobile exhaust, open solid waste burning, industrial emission and fugitive dusts from non-tar road surfaces have been identified as the main sources of air pollutants in Benin City [10]. Therefore stake holders should initiate policies and efforts geared towards reducing traffic especially during rush hours, tarring of dusty roads, ensuring proper disposal of solid waste remotely and implementing a dependable mass transit system to reduce the number of vehicles plying the city roads. Benin City has quite a number of interconnecting routes and small streets requiring rehabilitation. Proper rehabilitation of theses road would reduce concentration of fugitive dust emanating from the disturbance of non-tar surfaces.

6. Conclusion

Results from the study have shown that seasonality significantly varies with air pollutant concentration. The independent sample T-test revealed significant difference of 0.00 in mean variation for concentration of particulate matter between the dry and rainy seasons. In comparison to standards, values for $PM_{0.3\text{-}10.0\mu m}$ have categorised the environments of all the land use classes in the study area as the "moderately dirty" class 6 and "dirtier" classes 8 and 9. Values for CO did not exceed 90 ppm, which is the WHO limit for 15 minutes. Except for CO, mean values of particulate matter of all sizes were generally higher in the dry season compared with the rainy season. This study therefore concludes that seasonality influences the concentration of pollutants in the city. Policies and actions by stake holders should be geared towards use of cleaner energy, proper waste management and rehabilitation of dirt roads.

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