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Original Paper

Assessment of Air Pollution in Gboko, Benue State, Nigeria

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Abstract

The study assessed the spatio-temporal and seasonal variation in the concentration of CO, NO_2, SO_2 and PM_{10} in Gboko, Benue State, Nigeria. Data on the air pollutants were collected at four points between 8:00am-10:00am and 3:00pm-5:00pm daily, from 16th January to 24th February (dry season) and 5th June to 14th July (rainy season) in 2017 using Gasman hand-held gas monitors. Data were analysed using mean, coefficient of variation (CV) and Analysis of Variance (ANOVA). The result showed highest and lowest mean concentrations of CO of 21.86ppm (rainy season) and 17.00ppm (dry season) in the town center (Point 2, GBKC) and 2.46ppm (rainy season) and 2.45ppm (dry season) in the suburb (Point 1, YRA). The mean concentrations of CO, NO_2 and SO_2 were higher in rainy season, and the mean concentration of PM_{10} was higher in dry season, with the mean concentrations of NO_2, SO_2 and PM_{10} higher than the national acceptable levels in both seasons. The spatial variation in concentration of the air pollutants was significant with respect to land use/land cover types than seasons. There should be regular monitoring of air quality as the population and human activities increase in the town.

Keywords

air pollution, pollutants, land use/land cover, season, anova

1. Introduction

Air pollution, one of the key environmental problems associated with urbanisation (Cho & Choi, 2014), is the first observable and oldest environmental impact on climate by cities (Landsberg, 1981) and is a crucial challenge of the anthropocene threatening the stability of earth systems, thereby driving global climate change, destroying ecosystems and endangering human health (Power et al., 2018). The atmosphere can be regarded as polluted when it contains, to a considerable content, some extraneous gases or solid (Omobai, 1998). Air pollutants are substances, which present in the atmosphere under certain conditions, may become injurious to human, animals, plants or microbial life, or to prperty, or which may interfare with the use and enjoyment of life (Oke, 1987).

Urban air pollution has received global attention by researchers due to the human health and environmental impacts. Constant exposure to air pollutants could be responsible for about 16% of global deaths of poor and vulnerable populations (Power et al., 2018). WHO (2016) reported that of the outdoor air pollution-related premature deaths, 80% were due to asthmatic heart disease and strokes, 14% due to chronic obstructive pulmonary disease or acute lower respiratory infections, and 6% due to lung cancer. Kjellstrom et al. (2002) have classified the adverse health effects of air pollution into three namely clinical outcomes (hospoital admissions, loss of lung function and mortality), diminished quality of life and subclinical symptons that may interfere with daily activities. Several studies have documented the impact of air pollution on human health including cerebrovascular diseases among adults (Chan et al., 2006), spirometric lung function among adults (Penttinen et al., 2009), respiratory symptoms among smokers and non-smokers (Ediagbonya & Tobin, 2013), and respiratory diseases among children, elderly and those affacted by pre-existing respiratory diseases in urban areas (Sciaraffa et al., 2017).

Environmentally, Levin (2004) reported that urban areas are significant source areas for pollutants in distant receptor points, and urban pollutants influence plant growth by changing the amount of Photosynthetically Available Radiation (PAR), damage plants leaves due to acidity (Bergin, 2004), and shorten the in-leaf season for Crimean linden trees (Chmielewski et al., 1998). Urban pollution also induced acid rain which adversely affects aquatic systems, forests, monuments, soils, sensitivity of lakes and ecosystems (Guttikunda et al., 2004).

Land use/land cover, which refers to the biophysical state of the earth’s surface and immediate subsurface (Weng, 2001), human use of land, and physical and biological cover of the surface (Rimal, 2011), and the placement of activities and physical structures within a defined geographical area (Xu et al., 2016), influences local pollution patterns in cities (Weng & Yang, 2006), pollution sources and characteristics (Fameli et al., 2013), and the deposition of some air pollutants such as ozone and particulate matter and their precursors (Wu et al., 2012). The land use/land cover can be associated with gaseous and dust pollutants because of toxic products, injury, ergonomic hazards, noise, external pollution and traffic generation (Levy & Wegman, 2000). Manins et al. (2001) also noted that automobiles contribute more to air pollution than residential, agricultural and industrial land uses. Vegetation land cover also influences air pollution. Emilio et al. (1994) for instance noted that Amazonian deforestation has transformed Brazil into the fourth major contributor of carbon to the atmosphere, while Wu et al. (2012) stressed that isoprene emission generally decreases with increasing vegetation land use. Planting low-emiting trees in Los Angeles Basin is reported to have decreased ozone concentration (Taha, 1996). Previous studies have documented the correlation between urban land use/land cover and air pollutants including PM_{10} (Zou et al., 2016), SO_2, NO_2 and PM_{10} (Xu et al., 2016) and $PM_{2.5}$ (Superczynski & Christopher, 2011).

Studies have demostrated the bidirectional relationship between air pollution and climate. Rain washes pollutants out of the air so that there is improved air qaulity after prolong rain. Wind disperses air pollutants and temperature inversion worsens air pollution by trapping pollutants close to the ground (Landsberg, 1981; Manning et al., 2001). Urban heat island is demostrated to impact positively on air pollutants (Sarrat et al., 2006) and SO_2, NO_x and dust are found to be positively correlated with land surface temperature (LST) (Weng & Yang, 2006). On the other hand, air pollution is reported to affect urban thermal structure due to changes in radiative budget (Atwater, 1977), increase in cloud cover by 5% (Kaufman & Koren, 2006), linked to adavance and intensification of Asian monsoon (Lau et al., 2005) and increase in the concentration of Cloud Condensation Nuclei (CCN) and cloud drops (Shepherd, 2005).

Nigeria is one of the fastest urbanising countries in Africa. According to United Nations (2018) report, 98 million people, representing 50.3% of the total population, live in towns and cities in Nigeria in 2018. Several studies have been carried out on different aspects of air pollution in some cities and towns in the country (Tyubee, 2008; Oluyemi & Asubiojo, 2001; Abam & Unachukwu, 2009; Utang & Peterside, 2011; Okunola et al., 2012; Hassan & Abdullahi, 2012; Yusuf et al., 2013; Akinfolarin et al., 2017). Yusuf et al. (2013) adopted Factor Analysis (FA) to assess the spatial distribution and estimate the major sources of seven pollutants in Lagos and found that Factor 1, comprising CO, SO_2, H_2S, Noise and PM_{10}, and Factor 2, comprising CH_4 and NO_2, contributed 43.72% and 17-53% to the total variation in concentration of the pollutants. Hassan and Abdullahi (2012) assessed variation in low explosive limit (LEL) gases, H_2S and CO in densely populated Abuja Municipal Area Council (AMAC) and Kuje Area Council (KAC), and Dobi village in Gwagwalada Area Council (GAC) and reported that the concentration of the pollutants were higher in AMAC, Abuja metropolitan area, in both wet and dry season. In their study, Akinfolarin et al. (2017) documented the status of particulate matter ($PM_{2.5}$ and PM_{10}) in three industrial sites and one non-industrial site in Port Harcourt and reported higher concentration of particulate matter in industrial sites compared to non-industrial site. Tyubee (2008) investigated the effect of Urban Heat Island Intensity (UHII) and Urban Wind Speed Intensity (UWSI) on CO, NO, and SO_2 concentrations in Makurdi and found that the combined effect of the two proxies of urban growth varies from 2% (SO_2; 9:00am) to 24% (CO; 3:00pm), and mean concentrations of the pollutants exceeded the tolerance limit of Federal Environmtal Protection Agency's (FEPA) National Ambient Air Quality Standards (NAAQS). Abam and Unachukwu (2009) study on the impact of vehicular emmission on CO, NO_2, SO_2, PM_{10} and Noise in three locations in Calabar found that the concentration of NO_2 and PM_{10}, and Noise level were highest where traffic intersections and traffic count were high.

With the increasing rate of urbanisation in Nigeria, the number of urban dwellers vulnerable to the negative health impact of or expose to the health risks associated with air pollution may likely increase.

This situation will be worsened in towns and cities that lack planning ordinance relating land use zonation, experience collapse in public energy supply and over depend on biofuels for household, commercial and industrial energy supply. Studies on urban air pollution in the country are crucial for policy and decision making in urban planning, environmental and public health, sustainable energy and environmental conservation. The main objectives of the study are to (1) investigate the spatio-temporal and seasonal variation in concentration of CO, NO_2, SO_2 and PM_{10}, (2) compare the mean concentrations of the pollutants with the NAAQS of the country and (3) determine whether the spatial variation in concentration of the air pollutants among land use/land cover types and climate seasons was significant or not.

2. Method

2.1 Study Area

Gboko, the second largest town in Benue State, Nigeria, is located in the southern part of Gboko Local Government Area (LGA), covering parts of Yandev, Mbayion and Ipav districts, between latitudes 7^{o} $17^{1}30^{11}$ and 7^{o} 21^{1}N and longitudes 8^{o} 58^{1} 30^{11} and 9^{o} 02^{1} E (Figure 1). Gboko town became the headquarters of Tiv Division in 1934 and the administrative heaquarters of Gboko LGA in 1970. The town was famous as a hub of cement production and marketing in the country, following the commissioning of Benue Cement Company (BCC), one of the largest cement manufacturing plants in Nigeria and currently Dangote Cement Company, in 1980, home of BCC Lions FC and a cultural town of the Tiv ethnic nationality of northcentral Nigeria. The town is transvered by two inter-state highways (A344); Makurdi-Jalingo and Enugu-Jalingo. The town is located between Mkar hills, 6km east, and Dangote Cement Company, 15km NW (not shown), and Akperan Orshi College of Agriculture, Yandev (AOCAY), NE of the town.

Gboko is fast urbanising particularly towards NE and E where it has merged with Yandev and Mkar suburbs. The town, like most cities and towns in Nigeria, did not have a planning ordinance. The Gboko central market, the center of the town, is surrouneded by Tor Tiv Palace, J.S. Tarka stadium and St. Francis Catholic Cathedral. The western part of the town is dominantly the Government Reservation Area (GRA) where residences of senior citizens, senior governement officials and business community, hotels and other government establishments are located. Elsewhere, there is a mixture of residential, commercial, educational and adminstrative land uses.

It is widely believed that half of the population of the Gboko LGA, which grew from 361,000 people in 2006 (National census data) to a projected population of approximately 490,000 people in 2016 using 3.0% growth rate per anum, lives in the town.

The study area experiences a tropical wet and dry climate (Aw) with a characteristically rainy and dry season. The rainy season occurs from April to October and dry season from November to March (Figure 2). Annual rainfall ranges from 900-1900mm, with a mean annual rainfall of 1300 mm (1981-2016) and 94% of the total rainfall occurs in the rainy season. The prevailing wind direction is

NE in the dry season, and SW in the rainy season. The mean monthly temperature peaks in March/April (30°C) and then decreases to 27°C in January and the mean temperature of the study area is 28°C.

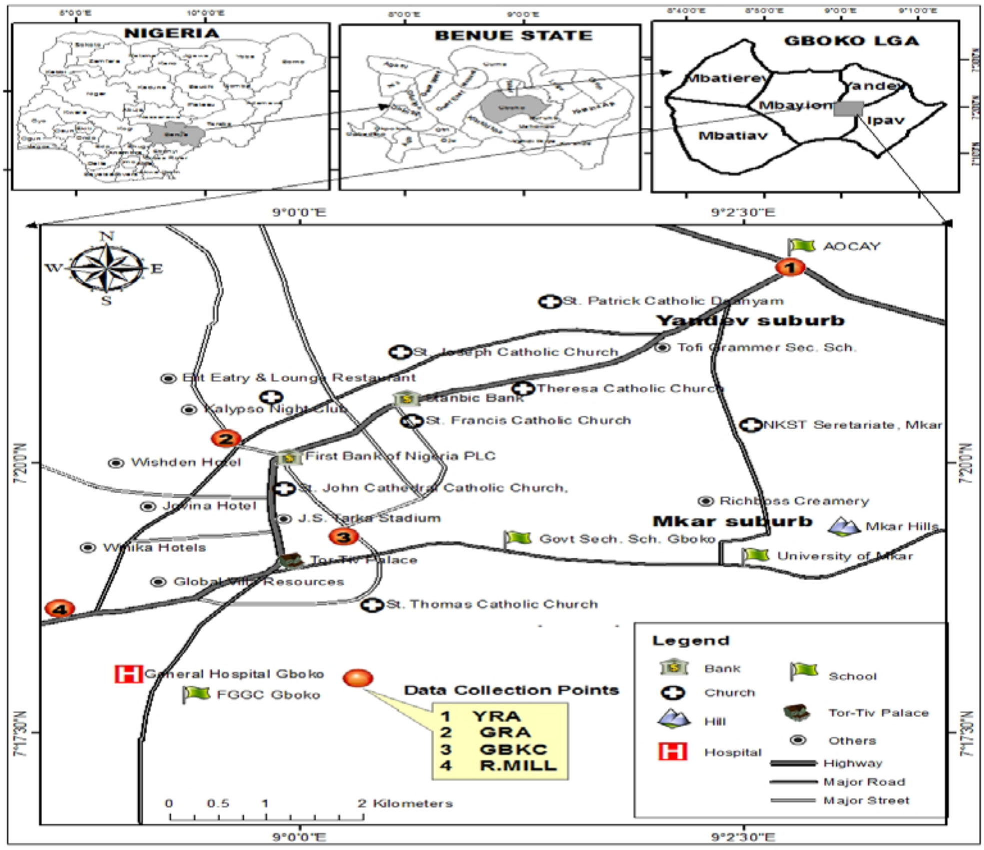

Figure 1. Location of Gboko and Data Collection Points

(a) (b)

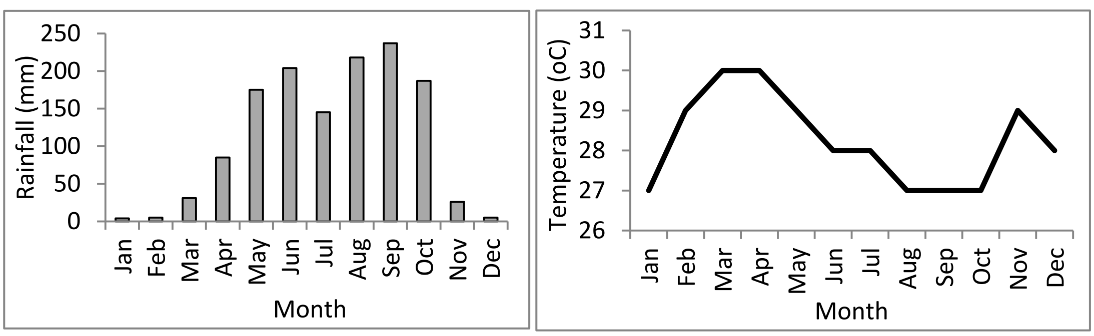

Figure 2. Distribution of Mean Monthly Rainfall (a) (1981-2016) and Mean Monthly Temperature (b) (2004 – 2017) in Gboko

Source: Weather station, Akperan Orshi College of Agriculture, Yandev (AOCAY).

2.2 Data Collection

Data on the concentration of carbon dioxide (CO), nitrogen dioxide (NO_2), surful dioxide (SO_2) and particulate matter (PM_{10}) were collected twice daily between 8:00am-10:00am and 3:00pm-5:00pm from 16th January to 24th February (dry season) and 5th June to 14th July (rainy season) in 2017 using Gasman hand-held gas monitors acquired from Benue State Environmental Sanitation Agency (BENSESA), Makurdi (Plate 1). Data collection on air pollutants were carried out, on working days only, by a staff of BENSESA assigned for that purpose. Initially, data on hydrogen sulfide (H_2S) were collected but not used in the study.

Plate 1. Hand-Held Gasman Pollutant Monitors Used in the Study (Photo by Grace H. Yiyeh)

A total of four locations were selected in the study area to represent the dominant land use/land cover (LULC) types and population density in order to assess the impact of LULC types on air pollutants. The choice of dry and rainy season is to examine the influence of climate on air pollution. The spatial location of the selected study points and their characteristics are presented in Figure 1 and Table 1.

Table 1. Some Characteristics of Selected Study Points

Point	Location	Code	Land use type	Population density	Urban/rural location
1	Yandev roundabout	YRA	Transport node	Medium	Suburb
2	Government Reservation Area	GRA	Residential with dense vegetation cover	Low	Urban
3	Gboko center (Market)	GBKC	Mixture of commercial, residential and transportation with little vegetation cover	High	Urban; town's center
4	Rice mills	R.MILL	Milling factories with little vegetation cover	Medium	Suburb

2.3 Data Analysis

Frequency distribution tables, means and Coefficient of Variation (CV) were used to analyse the data. Analysis of Variance (ANOVA) was used to test the hypotheses that variation in concentration of air pollutants was not statistically significant among LULC types and climate seasons. The result was also compared to the National Air Quality Control Standards (NAAQS) as stipulated by National Environmental Regulations (NER) (2014) to assess whether the mean concentrations of the air pollutants exceed the acceptable limits.

3. Result

3.1 Daily Variation in the Concentration of Pollutants in the Dry Season

The result of daily variation in the concentration of CO, NO_2, SO_2 and PM_{10} in the dry season is presented in Figures 3-6, and Table 2 summarises the concentration of the air pollutants in the dry season. The daily variation of CO shows that the highest and least concentration of 29.18ppm and 1.28ppm occurred on 9th February in Point 2 (Gboko central market, GBKC) and 20th January in Point 1 (Yandev roundabout, YRA) (Figure 3). The mean concentration of CO of 17.00ppm and 2.45ppm were highest and least in Point 2 (GBKC) and Point 1 (YRA) (Table 2). The daily variation in concentration of CO was higher and least in Point 2 (GBKC) and Point 3 (GRA) with CV of 35.13% and 28.54% (Table 2). The town center, as expected, has higher CO concentration, while the suburbs have lower concentration. The result clearly demostrates a typical urban-rural gradient of CO concentration.

Figure 4 indicates that the daily variation in NO_2 concentration was more pronounced at the beginning of the study period in all the four Points, and the highest daily concentration of 0.18ppm occurred on 18th January in Point 2 (GBKC). The mean concentrations of NO_2 were similar among the four Points whereas the day-to-day variation in the concentration was highest in Point 3 (GBKC) with a CV of 22.58% and lowest in Point 1 (YRA) with a CV of 15.71% (Table 2).

The daily variation in concentration of SO_2 in dry season is similar to that of NO_2 (Figure 5). However, the highest daily concentration of 0.23ppm was observed on 18th January in Point 1 (YRA). In addition, Point 1 (YRA) and Point 2 (GRA) have the largest and least daily variation in SO_2 concentration with CV of 22.47% and 5.22% respectively (Table 2).

The daily variation in concentration of PM_{10} in dry season shows that the beginning and end of the study period were very active in terms of emissions in all the four Points, and the highest and least daily concentration of 2.56mg/m^3 and 0.10mg/m^{3}occured on 20th January in Point 2 (GRA) and 28th January in Point 1 (YRA) (Figure 6). The concentration of PM_{10} was highest in Point 2 (GRA), with a mean of 1.01mg/m^3, and least in Point 1 (YRA), with a mean of 0.68mg/m^3 whereas the day-to-day variation in concentration of PM_{10} is highest in Point 2 (GRA), with a CV of 97.89%, and least in Point 3 (GBKC), with a CV of 31.96% (Table 2).

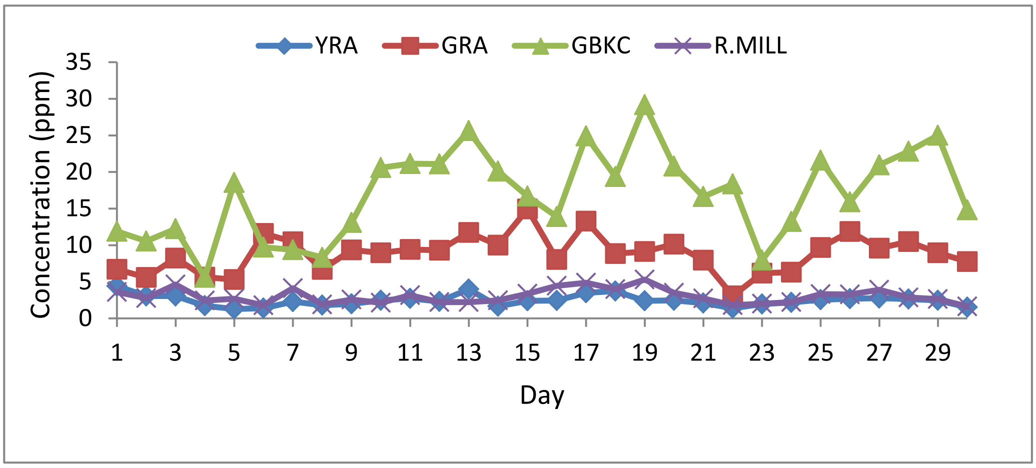

Figure 3. Daily Variation in CO Concentration in Gboko in the Dry Season in 2017

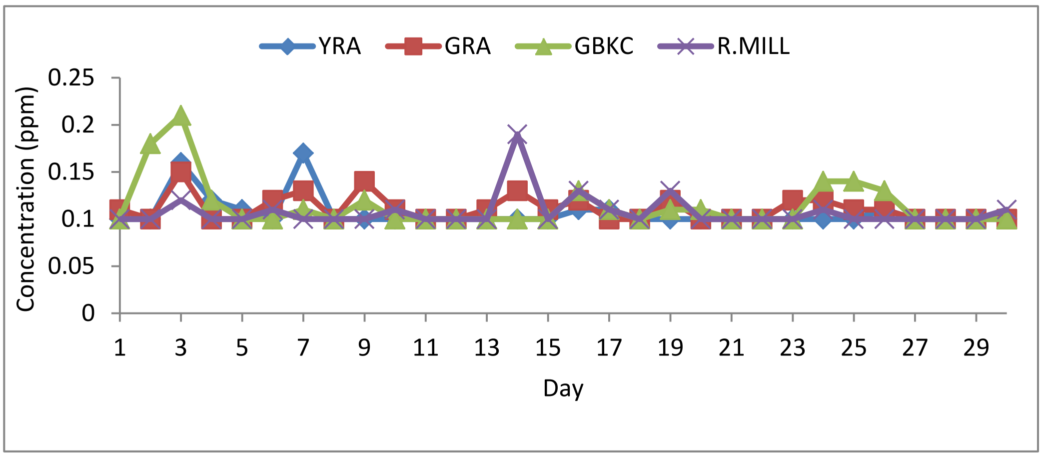

Figure 4. Daily Variation in NO_2Concentration in Gboko in the Dry Season in 2017

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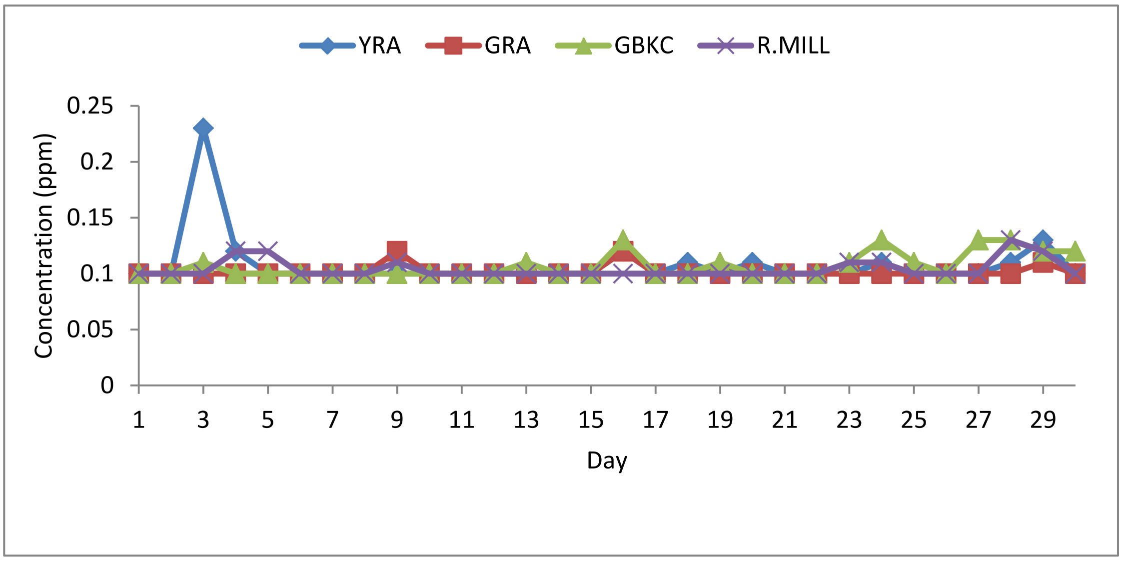

Figure 5. Daily Variation in SO_2Concentration in Gboko in the Dry Season in 2017

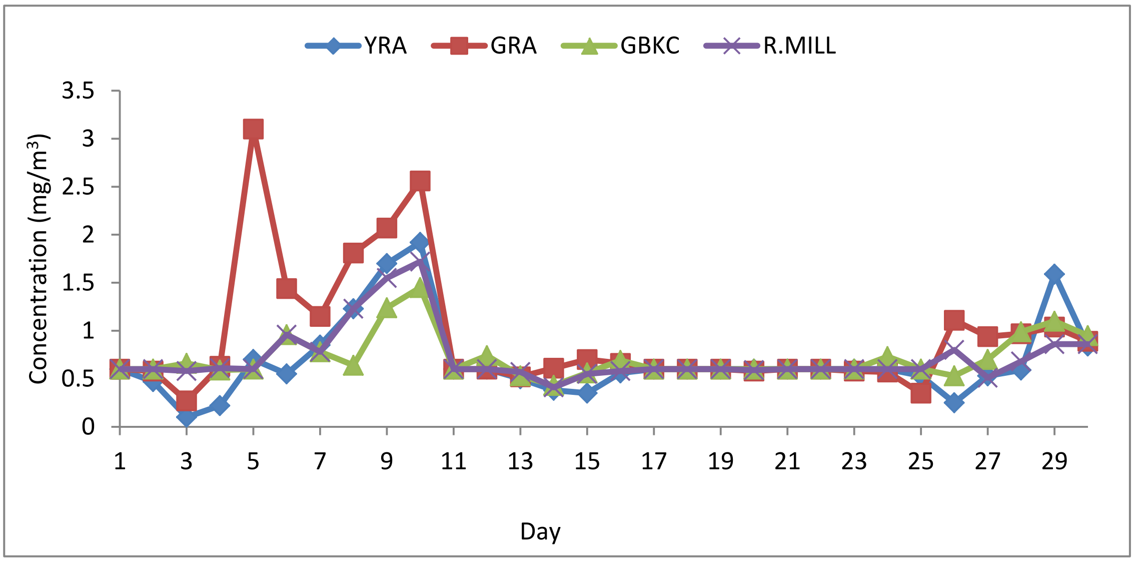

Figure 6. Daily Variation in PM_{10}Concentration in GbokoTown in the Dry Season in 2017

Table 2. Maximum, Minimum and Mean Concentration of Air Pollutants in Gboko in the Dry Season in 2017

Pollutant	Concentration			Coefficient of variation (CV)
	Maximum	Minimum	Mean	
Point 1 (Yandev roundabout)				
CO	4.41	1.28	2.45	30.99
NO_2	0.17	0.10	0.11	15.71
SO_2	0.23	0.10	0.11	60.44
PM_{10}	1.92	0.10	0.68	60.44
Point 2 (GRA)				
CO	17.96	3.09	8.85	28.54
NO_2	0.15	0.10	0.11	12.25
SO_2	0.12	0.10	0.10	5.22
PM_{10}	2.56	0.27	1.01	97.89
Point 3 (Gboko center)				
CO	29.18	5.59	17.00	35.13
NO_2	0.18	0.10	0.11	22.58
SO_2	0.13	0.10	0.11	10.16
PM_{10}	1.45	0.43	0.72	31.96
Point 4 (Rice mill)				
CO	5.32	1.63	3.02	32.71
NO_2	0.19	0.10	0.11	16.58
SO_2	0.13	0.10	0.10	7.82
PM_{10}	1.72	0.41	0.72	40.74

Note. CO, NO_2 and SO_2 values are in ppm and PM_{10} values are in mg/m^3.

3.2 Daily Variation in Concentration of Pollutants in the Rainy Season

The result of daily variation in concentration of CO, NO_2, SO_2 and PM_{10} in rainy season is presented in Figures 7-10 and Tables 3. Figure 7 shows that the highest and least daily concentration of CO of 35.66ppm and 1.42ppm occurred on 30th June in Point 3 (GBKC) and 19th June in Point 1 (YRA). The mean seasonal concentration of CO is highest (21.86ppm) in Point 3 (GBKC) and least (2.46ppm) in Point 1 (YRA), and the variation in daily concentration was highest and least in Point 3 (GBKC) and Point 2 (GRA) with CV of 32.72% and 22.10% (Table 3). The result clearly shows a typical urban-rural gradient of higher and lower CO concentration in urban and rural areas.

For NO_2, the highest daily concentration of 0.34ppm occurred on 29th June in Point 3 (GBKC) and least daily concentration of 0.10ppm occurred in all Points but on different dates (Figure 8). The mean concentrations of NO_2 were highest and least at Point 3 (GBKC) and Point 1 (YRA), with mean of 0.16ppm and 0.11ppm respectively, and the CV varies from 33.22% (Point 3, GBKC) to 16.29% (Point 1, YRA) (Table 3).

As is shown in Figure 9, the daily variation in concentration of SO_2 in the rainy season is generally uniform among the four points, and the highest daily concentration of 0.26ppm occurred on 29th June in Point 4 (Rice Mill). However, the day-to-day variation was relatively higher and lower in Point 4 (Rice Mills) and Point 1 (YRA) with CV of 31.36% and 22.96% respectively (Table 3).

The highest and least daily concentration of PM_{10} of 3.47mg/m^3 and 0.20mg/m^3 were recorded on 8th June and 20th June in Point 2 (GRA) and Point 1 (YRA) (Figure 10). However, the daily concentration of PM_{10} showed highest and least variability in Point 4 (Rice Mill), with a CV of 103.28%, and Point 2 (GBKC), with a CV of 72.35%. The mean concentrations were highest at Point 2 (GRA) (mean=0.82mg/m^3) and lowest in Points 1 (YRA) and 4 (Rice Mill) (mean = 0.49mg/m^3) (Table 3).

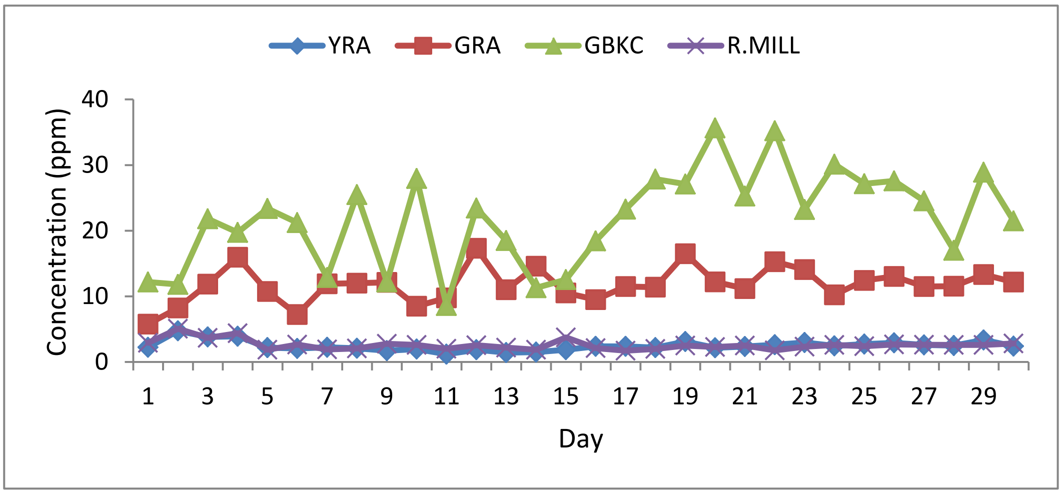

Figure 7. Daily Variation in CO Concentration in Gboko in Rainy Season in 2017

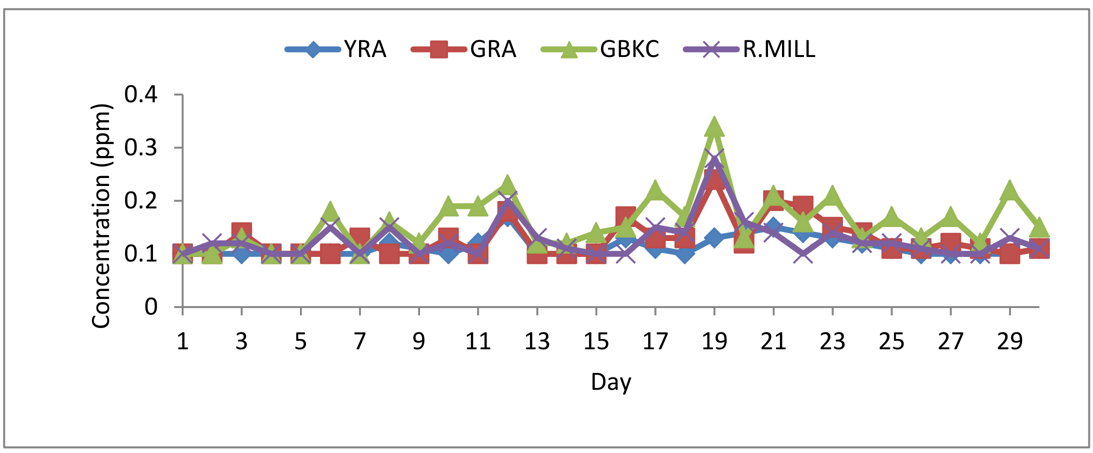

Figure 8. Daily Variation in NO_2 Concentration in Gboko in Rainy Season in 2017

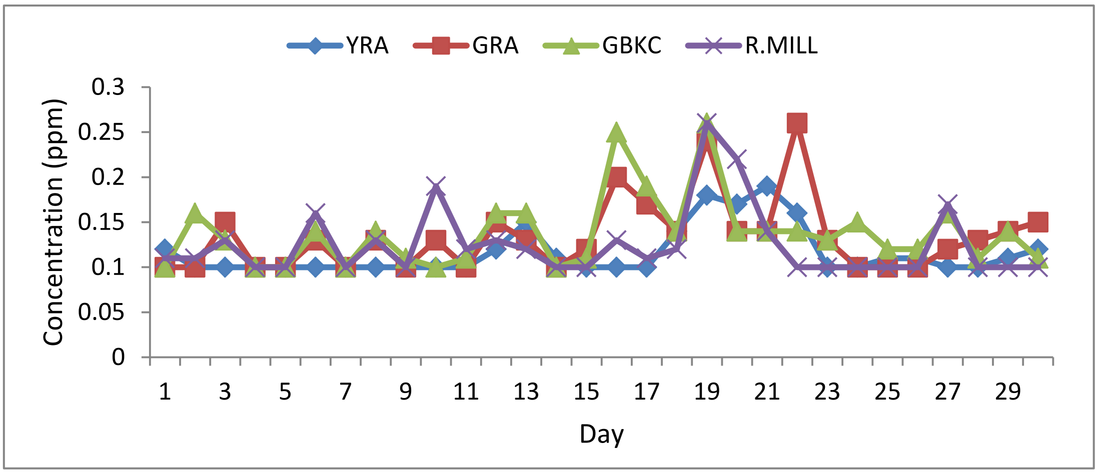

Figure 9. Daily Variation in SO_2Concentration in GbokoTown in Rainy Season in 2017

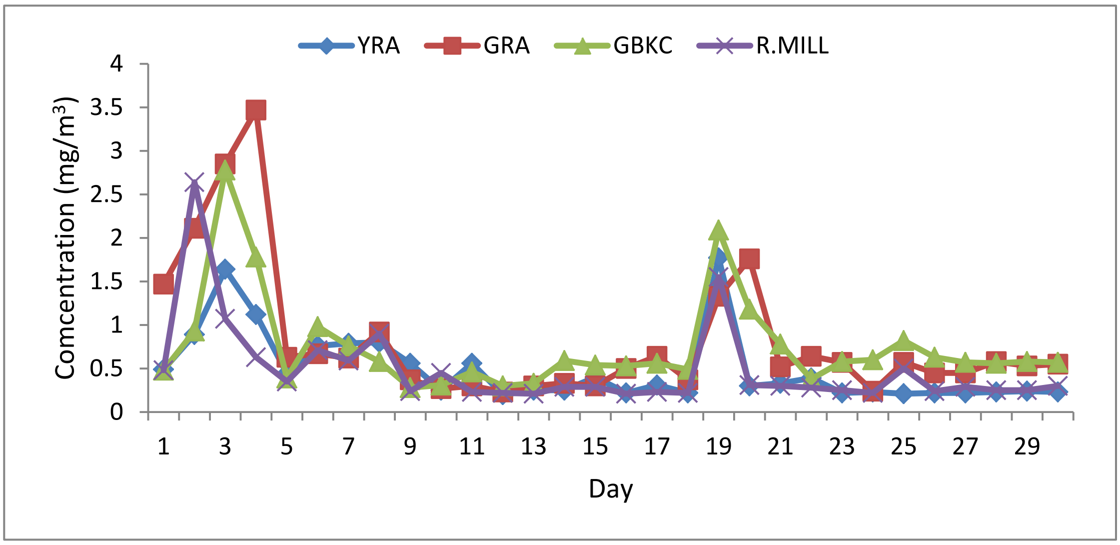

Figure 10. Daily Variation in PM_{10}Concentration in Gboko in Rainy Season in 2017

Table 3. Maximum, Minimum and Mean Concentration of Air Pollutants in Gboko in the RainySeason in 2017

Pollutant	Concentration			Coefficient of
	Maximum	Minimum	Mean	variation (CV)
Point 1 (Yandev roundabout)				
CO	4.47	1.42	2.46	30.92
NO_2	0.17	0.10	0.11	16.29
SO_2	0.19	0.10	0.12	22.96
PM_{10}	1.77	0.20	0.49	83.37
Point 2 (GRA)				

CO	17.32	5.77	11.78	22.10
NO_2	0.24	0.10	0.13	28.36
SO_2	0.24	0.10	0.13	30.15
PM_{10}	3.47	0.23	0.82	95.77
Point 3 (Gboko center)				
CO	35.66	8.59	21.86	32.72
NO_2	0.34	0.10	0.16	33.22
SO_2	0.25	0.10	0.14	28.87
PM_{10}	2.64	0.28	0.74	72.35
Point 4 (Rice mill)				
CO	5.05	1.72	2.59	29.12
NO_2	0.28	0.10	0.13	29.71
SO_2	0.26	0.10	0.13	31.36
PM_{10}	2.64	0.21	0.49	103.28

Note. CO, NO_2 and SO_2 values are in ppm and PM_{10} values are in mg/m^3.

3.3 Seasonal Variation in Concentration of Air Pollutants

The results of mean seasonal concentrations of CO, NO_2, SO_2 and PM_{10}, presented in Figures 11-14, are compared with the National Ambient Air Quality Standards (NAAQS) as stipulated by NER (2014) using 24-hour average concentration for SO_2 (120µg/m^3 or 0.0458ppm), NO_2 (120µg/m^3 or 0.0677ppm) and PM_{10} (150µg/m^3 or 0.150mg/m^3), and 1-hour average concentration for CO (10 mg/m^3 or 11.46ppm) to ascertain whether the concentrations are within or above the acceptable limit.

Figure 11 shows that the mean concentration of CO was higher in rainy season (9.67ppm) compares to dry season (7.83ppm), and mean concentrations of CO are consistently highest in Point 3 (GKBC) in both seasons, followed by Point 2 (GRA) and least in Point 1 (YRA). However, only the mean concentrations in Point 3 (GBKC), for both seasons, and Point 2 (GRA), for rainy season, are above the national acceptable limit of 10mg/m^3 (11.46ppm).

The mean seasonal concentrations of SO_2 and NO_2 are presented in Figures 12 and 13. The pattern of mean seasonal concentrations of both gases is similar though the mean season concentrations are higher in rainy season compared to dry season. However, the seasonal concentrations of both gases have exceeded the national acceptable limit of 120µg/m^3 or 0.0458ppm (SO_2) and 120µg/m^3 or 0.0458ppm (NO_2).

The result of seasonal variation in PM_{10} shows that the mean concentration is higher during dry season (0.78mg/m^3) than rainy season (0.64mg/m^3) unlike other air pollutants (Figure 14). Point 2 (GRA) has the highest seasonal concentration of PM_{10} of 0.82mg/m^3 (rainy season) and 1.01mg/m^3 (dry season), followed by Point 3 (GBKC) with mean of 0.74mg/m^3 (rainy season) and 0.72mg/m^3 (dry season) and least in Point 1 (YRA) with mean of 0.49mg/m^3 (rainy season) and 0.68mg/m^3 (dry season) (Figure 14). The mean seasonal concentrations of PM_{10} in all the points and seasons have exceeded the national tolerance limit of 0.15mg/m^3.

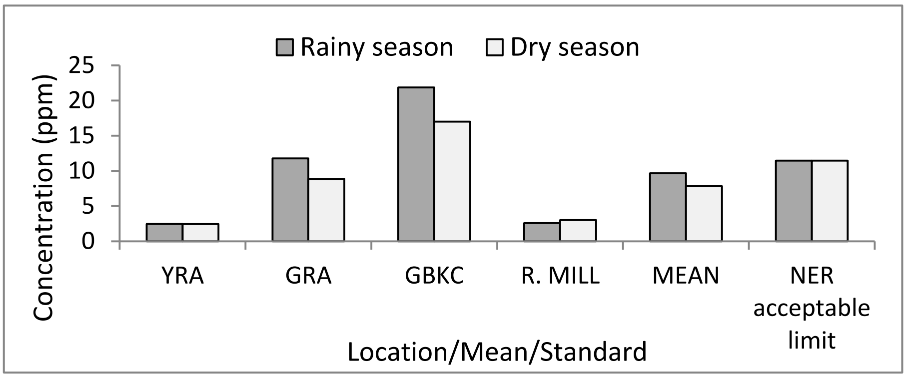

Figure 11. Seasonal Variation in CO Concentration in Gboko in 2017

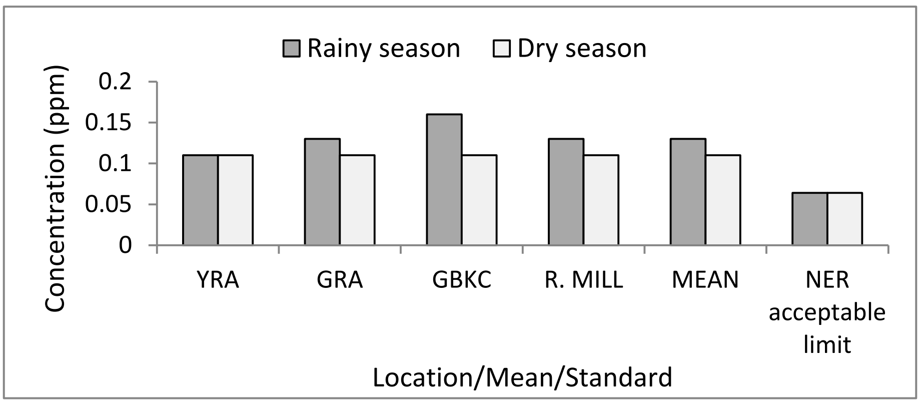

Figure 12. Seasonal Variation in NO_2Conentration in Gboko in 2017

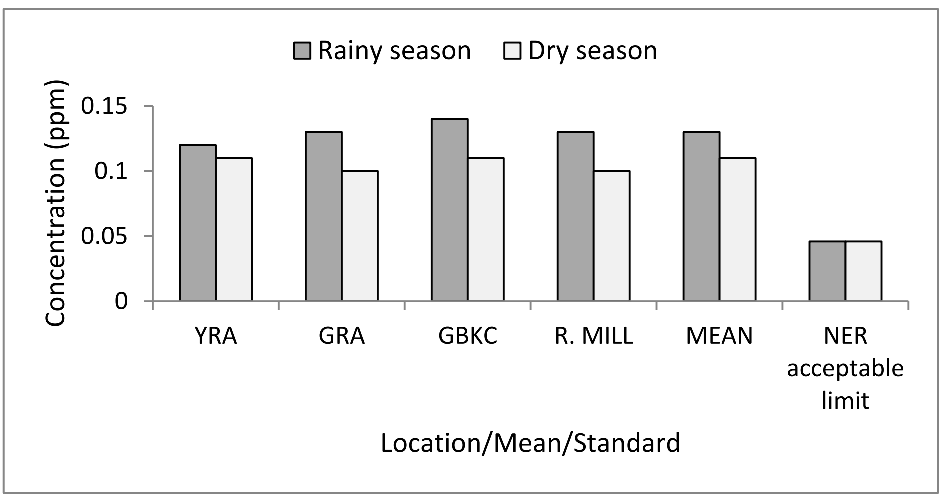

Figure 13. Seasonal Variation in SO_2Conentration in Gboko in 2017

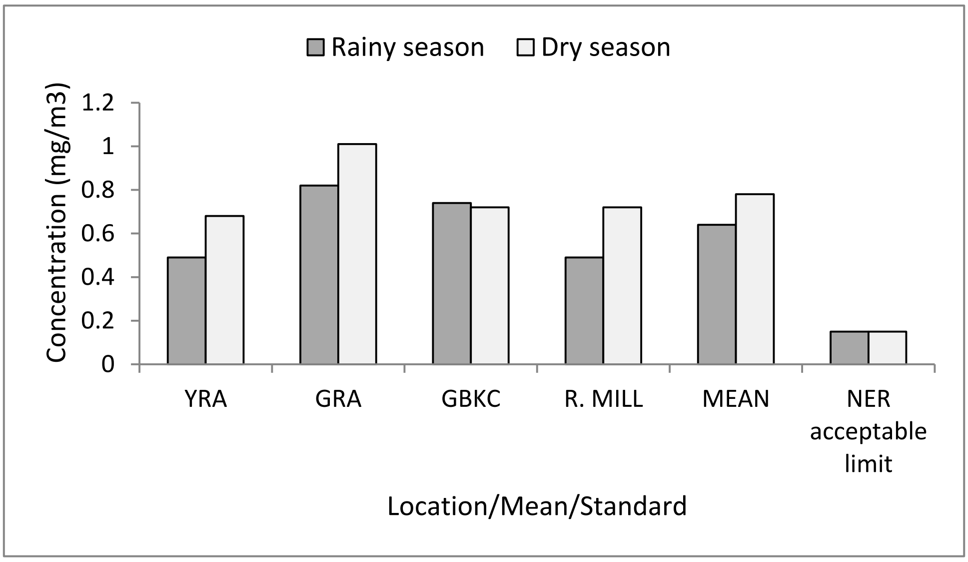

Figure 14. Seasonal Variation in PM_{10} Concentration in Gboko in 2017

3.4 Statistical Analysis of Spatial and Seasonal Variation in Pollutants

3.4.1 Testing for Spatial Variation in Concentration of Pollutants among Land Use/Land Cover Types

The null hypothesis (*Ho*), *there is no significant variation in the concentrations of pollutants among land use types in Gboko (i.e., pollutants concentrations = land use types = 0),* is tested using one-way analysis of variance (ANOVA) at 0.05 confidence level. The result is presented in Table 4 and shows that *Ho* is rejected since the calculated ***F*** value (18.63) is higher than the critical ***F*** table value (3.24) at 0.05 confidence level. The result indicates that there is a significant spatial variation in the concentrations of air pollutants among the four points in Gboko town. This suggests that the observed differences in the level of concentration of air pollutants in different parts of Gboko town during the study period did not occur by chance but are influenced by underlying LULC types.

Table 4. Result of Variation in the Concentration of Pollutants among LULC Types Using One-Way ANOVA

Sources of variation	Sum of squares	Df	Mean sum of squares	F	Remark
Between LULC types	43.58	3	14.53	18.63	Significant at 0.05 level
Within LULC types	12.12	16	0.78		
Total	55.70	19			

Note. Critical table value of *F* at 0.05 confidence level is 3.24.

3.4.2 Testing of Seasonal Variation in Concentration of Air Pollutants

The null hypothesis (*Ho*), *there is no significant variation in concentrations of pollutants between the climate seasons in Gboko (i.e., pollutants concentrations = seasons = 0),* is tested using one-way analysis of variance (ANOVA) at 0.05 confidence level. The result is presented in Table 5 and shows that *Ho* is accepted since the calculated ***F*** value (1.60) is lower than the critical ***F*** table value (5.32) at 0.05 confidence level. The result indicates that there is no significant difference in variation in the concentration of air pollutants in dry and rainy seasons in Gboko town. Therefore the null hypothesis is accepted, while the alternative is rejected. This suggests that climate is not a major factor in the observed spatial differences in seasonal variation in concentration of air pollutants in Gboko town during the period of study.

Table 5. Result of Variation in the Concentration of Pollutants among Seasons Using One-Way ANOVA

Sources of variation	Sum of squares	DF	Mean sum of squares	F	Remark
Between seasons	22.09	1	22.09	1.60	Not Significant at 0.05 level
Within seasons	110.58	8	13.82		
Total	132.67	9			

Note. Critical table value of *F* at 0.05 confidence level is 5.32.

4. Discussion

The spatial variation in air pollutants suggests a strong link between emmissions of pollutants and human activities. The higher concentration of CO in Point 2 (GBKC), the town center, is due to higher human and vehicular activities particularly the use of biofuels such as premiun motor spirit (PMS), kerosine, charcoal and fuelwood which are the major sources of CO. In addition, higher CO concentration in the town center may be attributed to decrease in vegetation cover that sequestrates carbon from the atmosphere thus lowering the atmospheric concentration of CO.

The higher mean concentrations of NO_2 and SO_2 in the rainy season is attributed to secondary sources in the atmosphere, through oxidation of nitric oxides (NO) and sulfur oxides (SO_x) to form NO_2 and SO_2 (Oke, 1987). Primary sources of NO_2 and SO_2 emissions include incomplete combustion in vehicles, electricity generators, rice milling mechines and other electrical appliances that use biofuels. Higher concentrations of PM_{10} in the dry season is related to the Saharan dust plume associated with the NE trade winds which prevail during the dry season, and locally derived dust from roads, markets, exposed and desiccated soils and fires. This is in agreement with Akinfolarin et al. (2017) who reported higher concentrations of particulate matters ($PM_{2.5}$ and PM_{10}) in three industrial areas in Port Harcourt in 2016. In addition, the town which is about 15km NW of Dangote Cement factory is located away from the area of plume deposition of cement factory (Ujoh et al., 2014) that may have influenced PM_{10} concentration. Bush and agricultural fires are major sources of particulate matter (Cusworth et al., 2018) that are also common in dry season in Gboko town.

The higher mean concentrations of NO_2, SO_2 and PM_{10}, above the acceptable levels, indicate that the town's atmosphere is polluted and urban dwellers are exposed to the health related risks of air pollution. Particulate matter (PM_{10}) is mostly associated with respiratory diseases (Ediagbonya & Tobin, 2013), while NO_2 and SO_2 are related to pulmonary and cardiovascular diseases (Oke, 1987).

The result of test of significant variation of air pollutants comfirms land use/land cover as the major factor of urban air pollution. This agrees with Utang and Peterside (2011) who reported a significant spatial variation in CO, NO_x, SO_x and HC among four points in Port Harcourt. Several studies have documented a positive relationshiop between land use/land cover and pollutants in cities including Guangzhou city (Weng & Yang, 2006), Wuhan (Xu et al., 2016) and Changsha-Zhouzhou-Xiangtan (CZT) agglomeration (Zou et al., 2016). The result of non-significant variation of air polluants in dry and rainy season is attributed to the fact that micro climates of cities differ significantly from the regional (macro) climate, with local pollution dispersion patterns relating more to the latter than the former. For instance, eddies caused by mechanical convection, due to buildings and chanelling effects on winds by streets orientation, may impact local dispersion of pollutants more than regional airflow. This confirms Fameli et al. (2013) who found that the diurnal variation in O_3 in the Greater Athens Area (GAA) was influenced more by land and sea breeze than planetary winds.

The result of spatio-temporal and seasonal variation in the concentration of CO, NO_2, SO_2 and PM_{10} concentration has implication on sustainable and renewable energy in Gboko town. The use of alternative, cleaner and environmentally friendly energy sources for household and demestic use should be encouraged. The Federal Government in 2009 announced the replacement of fuel wood and kerosene, the dominant cooking fossil fuels and major sources of CO_2 in the country, with biofuels such as ethanol and biogas. The ethanol fuel, produced from cassava feedstock, has lower CO_2 emmission (Ohimain, 2013), and biogas fuel, produced from agricultural residues and wastes, would reduce 357-60, 952 tons of CO_2 per annum in the country (Akinbami et al., 2001).

5. Conclusion

The result of variation in concentration of CO, NO_2, SO_2 and PM_{10} among four land use/land cover types and two climate seasons indicated higher concentrations of CO in the center of Gboko town compared to the suburbs. The mean concentration of CO, NO_2, and SO_2 were higher in rainy season compared to dry season, and the mean concentrations of PM_{10} were higher in the dry season compared to the rainy season, with NO_2, SO_2 and PM_{10} concentrations higher than the national acceptable levels in both seasons. The result of test of spatial variation in concentration of the pollutants showed that the variation was only significant among the four points compared to the seasons, suggesting that land use/land cover types have greater influence on spatial distribution of air pollutants than climate.

Stationary air pollution monitoring and meteorological stations should be established in Gboko for regular monitoring of air quality as the population and human activities increase and to provide baseline data for numerical simulations and empirical statistical modelling in analysing the relationship between land use and air pollution in the town. The influence of urban heat island induced circulation (UHIC), due to temperature gradient between the high pressure (cooler and moist condition) over the Mkar hills, in the east, and the low pressure (warmer and dry condition) in the town center, on spatial distribution of air pollutants in the town needs further scientific investigation.

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