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Assessment of Air Quality along Urbanization Gradient in Apo District of the Federal Capital Territory of Nigeria

Ishaya S., Adakayi P.E and Ojie Abang Francis

Department of Geography and Environmental Management University of Abuja, Nigeria

***Corresponding Author:** Ishaya S, Department of Geography and Environmental Management University of Abuja, Nigeria.*

ABSTRACT

The study assessed air quality along urbanization gradient in Apo District of FCT of Nigeria. Experimental research was employed and it enabled air quality data (NO, NO2, SO2, O3, CO and PM10) to be quantitatively gathered in the field using standard methods and equipment. Traffic volume along selected land uses in the three locations was obtained through traffic count approach. Data obtained was analyzed using averages, ANOVA, Pearson's correlation, cluster analysis and Factor Analysis (FA). Result obtained showed that the levels of PM, SO2, O3 and NO2 in the three locations were above FEPA threshold; only the level of CO was within FEPA recommended threshold. The core zone recorded the highest atmospheric pollutants, followed by the transitional zone and then the peripheral zone. Level of air pollutants does not vary significantly along urbanization gradient in APO (p>0.05). There was a considerable variation in the concentration of pollutants at different time of the day with high levels found in the evening followed by afternoon exception of NO whose concentration was high in the evening and morning. Across the three locations, roadside generated the highest amount of pollutants followed by motor parks while the residential area generated the lowest. In addition, Pearson's correlation revealed positive association between volume of traffic and level of SO2 and CO; as well as a negative association between bike and SO2 and CO. The study recommended that more roads with connectivity should be constructed in Apo to reduce the traffic density along the only transport corridor that links other major areas in the FCT; and recommends regular monitoring of atmospheric pollutants.

Keywords: *Urbanization gradient, Air pollutants, anthropogenic activities, Apo;*

Abbreviations: *Nomenclatures, Nitrogen oxide (NO), Nitrogen dioxide (NO2), Sulphur dioxide (SO2),Ozone (O3),Carbon monoxide (CO), Promethium (PM),Federal Environmental Protection Agency (FEPA), United State Environmental Protection Agency (USEPA)*

INTRODUCTION

Atmospheric pollution has become a serious environmental menace in many Nigerian cities (Ukemenam, 2014). Air pollution is thus, the introduction of chemicals, particulate matter, or biological materials that cause harm or discomfort to humans or other living organisms, or cause damage to the natural environment or built environment, into the atmosphere (Tawari and Abowei, 2012). Air pollution causes thousands of illnesses a day, leading to loss of working hours at work and school. In extreme cases, heart attacks, strokes, and irregular heartbeats can occur. It has been shown that breathing polluted air year-round can shorten life by one to three years and also damages our environment (Magaji and Hassan, 2015).

Air quality may be impacted by activities such as burning of fossil fuel by waste gas flaring from oil production facilities; burning of fuel in the operation of high capacity power generators for long periods and missions from vehicles among others. Emissions from these sources include sulphur dioxide, oxides of nitrogen, and carbon monoxide in addition to unburnt fossil fuel that may be presented as suspended particulates and soot (Adoki, 2012; Weli, 2014; Abad *et. al.*, 2014).

In city centres like Lagos, Port Harcourt and Abuja, especially on highly congested streets, traffic can be responsible for high concentration of ambient carbon monoxide levels, nitrogen oxides and hydrocarbons, and a large portion of the particulates (Abad *et. al.*, 2014). The high concentration of these elements has immense effects on man's health and continuous existence (Hassan and Okobia, 2008; Song *et. al.,* 2016). In recent time, however, Apo, one of the fast developing areas in Federal Capital Territory (FCT), has witnessed rapid and continuous change in land use and these changes have severely impacted on the ambient air quality of the area (Abdullahi *et. al.,* 2012). Increase in vehicular movement and other complex land uses such as road network, roadside mechanics, motor parts and residential areas among others have significant influence on air quality as well as on the accumulation of heavy metals in the soil (Zhao *et. al.,* 2006; Abad *et. al.,* 2014). The increase in anthropogenic activities along different urbanization gradients in the area has caused air pollution with inherent effects on man and biotic lives. Hassan and Okobia (2008) as well as Abdullahi *et. al.,* (2012) stated that air pollution in the Federal Capital City (FCT) of Nigeria is becoming overwhelming considering high vehicular traffic indicating increase in population and vehicles on the motor way emitting carbon monoxide directly into the atmosphere as a result of these anthropogenic activities.

In Nigeria and elsewhere, empirical studies have been carried out on the spatio-temporal and seasonal variations in air quality in relation to various land uses (Zhao *et. al.,* 2006; Hassan and Okobia, 2008; Zhang *et. al.,* 2010; Pervez *et. al.,* 2013; Weli and Ayoade, 2014; Syafei et al., 2014; Magaji and Hassan, 2015). These studies looked at the spatial variations in air quality in commercial areas, residential areas, locations, and road as well as human activities like abattoir either in the urban space or urban – rural divide and regional transportation system. The effect of particulate matter on air quality has also been studied (Weli and Ayoade, 2014). The studies mentioned above among numerous others reveal that there is abundant information about the state of the urban environment and factors that affect the ambient air quality.

However, in all these studies, the assessment of air quality along urbanization gradients (concentration of pollutants in highly disturbed areas in the core, transition zone and the periphery or suburban areas) has not been adequately documented. This is apparent because areas with high disturbance and immense human activities contribute greatly to the variation in air quality and the consequence exerted on the environment varies as well. Weli (2014) stated that different land use types, seasons and meteorological conditions are associated with different pollutant generation, concentration and dispersion respectively. This study make necessary attempts to empirically assess air quality among along urbanization gradient (core, transition zone and the periphery or suburban areas) in Apo a fringe area in the FCT of Nigeria.

STUDY AREA

Apo the study area is located in Abuja Municipal Area Council (AMAC). AMAC is the Area Council of the seat of the Government of the Federal Republic of Nigeria. It is the centre of focus in Nigeria with development changing at a pace hardly matched by any other part of the country. The AMAC strategically situated at the centre of the country within the Federal Capital Territory (FCT). It lies roughly on latitudes 7^0 25^1N and long 7^0 39^1E (Kalgo and Ayikika, 2000). The AMAC is bounded on the north by Kubwa and Karimu satellite towns, on the south by Kuje area council, while, Gwagwalada Area Council bounds it on the west and Nyanyan and Karu satellite towns on the east. The 2006 national population census put the population of the AMAC at 1,405,201 (NPC, 2006).The study area is almost predominantly an undulating terrain underlain by high-grade metamorphic and igneous rocks of pre-cambrian age situated on the Gwagwa plains (Ishaya, 2013). It has a couple of ranges and hills scattered around the city including the Bwari-Aso range and Katampe hills. The area has a fine natural drainage setting of small seasonal streams scattered all around. The streams take their rise from the hills and empty into the Jabi and Usuma rivers.

Just like the FCT, the study area has two main seasons, rainy (April to October) and dry (Nov. to March) with an average temperature of about 30^0C. This is characterized by high diurnal ranges with drops as high as 17^0C recorded between the highest and lowest temperatures in a day (Ishaya, 2013). The average annual rainfall varies from 1,100mm to 1,600mm with single maxima in September. High rainfall in the study area is associated with its location on the windward side of the Jos plateau which creates conditions favourable for such. The study area experiences' two weather conditions annually. These are the rainy season and the dry season. The rainy season begins from April and ends in October. The dry season (Harmattan) occurs between the months of November to March. This period, occasioned by the North East Trade Wind, is characterized by dust haze, intensified coldness and dryness. The high altitudes and undulating terrain of the study area act as moderating influence on the weather of the territory (Ishaya, 2013). A major weather phenomenon in the study area is the frequent occurrence of line squalls - a violent weather characteristic of low dark cloud cover, heavy rainstorms with thunder and lightning and a sudden rise in wind velocity. The phenomenon is associated with high connective activity aided by relief effects. The study area is located within the Guinea savanna vegetation zone of Nigeria. The natural vegetation of the city is constantly being reduced by urban infrastructure development. Though scattered trees 3-7 metres apart characterised the outskirt of the city. Examples of dominant species are *afzelias africana*, *anageisus leiocarpus* and *dameilla Oliveri*. Grasses such as *penisetum, andrapogun*, *pernicum* and *melius* species however dominate the area. The soils of the area are well drained, moderately leached with medium humus content and predominantly reddish friable porous sand to sandy clay texture. Their being more or less from exposed interfluve summits makes them ideal for urban development (Ishaya, 2013).

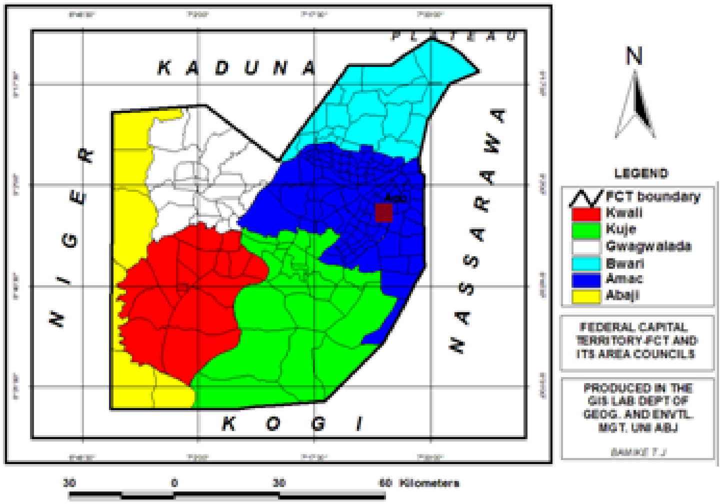

Figure1. *Map of Abuja Showing AMAC (Adapted from FCDA, 2010)*

METHODOLOGY

This study employed the experimental research method. The approach for data collection is purely quantitative and it involved going to the field to gather data/measure air pollutants or quality (NO, NO_2, SO_2, O_3, CO and PM_{10}) using standard methods and equipment. The purpose of an experiment is to study causal links; whether a change in one independent variable produces a change in another dependent variable (Hakim, 2000).

Types and Sources of Data

Data was obtained from the measurement of air quality at designated areas or location within the territorial boundaries of Apo i.e. field experiment using standardized equipment and traffic count approach. Data on NO, NO_2, SO_2, O_3, CO and PM_{10} were collected at different locations along urbanization gradient using Testo 350 Flu Gas Analyzer and Minivol Portable Air Sampler as well as a set of crow can gas dictator meter, or with some hard hold air quality monitors/equipment. Data on traffic volume was obtained using traffic counts in designated roads along the urbanization gradient and counting was done in the evening for a month. The collection of air quality data was done from 7am to 9am in the morning; 12 noon to 2pm in the afternoon and 4pm to 6pm in the evening. This is intended to get a comparative result which would show the intensity of activities at various times of the day and how they contribute in air pollution (Nwakanma *et. al.*, 2016).

Sampling Technique and Data Collection

Stratified sampling technique was used to determine sampling points along the urbanization gradient (core areas, transitional area and suburb areas). This sampling technique enables air quality data to be obtained across different locations, which makes it possible for comparison. However, along each of the urbanization gradient, air quality data was collected from three land uses: residential areas, Motor Park, mechanic shop and roadside. Along each urbanization gradient and land use, air quality was collected once in the morning, afternoon and evening for a month.

The collection of air quality was done in November 2016. Data was collected once a week for four weeks. The manual count method was used to collect data on traffic volume and traffic volume in the evening hours at designated roads along the urbanization gradient (along the roads in the core, transitional area and suburb) was carried out in a month. All vehicles that pass through a designated road during the fieldwork were counted.

Method of Data Analysis

Both descriptive and inferential statistical tools were used to give meaningful explanations to the data obtained. Descriptive tools such as averages, percentages, and tables was used to present the data for easy understanding of the pattern and variability of the air quality data; on the other hand, Pearson's correlation and ANOVA, was used to understand the association. The dimension of pollutants or identified pollutants was used to make future interference for appropriate decision making. The analysis above was performed using Statistical Package for Social Sciences (SPSS) Version (22.0) for Windows and excel spreadsheet.

Result on Air Pollutants or Quality in Apo

The result in table 1 shows the concentration of air quality along urbanization gradient in Apo, FCT. It also shows air quality across four different land uses in the area. The result shows clear variation in the concentration of air quality. Promethium (PM) contents in the three locations ranged from 0.31 to 0.46µg/m^3 which is above the threshold of 0.25µg/m^3 recommended by FEPA (Magaji and Hassan, 2015). The range reported here was also reported by Magaji and Hassan (2015) of 0.31 – 0.46 Mg/m^3. In the core zone, PM had high concentration along the road (0.46µg/m^3), while in transitional and peripheral zones; high content of PM was recorded in around the motor parks with values of 0.41 and 0.44µg/m^3 respectively. It therefore means that roadside and motor parks have high PM concentrations. This is expected as these land uses experience high fuel combustion from automobiles, power plants, and commercial activities resulting in the release of particular matter (Han, 2010). The content of carbon monoxide (CO) along the urbanization gradient ranged from 1.40 to 2.19ppm. This range is within the range of 1.83 to 2.17ppm obtained by Magaji and Hassan (2015) in a study carried out in Gwagwalada abattoir, Abuja but lower than 30 - 70ppm reported by Adelagun *et. al*, (2012). The concentration of CO in this study is within the 10ppm recommended by FEPA (Atubi, 2015; Ebong and Mkpenie, 2016). In the core area, the content of carbon monoxide (CO) was high in the motor park followed by the roadside with values of 2.14 and 2.13ppm respectively, while in the transitional zone, high CO contents were recorded in motor parks (2.11ppm) and roadside (1.98ppm) and in the peripheral zone, motor park and mechanic had high contents with values of 2.19 and 2.00ppm respectively. Like particulate matter (PM), high concentration of Carbon monoxide (CO) is recorded or observed around roadside, Motor Park and mechanic land areas. These areas are acknowledged by Han, (2010) to have high concentrations of CO due to heavy traffic congestion, residential and industrial activities. In a study carried out by Akpan and Ndoke (1999) in Northern Nigeria, high concentration of Carbon Dioxide (CO_2) was reported in heavily congested areas.

In addition, the concentration of Sulphur dioxide (SO_2) varied across the three locations and land uses with high concentrations noticed around roadside and motor park. SO_2 values ranged from 0.60 to 0.66ppm along the roadside and between 0.55 to 0.62ppm around the motor park. The range of SO_2 in the three areas (0.41 – 0.63ppm) is far above FEPA recommended level of 0.10ppm. Similar SO_2 range was also reported by Magaji and Hassan (2015) of 0.43 – 0.88ppm in a study carried out in Gwagwalada, Abuja, while Adelagun *et. al.*, (2012) reported SO_2 range of 0.23 – 0.60ppm in a study carried out in a sawmill industry, Lagos State. Also, Ebong and Mkpenie (2016) reported SO_2 range of 0.10ppm -0.40ppm in a study carried out in Uyo metropolis, Akwa Ibom. The act of crude oil processing that is carried out in these land uses could be responsible for the production of this gas (Green Facts, 2005). The result in Table 1 showed that low concentration of ozone (O_3) was recorded around residential and mechanic areas, while high contents of O_3 were recorded around roadside and motor parks. The range of 0.04 to 0.15ppm recorded across the three locations is slightly above EPA standard of 0.07ppm (EPA, 2017) in some land uses like roadside and motor parks.The combustion of fuel from vehicle results in the release of this harmful gas (Han, 2010). Likewise, high concentrations of nitrogen dioxide (NO_2) and nitrogen oxide (NO) were recorded around roadside and motor parks in the core, transitional and peripheral zones of Apo. For instance, in the core zone, NO_2 of 0.69 and 0.61ppm were recorded around roadside and motor parks, and for NO, values of 0.26 and 0.30ppm were also recorded around roadside and Motor Park. In all NO_2 ranged from 0.33 to 0.69ppm which is above the limit of 0.06ppm recommended by FEPA (Ebong and Mkpenie, 2016). Similar range of NO_2 was reported by Magaji and Hassan (2015). Magaji and Hassan (2015) reported the range of 0.33 to 0.78ppm for NO_2.

Similar range of 0.73 to 0.84ppm was reported by Adelagun *et. al.,* (2012), while the range of 0.14 to 1.09ppm was reported for Kano metropolis, Nigeria (Okunola *et. al.,* 2012). The high concentration of these gases around the roadside and motor parks is expected because they are the main sources nitrogen oxides. Koljonen (2007) cited in Han (2010) reported high emission of nitrogen oxides in traffic related areas or areas with high traffic.

Table1. *Concentration of air quality along urbanization gradients and land-uses*

Sampling points	PM ($\mu g/m^3$)	Co (ppm)	SO_2 (ppm)	O_3 (ppm)	NO_2 (ppm)	NO (ppm)
Core zone						
Roadside	0.46	2.13	0.63	0.09	0.69	0.26
Residential	0.33	1.96	0.50	0.04	0.36	0.19
Motor Park	0.43	2.14	0.61	0.10	0.61	0.30
Mechanic	0.39	1.99	0.54	0.05	0.59	0.21
Transitional zone						
Roadside	0.40	1.98	0.66	0.15	0.56	0.21
Residential	0.28	1.72	0.41	0.07	0.30	0.14
Motor Park	0.41	2.11	0.62	0.11	0.58	0.24
Mechanic	0.31	1.93	0.52	0.07	0.47	0.19
Peripheral zone or Suburb						
Roadside	0.42	1.90	0.60	0.09	0.52	0.24
Residential	0.31	1.40	0.44	0.06	0.33	0.17
Motor Park	0.44	2.19	0.55	0.11	0.61	0.29
Mechanic	0.37	2.00	0.53	0.07	0.49	0.21

Spatial Variation in Air Pollutants

Air pollutants vary over space and time. The air pollutants tend to be higher in urban area because of a combination of many elements such as industrial activities, energy production plants and domestic heating (Guerrieri *et. al.,* 2016). The spatial variation in air pollutants along urbanization gradient is shown in Table 2. The result in Table 2 indicated that PM content in the air was relatively high in the core zone followed by the peripheral zone but low in the transitional zone. The high PM content in the core and peripheral zones is expected because these areas have high human population and concentration of human activities that emit gases favourable to the formation of PM. This is so as a significant portion of PM is generated from the combustion of wood and fossil fuels, agricultural activities, commercial and industrial activities, construction and demolition activities, and rising of road dust into the air. In the core zones, construction works are ongoing and it enjoys high traffic which could be the reason for its high content. The concentration of PM did not vary significantly along the core, transitional and peripheral zones in Apo ($F = 0.800$, $p>0.05$).

The content of carbon monoxide (CO) did not vary significantly in the three zones ($F = 0.694$, $p>0.05$). However, high content of CO was recorded in the core zone (2.06ppm) followed by the peripheral zone (1.87ppm). As usual, the transitional zone had the lowest concentration of CO. The high economic activities and its high traffic congestion could be the reason for the high content of CO in the core and peripheral zones. According to USEPA (2008), mobile sources which include both on-road vehicles (e.g., cars, trucks, motorcycles) and non-road vehicles and engines account for the majority of CO emissions. The report also noted that high concentrations of CO normally occur in areas with heavy traffic congestion. The contents of sulphur dioxide (SO_2) ranged from 0.53 to 0.57ppm with high and low concentration found in the core and transitional zones respectively.

The core zone as a result of its high population and massive economic activities make the area to have high concentration of SO_2. EEA (2008) and USEPA (2009) noted that anthropogenic sulphur emission is principally originated from fossil fuel combustion. There are several industrial activities in the core and transitional zones of Apo which could be responsible for the relatively high contents of sulphur dioxide in the atmosphere. Department of the Environment and Heritage (2005) stated that about 99% of the sulfur dioxide in air comes from human sources such as industrial activity that processes materials that contain sulfur, e.g the generation of electricity from coal, oil or gas. In addition, SO_2 is introduced into the environment from industrial activities that burn fossil fuels containing sulfur as well as motor vehicle emissions due to fuel combustion (Department of the Environment and Heritage, 2005).

Furthermore, ozone (O_3) is an atmospheric pollutant that can have negative impacts on the environment and human health (USEPA, 2008). It acts as a greenhouse gas influencing Earth's radiative balance and surface temperatures (Worden *et. al.,* 2008). The concentration of Ozone (O_3) did not vary among the three locations considered in the present study ($F = 0.691$, $p>0.05$). Despite, the comparatively high (0.10ppm) value recorded in the transitional zone, the content of Ozone (O_3) was similar. This implies that the three locations generate or have human activities that result in the reduction in the content of Ozone (O_3) the atmosphere. The core zone has the lowest concentration of O_3 followed by the peripheral zone. This is expected considering the fact that ozone unlike levels of other air pollutants tend to be lower in urban polluted areas. This is because ozone disappears when it reacts with other pollutants, such as nitric oxide (Green Facts, 2016). This indeed is expected as the core and peripheral zone have high level of pollution from anthropogenic activities which resulted in the reduction in the levels of O_3.

Nitrogen gas comprises about 80% of the air. At high temperatures and under certain other conditions it can combine with oxygen in the air to form several different gaseous compounds collectively called nitrogen oxides (NO_x) such as nitrogen oxide (NO), nitrogen dioxide (NO_2). The concentration of nitrogen dioxide (NO_2) did not also vary along urbanization gradient ($F = 0.518$, $p>0.05$). It showed that the content of NO_2 in Apo ranged from 0.48 to 0.56ppm. High content of NO_2 was recorded in the core zone followed by the peripheral zone.

The high content of NO_2 in the three locations is expected considering the various anthropogenic activities carried out in these areas. These activities basically road transportation and increase vehicular use, manufacturing and construction industries release large quantities of NO_2 into the atmosphere. In an earlier study, EEA (2008) identified the anthropogenic sources of nitrogen oxides to include public electricity and heat production, road transportation, manufacturing and construction activities and agricultural activities among others. In addition, the content of nitrogen oxide (NO) in the core, transitional and peripheral zones of Apo in FCT ranged from 0.20 to 0.24ppm. There was significant variation in the concentration of nitrogen oxide (NO) in the area ($F = 0.953$, $p>0.05$). Like NO_2 the sources of NO are automobiles, power plants and chemical processes mostly from industries. These activities result in the concentration of NO in the atmosphere. In addition, the result represented in Table 2 gives answer to the first research hypothesis that the level of air pollutants does not vary significantly along urbanization gradient in APO. This is so as the distribution or concentration to pollutants tend to be within the same range in the three selected locations.

Table2. *Mean concentration of air quality in Apo along urbanization gradient*

Parameters	Urbanization gradient			F-values
	Core zone	Transitional zone	Peripheral zone	
PM ($\mu g/m^3$)	0.40	0.35	0.39	0.800 ns
Co (ppm)	2.06	1.94	1.87	0.694 ns
SO_2 (ppm)	0.57	0.55	0.53	0.234 ns
O_3 (ppm)	0.07	0.10	0.08	0.691 ns
NO_2 (ppm)	0.56	0.48	0.49	0.518 ns
NO (ppm)	0.24	0.20	0.23	0.953 ns

ns = *Not significant at 5% alpha level*

Temporal variation in air pollutants

In every urban environment, economic activities and everyday life create daily variations in concentrations of air pollutants (Makra *et. al.,* 2010). The monitoring of periods of high concentration enables policies to be put in place to reduce the concentration effect on human. The temporal variation (morning, afternoon and evening) in the concentration of air pollutants in three different locations in Apo is presented in Table 3. It shows that there is a considerable variation in the concentration of pollutants at different time of the day. In the core zone, the concentration of PM was high in the evening followed by afternoon. It showed that the concentration increases with the time of the day being low in the morning and high in the evening. The same pattern was observed for other pollutants with exception of NO whose concentration was high in the evening and morning. It therefore means that air pollutants tend to be high in the evening and afternoon. This is expected due to the increased vehicular movement and traffic buildup, industrial and residential activities, wastes incineration and other human activities that favour the emission of these gases into the atmosphere during this time. Similar trend in the concentration of air pollutants at different time of the day was reported by Magaji and Hassan (2015) and Etim (2016). The study of Magaji and Hassan (2015) also showed that pollutant levels were high in the evening. In the transitional and peripheral zones, the level of PM was high in the evening and morning, while other parameters were high in the evening followed by afternoon. This again implies that the release of air pollutants in the area occur during these time periods when the intensity of anthropogenic activities is high. Makra *et. al.*, (2010) stated that in mainly cities, motor vehicle traffic is the most important sources of air pollution. The increase in population results in the increase in vehicular traffic, waste disposal, and other environmental challenges which pollute a city's ambient air.

Table3. *Mean temporal variation in the concentration of pollutants in Apo*

Time of the day	PM (μg/m^3)	Co (ppm)	SO$_2$ (ppm)	O$_3$ (ppm)	NO$_2$ (ppm)	NO(ppm)
Core zone						
Morning	0.31	1.96	0.61	0.11	0.36	0.26
Afternoon	0.33	1.98	0.63	0.11	0.40	0.21
Evening	0.41	2.11	0.66	0.15	0.69	0.30
Transitional zone						
	PM (μg/m^3)	**Co(ppm)**	**SO$_2$(ppm)**	**O$_3$(ppm)**	**NO$_2$(ppm)**	**NO(ppm)**
Morning	0.28	1.90	0.41	0.06	0.47	0.14
Afternoon	0.26	1.96	0.52	0.08	0.46	0.21
Evening	0.31	2.00	0.62	0.10	0.58	0.24
Peripheral zone or Suburb						
	PM (μg/m^3)	**Co(ppm)**	**SO$_2$(ppm)**	**O$_3$(ppm)**	**NO$_2$(ppm)**	**NO(ppm)**
Morning	0.31	1.40	0.40	0.08	0.33	0.17
Afternoon	0.37	1.40	0.44	0.06	0.40	0.21
Evening	0.42	1.90	0.53	0.11	0.50	0.24

Table4. *Air quality index*

AQI categories	AQI Rating	PM (μg/m3)	CO (ppm)	NO$_2$ (ppm)	SO$_2$ (ppm)	O$_3$
Very good (0-15)	A	0 – 15	0 - 2	0 - 0.02	0 - 0.002	
Good (16-31)	B	51-75	2.1-4.0	0.02-0.03	0.02-0.03	
Moderate (32-49)	C	76-100	4.1-6.0	0.03-0.04	0.03-0.04	
Poor (50-99)	D	101-150	6.1-9.0	0.04-0.06	0.03-0.04	
Very poor (100 or over)	E	>150	>9.0	>0.06	>0.06	

Source: *USEPA, (2000) cited Atubi (2015) and Magaji and Hassan (2015)*

Air Quality Index (AQI)

AQI is an index established by USEPA (2008) cited in Atubi (2015) which is used for assessing the status of ambient air pollutants and the associated health problems. The ambient air pollutants are classified into categories ranging from very good to very poor (Table 4). From (0-15) AQI rating is A which is very good, (16-31) AQI is B which is good, (32-49) AQI is C which is moderate, (50-99) AQI is D which is poor and (100 or above) AQI is E is very poor. Results in Table 5 show the AQI for analyzed air pollutants in Apo. The range obtained for the respective air pollutants in Table 1 was compared with the AQI index in Table 5. The result obtained as depicted in Table revealed that NO$_2$, SO$_2$ and NO were in the E category (very poor). The status of NO$_2$, SO$_2$ and NO recorded is similar to the status of these air pollutants by Magaji Akwa Ibom State. The ranges reported for PM and CO were within the very good category. AQI class for ozone (O$_3$) is not available however. The result obtained therefore indicates that the concentration of NO, NO$_2$ and SO$_2$ in

Apo and it's environ may pose a serious health problem to people when they are exposed to these gases for a long time.

Table5. *Air quality status in Apo*

Parameters	Measured range	Air quality rating
PM (µg/m^3)	0.31 – 0.46	A (Very good)
CO (ppm)	1.40 – 2.19	A (Very good)
NO2 (ppm)	0.41 – 0.63	E Very poor
SO2 (ppm)	0.30 – 0.69	E Very poor
NO (ppm)	0.14 – 0.30	E Very poor
O_3	----------	------------

Association between Air Qualities in the Core Zone of Apo

The information in Table 6 shows the associations or interrelationships between air pollutants in the core zone. This was achieved using Pearson's correlation. The result showed that there is positive and significant association between SO_2 and PM ($r = 0.980$, $p<0.05$), SO_2 and CO ($r = 0.974$, $p<0.05$), O_3 and CO ($r = 0.995$, $p<0.05$), NO_2 and PM ($r = 0.961$, $p<0.05$), NO and CO ($r = 0.957$, $p<0.05$) between NO and O_3 ($r = 0.980$, $p<0.05$). The result implies that an increase in SO_2 would result in a corresponding increase in the contents of PM. This applies to other positive and significant factors or elements. The result also showed that positive but insignificant association existed between CO and PM, O_3 and PM, O_3 and SO_2, among others The positive pattern of association means that an increase in one metal would result in a parallel increase in the other metal and vice versa. In addition, the positive association between the air quality parameters suggests that they are likely to be influenced by similar anthropogenic and environmental factors (Iwara *et. al.*, 2012). The positive and significant association shows that the parameters have similar source of emission in the atmosphere.

Table6. *Zero order correlation matrix in the core zone*

Variables	PM	Co	SO_2	O_3	NO_2	NO
PM (µg/m^3)	1					
Co (ppm)	0.913	1				
SO_2 (ppm)	0.980*	0.974*	1			
O_3 (ppm)	0.886	0.995*	0.954	1		
NO_2 (ppm)	0.961*	0.783	0.889	0.759	1	
NO (ppm)	0.812	0.957*	0.887	0.980*	0.696	1

**Correlation is significant at the 0.05 level (2-tailed).*

Association between Air Qualities in the Transitional Zone of Apo

The information in Table 7 shows the association between air pollutants in the transitional zone. The result showed that there are positive and significant associations between SO_2 and PM ($r = 0.953$, $p<0.05$), NO_2 and O_3 ($r = 0.964$, $p<0.05$), NO_2 and SO_2 ($r = 0.966$, $p<0.05$), NO and CO ($r = 0.998$, $p<0.05$) and between NO and NO_2 ($r = 0.972$, $p<0.05$). As usual, the positive signs or coefficients imply that an increase in NO_2 would result in a corresponding increase in the contents of NO and vice versa. This applies to other positive and significant factors. The result also showed that positive but insignificant association existed between CO and PM, NO and PM, NO_2 and SO_2 among others. The general positive coefficients mean that the air quality parameters are influenced by similar anthropogenic and environmental factors (Iwara *et. al.*, 2012).

Table7. *Zero order correlation matrix in the transitional zone*

Variables	PM	Co	SO_2	O_3	NO_2	NO
PM (µg/m^3)	1					
Co (ppm)	0.888	1				
SO_2 (ppm)	0.953*	0.873	1			
O_3 (ppm)	0.860	0.569	0.880	1		
NO_2 (ppm)	0.927	0.964*	0.966*	0.730	1	
NO (ppm)	0.918	0.998*	0.898	0.621	0.972*	1

**Correlation is significant at the 0.05 level (2-tailed).*

Table8. *Zero order correlation matrix in the peripheral zone*

Variables	PM	Co	SO_2	O_3	NO_2	NO
PM ($\mu g/m^3$)	1					
Co (ppm)	0.885	1				
SO_2 (ppm)	0.884	0.751	1			
O_3 (ppm)	0.946	0.801	0.697	1		
NO_2 (ppm)	0.967*	0.970*	0.808	0.918	1	
NO (ppm)	0.960*	0.882	0.701	0.988*	0.972*	1

**Correlation is significant at the 0.05 level (2-tailed).*

Association between Air Qualities in the Peripheral Zone of Apo

The information in Table 8 shows the association between air pollutants in the peripheral zone. The result revealed positive associations between the air quality parameters. It showed positive and significant associations between NO_2 and PM ($r = 0.967$, $p<0.05$), NO_2 and CO ($r = 0.970$, $p<0.05$), NO and PM ($r = 0.960$, $p<0.05$) and NO and NO_2 ($r = 0.972$, $p<0.05$).Characteristically, the positive coefficients entail increase in NO_2 would result in a corresponding increase in the contents of PM and vice versa. It also entails that increase in NO_2 would result in a resultant increase in CO. This as stated in the preceding sections applies to other positive factors. The result also showed that positive but insignificant association existed between CO and PM, NO and PM, NO_2 and SO_2 among others. The general association between the air quality parameters means they are influenced by similar anthropogenic and environmental factors.

Volume of Traffic in Apo

The average traffic volume distribution depicted in Table 9 showed that cars followed by buses and bikes were more prevalent during the duration of study (cars>bus>bikes>trucks) along urbanization gradient in Apo. In the core zone, cars were most prevalent across the different land uses, this was followed by buses and the least was bike. Hence, in the core zone, the order of vehicular traffic was cars>buses>trucks>bikes. Looking at the different land uses, the result in Table 9 identified roadside to have the highest number of vehicles during the duration of the study and time considered, this was followed by the residential area, while mechanic area had the lowest vehicle count of 4001, 2767 and 398 respectively.

At the transitional zone, there was variation in the pattern of vehicular traffic across land use. As usual, cars were most prevalent followed by buses and then bikes. The number of trucks decreased a people move away from the city centre. It also indicated that roadside had the highest vehicular traffic or count followed by motor parks and then mechanic workshop with traffic counts of 1839, 1606 and 252 respectively. In addition, peripheral zone, there was a marked difference in vehicular traffic or count as well as land use generating most of the traffic. It showed that cars were most prevalent in the zone followed by bikes and then buses. The prevalence of cars and bike is expected as the area is dominated by low income households who depend on cars and bikes as their main modal choice.

The high number of bikes in this zone is also expected due to the ban on motorcycles in the core and some parts in the transitional zones mostly areas close to the core area. At the peripheral zone bikes and cars are the main vehicular modes of transportation. Hence, the order of vehicular movement is cars>bikes>buses>trucks. The order of vehicular traffic reported in this study pays credence to the study of Etim (2016) who also reported the prevalence of cars in Ibadan Metropolis, southwestern Nigeria. He also reported the prevalence of cars and bikes in the evening peak hours. There was however, no significant difference in vehicular traffic among the zones ($F = 0.845$, $p>0.05$). This may be attributed to the increase number of vehicular count across the three zones.

Table9. *Average number of vehicles/hour during evening peak hour in Apo*

Locations	Core zone			
	Bus	**Truck**	**Cars**	**Bike**
Roadside	177	474	2980	370
Residential area	451	289	1726	301
Motor park	789	183	1389	114
Mechanic	103	91	141	63
	Transitional zone			
Roadside	127	146	1331	235
Residential area	128	91	1013	332
Motor park	424	93	996	93
Mechanic	87	37	86	42
	Peripheral zone			
Roadside	218	251	2434	509
Residential area	324	101	1362	480
Motor park	512	89	1247	142
Mechanic	89	68	116	75

Association between Volume of Traffic and the Level of SO2 and CO in the Atmosphere

The association between vehicular traffic in terms of volume and the concentration of SO_2 and CO is shown in Table 10. The result showed that there are positive but insignificant associations between Car and SO_2 (r = 0. 350, p>0.05), bus and SO_2 (r = 0.170, p>0.05), truck and SO_2 (r = 0.387, p>0.05). It also showed that positive but insignificant associations existed between car and CO (r = 0.076, p>0.05), bus and CO (r = 0.296, p>0.05) and truck and CO (r = 0.246, p>0.05), while negative and insignificant associations existed between bike and SO_2 (r = -0.184, p>0.05), bike and CO (r = -0.569, p>0.05). It therefore means that car, bus and truck are positively related to SO_2 and CO; implying increase in the level of SO_2 and CO with the increase in the volume of car, bus and truck. Etim (2016) reported a positive but insignificant relationship between traffic volume and ambient CO concentration in Ibadan, Nigeria. The increase in ambient SO_2 and CO is attributed to the increase in vehicular volume as well as the type of fuel used. In a related study, Etim (2016) attributed the positive association between traffic volume and ambient CO concentration in the morning and evening periods to the prevailing meteorological conditions such as exhaust emissions increase with decreasing ambient temperature and high traffic, quality of vehicles; age, maintenance and fuel type.

Table10. *Pearson's correlation coefficient for CO, SO2 and vehicular volume*

Vehicles	Correlation coefficients	
	SO_2	**CO**
Car	0.350 ns	0.076 ns
Bus	0.170 ns	0.296 ns
Truck	0.387 ns	0.246 ns
Bike	-0.184 ns	-0.569 ns

ns = *Correlation is insignificant at the 0.05 level (2-tailed)*

CONCLUSION

The study has shown that the level of pollutants in the atmosphere tend to decreases from the core to the peripheral zones. However, despite this, the concentration of pollutants does not vary due to the high concentration of pollutants in the study locations. The various anthropogenic activities carried out in the four land uses account for the level of pollutants in the atmosphere. The concentrations of PM, NO, NO_2 and SO_2 in Apo and it's environ may pose a serious health problem to people when they are exposed to these gases for a long time. This is apparent as their concentrations in the atmosphere across the three locations (core, transitional and peripheral) are beyond FEPA permissible threshold. It therefore means that necessary intervention is required to reduce the high concentration of pollutants in the area. The concentration of pollutants is observed to vary in quantities or amount at different time of the day with high levels found in the evening followed by afternoon. These time periods generate high traffic density and volume as well as experience increased level of anthropogenic activities that favour the buildup of pollutants in the atmosphere. In the three locations considered for the present study, roadside is observed to generate the highest amount of pollutants into the atmosphere which therefore implies that major roads within where the samples were collected Apo are not safe from traffic related pollution threats.

RECOMMENDATIONS

Based on the research findings, the following are suggested to minimize the concentration of pollutants in Apo and beyond.

1. More roads with connectivity should be constructed in Apo to reduce the traffic density along the only transport corridor that links other major areas in the FCT.
2. There should be regular monitoring of atmospheric pollutants around the area in order to prevent the potential health and atmospheric related impacts of such air toxics in the region.
3. Government should provide public transport facilities (mass transit buses) to reduce the use of personal cars. This will reduce greenhouse gas emission by providing a convenient option to reduce unnecessary driving, lowering emissions per passenger kilometer travelled and supporting more compact urban design.

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