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Spatial Variation of Air Quality in Mpape Area of Abuja, Nigeria

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ABSTRACT

The study assessed air quality along selected area of interest in Mpape Area of the FCT, Nigeria. Particularly, it examined air quality variation in the heavily built areas, industrial areas, and control sites areas in Mpape. The experimental research was employed and air quality variables such as NH_3, NO_2, SO_2, H_2S CO_2 and PM_{10} and PM_{25} were quantitatively gathered in the field using standard methods and equipments such as Minivol Portable Air Sampler, A set of Crow Can Dictator Meter, and GPS. Traffic volume along selected land uses in the three locations was obtained through traffic count approach. Data obtained were analyzed using averages, ANOVA, Pearson's correlation, cluster analysis and Factor analysis. Across the studied locations, high content of carbon monoxide (CO_2) was recorded in Arab Quarry District followed by Millennium Avenue and with mean values of 1.76 ppm and 1.50ppm respectively, while in the lowest concentration of CO_2 was recorded in the Control site with a mean value of 1.18ppm. The range of SO_2 in the present study is above FEPA recommended level of 0.10ppm. The range is also within WHO's 24hrs allowable limit of 20ppm, the concentration of nitrogen dioxide (NO_2) varied significantly among the different locations ($F = 30.540$, $p<0.05$). The concentration of ammonia (NH_3) is ranged from 0.04 to 0.06ppm. The contents of atmospheric particulate matters (PM), $PM_{2.5}$ and PM_{10} also varied among the selected locations. For $PM_{2.5}$, it value ranged from 0.18 to 0.27μg/m^3 which is slightly above the threshold of 0.25μg/m^3 recommended by FEPA, mostly for ambient air quality in Angwan Gwari and Millennium Avenue areas. The range of $PM_{2.5}$ is within WHO's limit of 20μg/m^3 for 24hrs mean concentration. Result of ANOVA showed that the concentration of $PM_{2.5}$ varied significantly among the various locations ($F = 10.758$ $p<0.05$). Furthermore, for PM_{10}, it value ranged from 0.16 to 0.26μg/m^3 which is also slightly above the threshold of 0.25μg/m^3 recommended by FEPA, mostly in Arab Quarry District and to some extent Angwan

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Gwari/ Millennium Avenue. These areas have increased concentrations of PM_{10}. The range of PM_{10} reported in the present study is within WHO's limit of 24hrs mean concentration of 50µg/m^3. Also, result of ANOVA showed that the concentration of PM_{10} varied significantly among the various locations ($F = 9.880$ $p<0.05$). The result therefore means that Arab Quarry District and Angwan Gwari/ Millennium Avenue have high PM_{10} and $PM_{2.5}$ concentrations. Cluster analysis classifies the principal pollutants of Mpape into two homogenous groups (SO_2 and PM, and NO_2) and also identifies anthropogenic activities (principally the combustion of fuel) as the primary source of emission of these groups of gases or pollutants into the atmosphere. Factor Analysis identified anthropogenic activities as the main sources of pollution of PM, NO_2, SO_2, NO and CO_2 in Mpape environs. From the result of this research, 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; Government should assist in the development of these new technologies that will enhance engine efficiency and reduce fuel consumption through the funding of research.

***Keywords*:** Variables, Particulate Matters, Atmospheric Pollutant, Mpape Area of Abuja

1. INTRODUCTION

Atmospheric pollution overtime has become a complacent menace that characterizes many major cities in today's Nigeria. In addition to that, megacities like Abuja, Port-Harcourt and Lagos just to name a few have been associated with incomplete energy combustion in the economic/transportation system which generates high level of localized air pollution, thus; it is of interest to note that; there is an agreeable correlation between *industrialization and air pollution* (Alo, 2008).

The World Resources Institute (1992) has established that; motorized machination produces more source of air pollution than any other single human activity, and every human activity combined. In cities of Nigeria like Lagos and Abuja, especially on highly congested streets, volume of vehicular traffic can be established as the major culprit for high concentration of ambient carbon monoxide levels, nitrogen oxides and hydrocarbons, and a large portion of the particulates (Savile 1993). Without doubt, the high concentration of these elements has immense effects on man's health and continuous existence (Hassan and Okobia, 2008; Song, *et al*., 2016). The air quality around a particular location can be influenced by activities such as burning of fossil fuel, from waste disposal/collection spots, gas flaring from oil production facilities, burning of fuel in the operation of high capacity power generators over long period of time, and emissions from vehicles among others (Adoki, 2012).

Emissions from these sources includes but not limited to sulphur dioxide, oxides of nitrogen, and carbon monoxide in addition to incomplete combustion of fossil fuel that may be presented as suspended particulates and soot (Adoki, 2012). The largest singular anthropogenic cause of sulphur dioxide's presence in the atmosphere is the combustion of sulphur-containing fossil fuel; it also pertinent to note that, oxides of sulphur introduced into the atmosphere can remain suspended for days allowing wide distribution of the pollutant. This gas become more troublesome and concentrated in areas experiencing changes in land use, and one of the many effects to the environment is in the formation of acid rain (Weli, 2014; Abad, *et al*., 2014).

Zhou, *et al*., (2004) cited in Zhao, *et al*., (2006) opined that, urbanization and the complex nature of human activities lead to alterations of the local climate, and in particular create a significant heat island effect. The movement (urbanization) of people into the Mpape area, 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).

Literature shows that air pollution can contribute to increase in hospital admission, lead to absence from work and school, increase in mortality rate (Hopke, 2009; Magaji and Hassan, 2015); for animals, there are the problems of mottled teeth and condition of the joints known as exostosis leading to lameness and ultimate death (Han and Naeher; 2006). For vegetations, gaseous pollutants have been reported to cause destruction of chlorophyll and photosynthetic activity, which untimely leads to death of plant (Qi, *et al*., 2000). In the case of atmospheric properties, air pollutants cause visibility reduction and alteration in temperatures among others (Cao, *et al*., 2004). The continuous development of estates to meet the increasing housing demands of people within the study area has resulted in the massive loss of vegetal cover and this has immense consequences on the ambient air quality as it reduces the volume of CO absorbent in the form of vegetal covers. Hassan and Okobia (2008) as well as Abdullahi, *et al*., (2012) stated that pollution in the Federal Capital City (FCT) of Nigeria is increasing, considering high vehicular traffic indicating an increase in population and vehicles on the motorway emitting carbon monoxide directly into the atmosphere as a result of these anthropogenic activities. In recent time, Mpape experienced a rapid and continuous change in land use and these changes have severely affected the ambient air quality of the area due to human activities, and unprecedented land use over the decade (Abdullahi, *et al*., 2012).

The Mpape area as already pointed out is experiencing high rate of urbanization; and this is so because the area has become a place of attraction to many form of industrial activities. And this increase in urbanization as experienced in the area has led to serious environmental and ecological problems, both in the core, and peripheral with specifics to the air, but not limited to the state of the air, but also the waters.

All of the world urban air quality is influenced by various factors, such as growth of population and economic activities, increase of car ownership, heavy dependence on the use of fossil resources in our society, and meteorological factors (Syafei , *et al*., 2014), but not undermining other source of air pollution that are of natural source (Zhao, *et al*., 2006).

However, in many areas, anthropogenic inputs are proportionately greater than those from natural sources because they are products of industrial, residential, vehicular and domestic waste sources (Zhao, *et al*., 2006). Air quality in urban areas is a serious environmental concern because of the complex and continuous changes in land use that increase the concentration of pollutants in the atmosphere. Urban emissions have become one of the primary cause of atmospheric problems such as ozone layer depletion, photochemical smog, global warming and climate change (Mamtimin and Meixner, 2011).

2. STATEMENT OF THE PROBLEM

Mpape, today have been subject to the unprecedented change in land use from forest, and other green areas to residential, quarry, roads, parking facilities like motor parks and other land uses to meet the needs of the massive influx of people into the area. This has altered the area's local climate and making air pollution a serious issue of environmental concern as it varies along local areas of Mpape (Ukemenam, 2014). Air pollution influences negatively and immensely on human health, wellbeing and the environment. Air pollution arising essentially from anthropogenic activities, which is triggered by changes in land uses caused by increase urbanization and population increase, constitutes a serious environmental problem. Atmospheric pollution has emerged as a problem in most African countries only in the past few decades, its severity and impacts are still largely unknown, although it is believed that gaseous pollutants and acid rain have adversely affected vegetation, soils and water in some areas (Ukemenam, 2014).

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 in either the urban space or urban – rural divide and regional transportation system. The effect of particulate matter on air quality has also been studied (Weli, 2014; 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.

Weli and Ayoade (2014) have also studied the effect of particulate matter on air quality. Their studies among numerous others have revealed that, there is abundant information about the state of the urban environment and factors that affect the ambient air quality. This is apparently 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. The high vehicular movement and traffic as well as other human activities that have become apparent in the area have modified the air quality of the area, and this need to be monitored.

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.

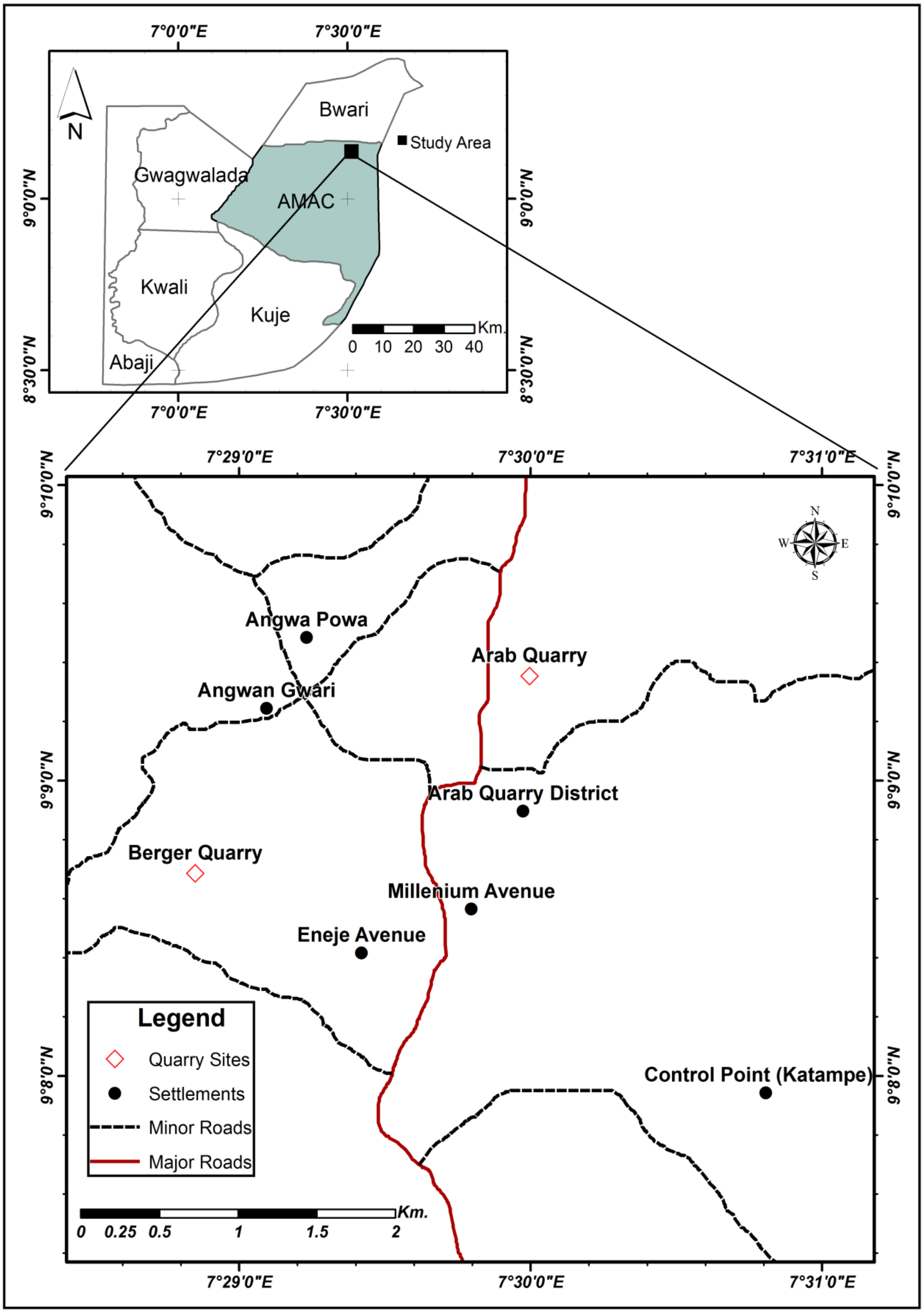
However, in all of these studies, the assessment of air quality variation within a homogenous but yet heterogeneous urban setting have not been adequately documented, in this regards, ***Spatial Variation*** in air quality in Mpape Area of Abuja; as such, this gap in knowledge forms the major theme of this research work.

3. AIM AND OBJECTIVES OF THE STUDY

The aim of this study is to assess the quality of air, and the varying degree of variation in air quality in Mpape Abuja. This aim will be achieved through the following objectives:

i. Determine the concentration levels of the pollutants in the study area and assess compliance to WHO safety limits.
ii. Thus, compare the air concentration in the study area with FME and WHO Standards.

3. 1. Study Area



Map 1. The Study Area

Mpape the study is located in Bwari Area Council, and Bwari Area Council is said to be amongst the five Area council of the Federal Capital Territory of Abuja. The study area lies within Latitudes: 9º7′0″N, and 9º9′30″N and Longitudes 7º28′30″E, and 7º30′30″E, as shown in see Map 1 (Gbigbi, 2009). Mpape from the map's description below is a border town that lies between AMAC and Bwari as it is bounded on the south by Maitama hills, on the West by Dutse Alhaji. With this strategic and phenomenal location of Mpape, the 2006 national population census (provisional figure) put the population of the Mpape area at 119,537 (NPC, 2006), due to it is proximity to the city center and to the hinter-lands of Bwari thus making it a dwelling center for 30% of the AMAC workforce

3. 2. Population, Urban and Economic Settings of Mpape

Mpape's population is projected to grow from more than 18 thousand people in 1999 to 119,537 in 2016, becoming the country's most populous suburb, with a population growth rate of 2.44%. Mpape's sustained high population growth rate will continue for the foreseeable future because of population momentum and its high birth rate. Abuja has not successfully implemented family planning programs to reduce and space births because of a lack of political will, government financing, and the availability and affordability of services and products, as well as a cultural preference for large families. Increased educational attainment, especially among women, and improvements in health care are needed to encourage and to better enable parents to opt for smaller families. Nigeria needs to harness the potential of its burgeoning youth population in order to boost economic development, reduce widespread poverty, and channel large numbers of unemployed youth into productive activities and away from ongoing religious and ethnic violence (NPC 2006 est).

Air quality around a location 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 emissions 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). The largest single anthropogenic source of sulphur dioxide is the combustion of sulphur-containing fossil fuel. Sulphur Dioxide is emitted directly into the atmosphere and can remain suspended for days allowing for wide distribution of the pollutant. One effect of sulphur dioxide is the formation of acid rain. Sulphur dioxide in the air is hazardous to vegetation. High SOx emission level is due to some extent from automobile emissions. These gases become more troublesome and concentrated in areas experiencing changes in land use (Weli, 2014; Abad *et al.*, 2014). In recent time, however, Mpape, one of the fast developing areas in Federal Capital Territory (FCT), Abuja 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).

This indeed is the situation as the area has witnessed unprecedented land use change over the past two decades caused by the movement of people and expansion of human activities in the area. Zhou *et al.*, (2004) cited in Zhao *et al.*, (2006) stated that urbanization and the complex nature of human activities lead to alterations of the local climate, and in particular creates a significant heat island effect. The intrusion (urbanization) of people into the area, 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 continuous building of houses (mostly estates) to meet the increasing housing demands of people in the area has resulted in the massive loss of vegetal cover and this has immense consequences on the ambient air quality.

Land use change is globally recognized as one of the leading and primary causes of rapid change in vegetation, threats to biodiversity, air pollution and increase in the accumulation in heavy metal in the soil (Abad *et al.*, 2014). The increase in the number of these 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 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 because of these anthropogenic activities.

4. RESEARCH METHODOLOGY

4. 1. Reconnaissance Survey

A preliminary survey of the study area was embarked in order to familiarize with the study area's demographic structure, nature of on-going anthropogenic activities, and change in land use and land cover. This survey was carried out within a 5days period before the area was selected as the base for the research.

4. 2. Data type and Sources

This study made use of primary data to provide answers to the research objectives and hypotheses. The major advantage of primary data is that, they are collected in a way specifically tailored to a particular research question, which means they are probably the data best suited to answering that question (Spence and Owens, 2011). In addition, the data to be collected for the purpose of this research are air pollution parameters such as; CO_2, SO_2, NO_2, NH_3, $PM_{2.5}$, PM_{10}, and H_2S.

4. 3. Primary Sources of Data

Data on air pollutants (CO_2, SO_2, NO_2, NH_3, $PM_{2.5}$, PM_{10}, and H_2S) along Mpape area; and data on the volume of traffic along selected Mpape city center will be collected.

The aforementioned sets of primary data was obtained from the measurement of air quality at designated areas or location within the territorial boundaries of Mpape i.e. field experiment using standardized equipment and traffic count approach.

4. 4. Materials and Equipment

These data set were collected at different locations along Mpape using Minivol Portable Air Sampler as well as a set of Crow Can gas dictator meter.

In addition, the Geographic Positioning System (GPS) was also used to get the actual coordinates of the sampling points of interest during the course of data collection.

Air quality collection exercise ensure from 7am to 11am in the morning, 3pm in the afternoon to 6pm in the evening within a period of 14days. With the intention to get a comparative result that will show the intensity of activities at various times of the day and how they contribute in air pollution (Nwakanma, *et al*., 2016).

4. 5. Sampling Technique

This study made use of clustered sampling technique. This sampling technique is used when mutually homogenous yet internally heterogeneous grouping are evident in a statistical population. The air quality data was collected from areas within the; Quarry sites, Built up areas, Major roads, and Minor roads as depicted in the map of the study area.

In addition, this sampling technique enable air quality data to be obtained across different locations, which will in turn, enjoins this research to the gains of comparative analysis.

However, the Mpape city center air quality data will be collected from three broad holistic land uses: Residential areas, Economic and Roadside due to the varying difference in human activities that have significant influence on ambient air quality.

4. 6. Data Collection

The collection of air quality for this study was carried out in the month of May 2017 through out a 14days period. During data collection, locations were geo-referenced using GPS, in addition, the site characteristics of each location will be noted during data collection in order to relate variation in air quality of site factors. The spatial variations in atmospheric pollutants concentration in this study was evaluated by analyzing the actively sampled pollution data from different locations along Mpape city centers.

Table 1. Points of Air Samples Collections with GPS Coordinates

	Location	Coordinates	Elevations
A	Angwan Powa	**Point 1** N 09º9’3.15” E 07º29’8.05”	628m
	Angwan Gwari	**Point 2** N 09º8’58.99” E 07º29’1.38”	622m
B	Millennium Avenue	**Point 3** N 09º8’19.48” E 07º29’46.55”	617m
	Eneje Avenue	**Point 4** N 09º8’12.39” E 07º29’24.81”	621m
C	Arab Quarry District	**Point 5** N 09º8’39.15” E 07º29’57.26”	623m
	Katampe Estate (Control Point)	**Point 6** N 09º7’44.50” E 07º30’42.71”	618m

4. 7. Ambient Air Monitoring

When setting ambient air sampling units, procedures described by Harrop (2002) cited in Adoki (2012) was adhere to. Thus, monitoring sites weree classified into four classes: quarry site, built up areas, major and minor roads. However, when selecting a monitoring site, parameters including possible chemicals or physical interference, locality, terrain, services and local activities were considered.

4. 8. Method of Data Analysis

Both descriptive and inferential statistical tools were deployed to give meaningful explanations to the data obtained from the processes explained earlier. A descriptive statistical tool such as averages, percentages, and tables was used to present the data for easy understanding of the pattern and variability of air quality. Furthermore, Pearson's correlation, ANOVA, cluster analysis and factor analysis was used to highlight the association, source of air pollutants (natural or anthropogenic) and significant pollutants that vary among the locations.

Pearson's correlation was used to examine the association between (traffic volume) and air pollutants: NO_2, SO_2 and CO as well as understand the nature and strength of the association between the pollutants. A One-Way Analysis of Variance Test will be used to compare the mean variations in air quality along Mpape city center as well as land uses.

Cluster analysis will be used to clarify or group the pollutants into different sources pollution. In order to classify or group the pollutants and identify their sources, hierarchical cluster analysis will be performed using the following settings: the linkage type used will be nearest neighbor and the distance method will be the Pearson correlation.

In concise, cluster analysis will be used to recognize the source and somewhat homogeneous groups of air pollution (Hu, *et al*., 2013; Ewa, *et al*., 2013). Factor analysis being a higher multivariate statistical tool was used to identify dimensions in air pollutants along Mpape city center as well as pick out the air pollutants that is most varied across the sites. The dimension of pollutants or identified pollutants will be used to make future interference for appropriate decision-making.

4. 9. Data Analysis, Presentation and Interpretation of Result

The result shows the concentration of air quality across different locations and control in Mpape, FCT. The result shows clear variation in the concentration of air quality across the different locations considered in the study. The content of CO_2 across the different locations ranged from 1.18 to 1.76 ppm. This range is within the comparative range of 1.83 to 2.17 ppm as obtained by Magaji and Hassan (2015) around abattoir area in Gwagwalada, but lower than the 10.25 – 31.67 ppm reported by Attah (2015) across different land uses in Kaduna Metropolis. The concentration of CO_2 in this study is within the 10ppm recommended by FEPA (Atubi, 2015: Ebong and Mkpenie, 2016). It is also within WHO's 90 ppm limit for 15 minutes (Balogun and Orimoogunje, 2015). Across the studied locations, high content of carbon monoxide (CO_2) was recorded in Arab Quarry District followed by Millennium Avenue and with mean values of 1.76 and 1.50 ppm respectively, while in the lowest concentration of CO_2 was recorded in the control with a mean value of 1.18 ppm. This implies that the ***Control*** witnesses reduced traffic congestion and presence of industrial activities that favour the increase in CO_2 pollutants or concentration in the atmosphere. CO_2 content is acknowledged by Han, (2010) to in heavy traffic congestion, residential and industrial activities. In a study carried out by Akpan and Ndoke (1999) in Northern Nigeria, high concentration of CO_2 was reported in heavily congested areas. Hence, the high CO_2 content recorded in Arab Quarry District is associated with the industrial activities in the area. This is the case with Millennium Avenue and other areas with increasing concentration of CO_2 in the atmosphere. Results of ANOVA showed that the concentration of CO_2 varied significantly among the various locations ($F = 19.350$, $p<0.05$). This is expected due to the varied human activities carried out in these locations. Due to human activities such as the combustion of fossil fuels, deforestation, wood burning, natural gas, coal, or wood-burning stoves and heaters, the concentration of atmospheric carbon dioxide has increased by about 35 per cent since the era of industrialization began (Amin, 2009; Atubi, 2015). Han and Naeher, (2006) stated that CO_2 results from the incomplete combustion of diesel or gasoline in traffic engines, non-transportation fuel combustion, bush burning and some indoor sources such as a leaking gas stove.

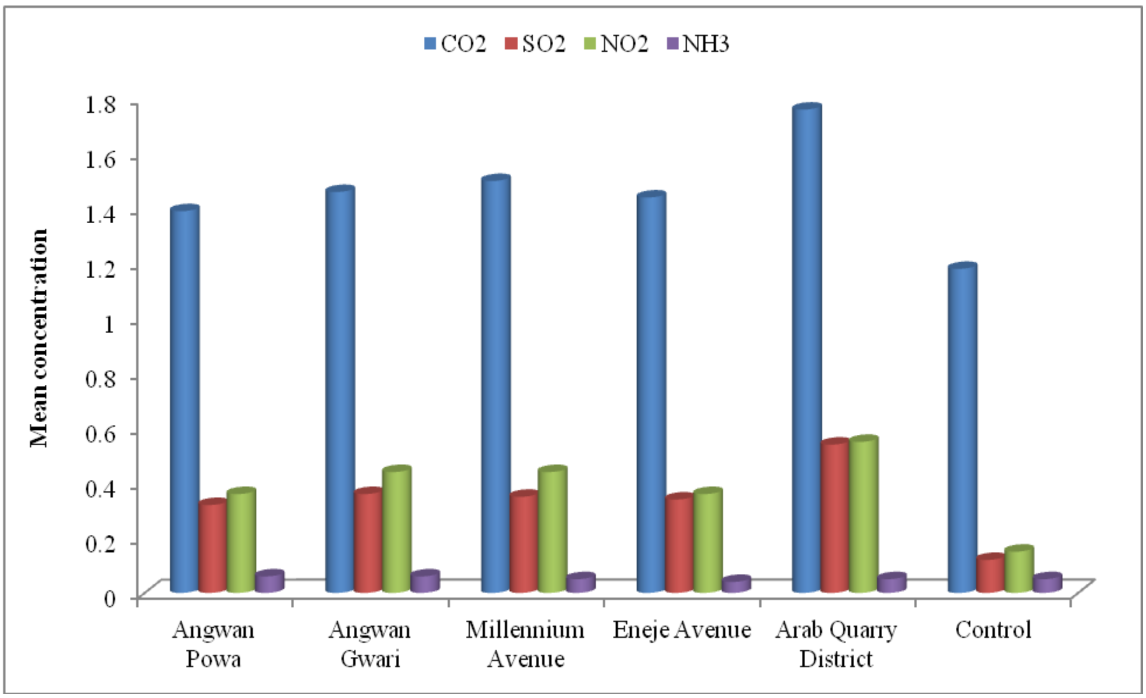


Fig. 1. Spatial concentration of ambient Air qualities amongst locations of the study area

The concentration of Sulphur dioxide (SO_2) showed varied concentrations across the studied locations with high concentration of 0.54 ppm recorded within Arab Quarry District. SO_2 concentration was comparatively the same in other locations with the exception of the control which had the lowest concentration of 0.12 ppm. SO_2 values ranged from 0.12 to 0.54 pp. Result of ANOVA showed that the concentration of SO_2 varied significantly among the different locations ($F = 20.840$, $p<0.05$). The range of SO_2 in the in the present study is above FEPA recommended level of 0.10 ppm. The range is also within WHO's 24 hrs allowable limit of 20ppm. The control experienced the lowest SO_2 concentration probably as a result of reduced anthropogenic activities. EEA (2008) and US EPA (2009) noted that anthropogenic sulphur emission principally originate from fossil fuel combustion (electricity, fossil fuel combustion, industrial process, non-road equipment and fire among others). The existence of several industrial activities in Arab Quarry District 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. In addition, SO_2 is introduced into the environment from industrial activities that burn fossil fuels containing sulfur as well as motor (Atubi, 2015).

Table 2. Concentration of Air Quality across different locations in Mpape.

Locations	Mean concentration of parameters						
	CO_2	**SO_2**	**NO_2**	**NH_3**	**$PM_{2.5}$**	**PM_{10}**	**H_2S**
Angwan Powa	1.39	0.32	0.36	0.06	0.25	0.20	0.11
Angwan Gwari	1.46	0.36	0.44	0.06	0.27	0.23	0.16
Millennium Avenue	1.50	0.35	0.44	0.05	0.27	0.23	0.11
Eneje Avenue	1.44	0.34	0.36	0.04	0.22	0.20	0.13
Arab Quarry District	1.76	0.54	0.55	0.05	0.26	0.26	0.16
Control	**1.18**	**0.12**	**0.15**	**0.05**	**0.18**	**0.16**	**0.08**

Likewise, the contents of nitrogen dioxide (NO_2) varied across the different locations. It showed that high concentrations of nitrogen dioxide (NO_2) were recorded in Arab Quarry District and Millennium Avenue/Angwan Gwari with mean values of 0.55 ppm and 0.44 ppm respectively, As usual, the lowest concentration of NO_2 was recorded in the control site with a mean value of 0.15 ppm. The concentration of nitrogen dioxide (NO_2) varied significantly among the different locations ($F = 30.540$, $p < 0.05$). In all, NO_2 ranged from 0.15 to 0.55 ppm which is above the limit of 0.06 ppm recommended by FEPA (Ebong and Mkpenie, 2016). The range is however within WHO's 1hr mean allowable limit of 200ppm. It also agrees with the range of 0.14 to 1.09 ppm reported in Kano metropolis, Nigeria by Okunola, Uzairu, Gimba *et al.*, (2012); while, the range of 0.73 to 0.84 ppm reported by Adelagun *et al.*, (2012) was far above the range reported in the present study. The high concentration of NO_2 in Arab Quarry District and Millennium Avenue/Angwan Gwari may be attributed to high traffic congestion and construction activities. The activities in these areas 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.

Ammonia (NH_3) is the third abundant nitrogen-containing gas in the atmosphere after N_2 and N_2O (Seinfeld and Pandis 1998 cited in Liu, Wang, Wang *et al.*, 2014). The concentration of ammonia (NH_3) in the present study ranged from 0.04 to 0.06 ppm. Across the studied locations, high content of NH_3 was recorded in Angwan Powa and Angwan Gwari with a mean value of 0.06 ppm respectively, while in the lowest concentration was recorded in Eneje Avenue with a mean value of 0.04 ppm. NH_3 range of 0.04 to 0.06 ppm is within the limit of 0.30 ppm recommended by FEPA. Results of ANOVA showed that the concentration of NH_3 did not vary significantly among the various locations ($F = 1.445$ $p>0.05$). The insignificant variation implies that the respective locations have similar concentration of NH_3 in the atmosphere. According to Liu *et al.*, (2014), the major sources for atmospheric NH_3 include animal wastes, biological processes in soils and ammonia-based chemical fertilizers, followed by biomass burning, and sewage treatment plants as well as traffic. Meng, Lin, Jiang *et al.*, (2011) recognised traffic as an important source of ammonia in urban areas. However, the comparatively high contents of NH_3 in Angwan Powa and Angwan Gwari may be attributed to increased vehicular congestion and refuse decomposition in the area.

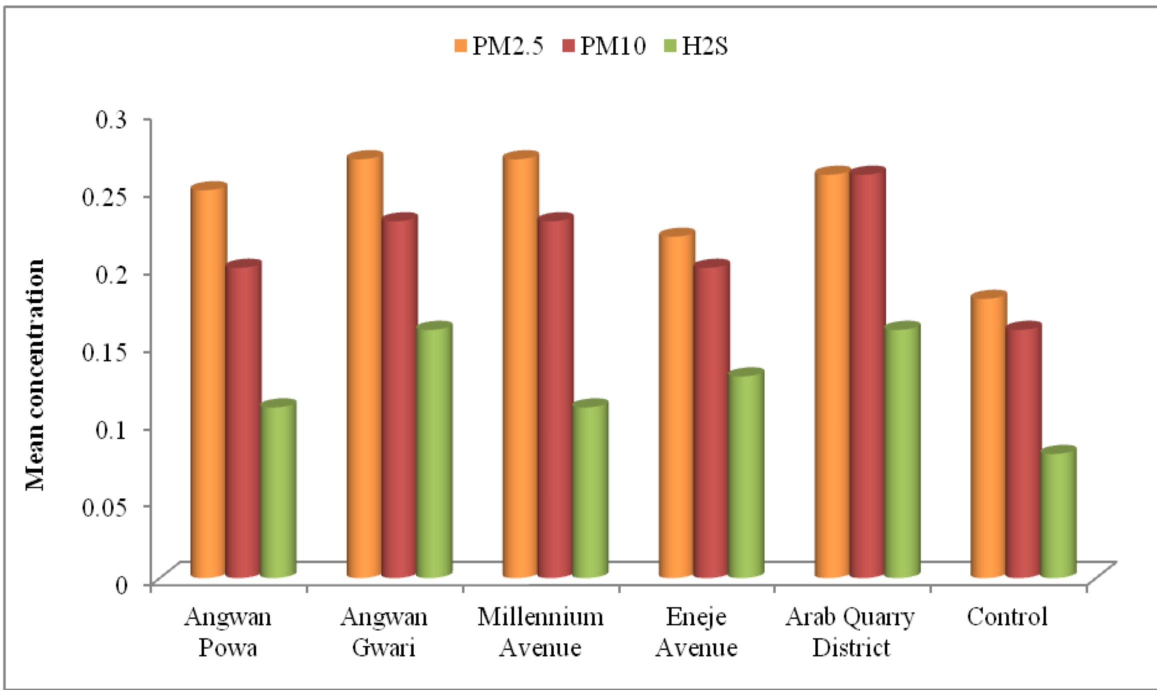


Fig. 2. Spatial Variation of Particulate Matters and H_2S across the Study Area

In addition, the contents of atmospheric particulate matters (PM), $PM_{2.5}$ and PM_{10} also varied among the selected locations. For $PM_{2.5}$, it value ranged from 0.18 to 0.27µg/m^3 which is slightly above the threshold of 0.25µg/m^3 recommended by FEPA, mostly for ambient air quality in Angwan Gwari and Millennium Avenue areas. The range of $PM_{2.5}$ is within WHO's limit of 20 µg/m^3 for 24hrs mean concentration (WHO, 2006). Result of ANOVA showed that the concentration of $PM_{2.5}$ varied significantly among the various locations ($F = 10.758$ $p < 0.05$). Furthermore, for PM_{10}, it value ranged from 0.16 to 0.26 µg/m^3 which is also slightly above the threshold of 0.25 µg/m^3 recommended by FEPA (Magaji and Hassan, 2015), mostly in Arab Quarry District and to some extent Angwan Gwari/ Millennium Avenue. These areas have increased concentrations of PM_{10}. The range of PM_{10} reported in the present study is within WHO's limit of 24 hrs mean concentration of 50 µg/m^3. Also, result of ANOVA showed that the concentration of PM_{10} varied significantly among the various locations ($F = 9.880$ $p<0.05$).

The result therefore means that Arab Quarry District and Angwan Gwari/ Millennium Avenue have high PM concentrations. This is expected as these land uses experience high fuel combustion from automobiles, power plants, commercial and industrial activities resulting in the release of particular matter (Han, 2010).

The Arab Quarry District, Angwan Gwari and Millennium Avenue areas are expected to have high PM because these areas have high 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 (https://www.valleyair.org/Air_Quality_Plans/AQ_plans_PM_sources.htm).

More so, the concentration of H_2S (Hydrogen sulfide) ranged from 0.08 to 0.16ppm with high and low values recorded in Arab Quarry District/Angwan Gwari and control sites with mean values of 0.16 and 0.08 ppm. The range of H_2S reported in the present study is far below the range of 0.33 to 3.17 ppm reported by Okunola *et al.*, (2012) along high traffic roads in Kano. The high concentration of H_2S in Arab Quarry District/Angwan Gwari is attributed to the decay of decay of food stuff, waste and refuse. In these areas, heaps of organic wastes are found and this contributes to the emission of H_2S. According to Okunola *et al.*, (2012), H_2S is gases emitted during the decay of organic matter. They argued that the decay of food stuff, waste and refuse left for a long time result in high H_2S emission. The H_2S level in this study is lower than the range of 0.167 – 0.265 ppm reported in Abeokuta metropolis, Nigeria by Oguntoke and Yusuf, (2008). In comparison to earlier and related studies, the concentration of H_2S could be said to be low in Mpape. Studies show that Nigeria has no permissible limit for H_2S (Ohimain, Izah and Abah, 2013).

4. 10. Air Quality Index (AQI)

AQI is an index established by USEPA (2000) 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 3). 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.

Table 3. Air quality index.

AQI categories	**AQI Rating**	**PM ($\mu g/m^3$)**	**CO_2 (ppm)**	**NO_2 (ppm)**	**SO_2 (ppm)**	**NH_3 (ppm)**
Very good (0-15)	A	0 - 15	0 - 2	0 - 0.02	0 - 0.002	0 – 50
Good (16-31)	B	51-75	2.1-4.0	0.02-0.03	0.02-0.03	0 – 50
Moderate (32-49)	C	76-100	4.1-6.0	0.03-0.04	0.03-0.04	51 – 100
Poor (50-99)	D	101-150	6.1-9.0	0.04-0.06	0.03-0.04	201 – 300
Very poor (100 or over)	E	>150	>9.0	>0.06	>0.06	301 - 500

Source: USEPA, (2000)

Results in Table 3 show the AQI for analysed air pollutants in Mpape. The range obtained for the respective air pollutants was compared with the AQI index in Table 3. The result obtained as depicted in Table 3 revealed that $PM_{2.5}$ and PM_{10}, CO_2 and NH_3 were in the A category (very good). This implies that the concentration of $PM_{2.5}$ and PM_{10}, CO_2 and NH_3 is considered satisfactory, and air pollution poses little or no risk to inhabitants in the area. It also showed that NO_2 and SO_2 were in the E category (very poor). The results in the E category imply health warnings of emergency conditions as inhabitants in the area are more likely to be affected by the contents of NO_2 and SO_2. The status of NO_2 and SO_2 being very poor with health implications is similar to the status of reported by Magaji and Hassan (2015) in Gwagwalada, Abuja and Ebong and Mkpenie (2016) in Uyo metropolis, Akwa Ibom State. The ranges reported for PM and CO_2 were within the very good category. AQI class for other air parameters is not available however. The result obtained therefore indicates that the concentration of CO_2, $PM_{2.5}$, PM_{10} and NH_3 in Mpape may not pose a serious health problem to people when they are exposed to these gases for a long time.

Table 4. Air quality status in Mpape.

Parameters	Measured range	Air quality rating
$PM_{2.5}$ (µg/m^3)	0.03 – 0.40	A (Very good)
PM_{10} (µg/m^3)	0.09 – 0.56	A (Very good)
CO_2 (ppm)	1.00 – 2.90	A (Very good)
NO_2 (ppm)	0.01 – 0.90	E Very poor
SO_2 (ppm)	0.01 – 0.91	E Very poor
NH_3 (ppm)	0.00 – 0.19	A (Very good)

Source: Field Research 2017

4. 11. Pollution Index (PI)

Pollution index (PI) was developed and applied by Cannistraro and Ponterio (2009) for reporting air quality status in a given area. The pollution index method is based on a simple indicator of the air quality in an urban context that is useful for communicating to citizens' information about the state of air quality of a waste urban area (Kanchan and Goyal, 2015).

In the present study, the calculation of Pollution Index was carried out using the formula given by EPA (2017) as follows:

$$Index = \frac{\text{Pollutant Concentration}}{\text{Pollutant Standard Level}} \times 100$$

The standard pollutant levels for some of the studied ambient air quality variables are shown in Table 5. In estimating the pollution index (PI), the PI of the respective pollutants at different time periods was carried out, after which their averages were determined. The estimation was done for the respective locations.

Table 5. Standard pollutant levels.

Pollutants	Standard level
Nitrogen dioxide	120 ppm
Sulfur dioxide	200 ppm
Carbon monoxide	9 ppm
Particles (PM_{10})	50 $\mu g/m^3$
Particles ($PM_{2.5}$)	25 $\mu g/m^3$

Source: EPA (2017)

The results on PI of all the respective locations are shown in Table 6. The decision for ascertaining the PI according to Kanchan and Goyal (2015) is shown in Table 5. The values for the respective pollutants fall within the 0 – 50 category implying no risk attached to the ambient air quality parameters in the area. The values of the pollution index do not show much fluctuation implying to some extent similar level of anthropogenic pollution in area. However, among the locations studied Arab Quarry District show slight increase in ambient air pollution (21.79) as compared to other areas with low inputs from anthropogenic sources. In general, there is low PI value in the area indicating high dilution and dispersion of air pollutants in the area.

Table 6. Concentration of air quality across different locations in Mpape.

Locations	Pollution index					Total
	CO_2	SO_2	NO_2	$PM_{2.5}$	PM_{10}	
Angwan Powa	15.5	0.17	0.30	0.49	0.79	17.25
Angwan Gwari	16.2	0.18	0.37	0.55	0.90	18.2
Millennium Avenue	16.7	0.18	0.37	0.53	0.93	18.71
Eneje Avenue	16.0	0.17	0.30	0.43	0.80	17.7
Arab Quarry District	19.5	0.27	0.46	0.52	1.04	21.79
Control	13.2	0.06	0.12	0.35	0.62	14.35
Total	**97.10**	**1.03**	**1.92**	**2.87**	**5.08**	

Source: Researcher's fieldwork, 2017

Thus, the PI of Mpape obtained from different locations indicates the complete absence of pollution concern despite the numerous human activities in the area. Furthermore, a look at the level of pollution of the respective pollutants indicated that while other pollutants showed very low level of pollution, CO_2 indicated moderate pollution concern. It therefore means that the sources of CO_2 pollution or concentration in the area need to be monitored to reduce the future threats of CO_2.

4. 12. Association between Air Qualities

Pearson's correlation is used to examine the association between air pollutants as well as identify pollutants with similar source of pollution. The analysis is carried out for the respective locations considered in the present study. This is intended to identify the spatial pattern in ambient air quality in the studied locations.

4. 13. Association between Air Qualities in Angwan Powa

The information in Table 8 shows the associations between air pollutants in Angwan Powa. The result showed that there is positive and significant association between SO_2 and CO_2 ($r = 0.521$, $p<0.01$), PM_{10} and CO_2 ($r = 0.367$, $p<0.01$), PM_{10} and SO_2 ($r = 0.320$, $p<0.01$), and between H_2S and NH_3 ($r = 0.368$, $p<0.01$). The positive association simply indicates that an increase in one pollutant will bring about a corresponding increase in the other pollutant and vice versa. For instance, the association SO_2 and CO_2 implies that an increase in SO_2 will result in a corresponding increase in the contents of CO_2. It shows that any anthropogenic factor responsible for the increase in the concentration of SO_2 will also cause the increase in the concentration of CO_2. This applies to other positive and significant factors or elements.

Table 7. Zero order correlation matrix in Angwan Powa.

Variables	**CO_2**	**SO_2**	**NO_2**	**NH_3**	**$PM_{2.5}$**	**PM_{10}**	**H_2S**
CO_2	1						
SO_2	0.521*	1					
NO_2	0.096	0.241	1				
NH_3	-0.045	-0.086	-0.291	1			
$PM_{2.5}$	0.011	0.093	0.104	0.162	1		
PM_{10}	0.367*	0.320*	0.080	-0.251	0.016	1	
H2S	0.200	0.192	0.152	0.368*	0.141	-0.101	1

*Correlation is significant at the 0.01 level (2-tailed).

The result also showed that positive but insignificant association existed between some air parameters. There is also negative and insignificant association between air parameters.

The positive association between the air quality parameters suggests that they are likely to be influenced by similar anthropogenic factors, while the negative association between the air quality parameters means that they are not influenced by similar anthropogenic factors (Iwara et al., 2012). In all, the positive and significant association shows that the parameters have similar source of emission in the atmosphere.

4. 14. Association between Air Qualities in Angwan Gwari

The association between air pollutants in Angwan Gwari is shown in Table 8. The result showed that there is positive and significant association between SO_2 and CO_2 ($r = 0.458$, $p<0.01$), NO_2 and SO_2 ($r = 0.460$, $p<0.01$), H_2S and NO_2 ($r = 0.315$, $p<0.01$) and between H_2S and $PM_{2.5}$ ($r = 0.436$, $p<0.01$). As usual, the positive association implies that an increase in one pollutant will bring about a corresponding increase in the other pollutant and vice versa. For instance, the association NO_2 and SO_2 implies that an increase in NO_2 will result in a corresponding increase in the contents of SO_2. This applies to other positive and significant factors or elements. The positive association suggests they pollutants are influenced by similar anthropogenic factors, while the negative association means that they are not influenced by similar anthropogenic factors (Iwara et al., 2012).

Table 8. Zero order correlation matrix in Angwan Gwari

Variables	**CO_2**	**SO_2**	**NO_2**	**NH_3**	**$PM_{2.5}$**	**PM_{10}**	**H_2S**
CO_2	1						
SO_2	0.458*	1					
NO_2	0.226	0.460*	1				
NH_3	-0.113	-0.221	-0.188	1			
$PM_{2.5}$	0.121	0.181	0.226	0.133	1		
PM_{10}	0.310	0.220	0.010	-0.073	0.095	1	
H_2S	0.043	0.192	0.315^{+}	0.256	0.436*	-0.047	1

* Correlation is significant at the 0.01 level (2-tailed).
$^{+}$ Correlation is significant at the 0.05 level (2-tailed).

4. 15. Association between Air Qualities in Millennium Avenue

As shown in Table 9, there is positive and significant association between SO_2 and CO_2 ($r = 0.340$, $p<0.05$) and between NO_2 and SO_2 ($r = 0.371$, $p<0.05$). The positive association implies that an increase NO_2 will result in a corresponding increase in the contents of SO_2.

Table 9. Zero order correlation matrix in Millennium Avenue.

Variables	CO_2	SO_2	NO_2	NH_3	$PM_{2.5}$	PM_{10}	H_2S
CO_2	1						
SO_2	0.340*	1					
NO_2	0.089	0.371*	1				
NH_3	-0.062	0.022	0.140	1			
$PM_{2.5}$	0.217	0.011	0.278	0.030	1		
PM_{10}	0.139	0.214	0.114	-0.244	0.232	1	
H_2S	-0.026	0.150	-0.056	0.091	0.059	0.014	1

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

4. 16. Association between Air Qualities in Eneje Avenue

The pattern of association observed in Millennium Avenue was also observed in Eneji Avenue (Table 10). The obtained results reveals the existence of positive and significant association between SO_2 and CO_2 ($r = 0.443$, $p<0.01$) and between NO_2 and SO_2 ($r = 0.416$, $p<0.01$). The positive association implies that an increase in the concentration of SO_2 will result in a corresponding increase in the concentration of CO_2 and vice versa.

Table 10. Zero order correlation matrix in Eneje Avenue.

Variables	CO_2	SO_2	NO_2	NH_3	$PM_{2.5}$	PM_{10}	H_2S
CO_2	1						
SO_2	0.443*	1					
NO_2	0.416*	0.276	1				
NH_3	0.226	-0.001	0.103	1			
$PM_{2.5}$	0.022	-0.088	0.163	0.156	1		
PM_{10}	0.163	0.021	0.108	-0.282	-0.058	1	
H2S	0.124	0.276	0.263	0.150	-0.001	-0.118	11

* Correlation is significant at the 0.01 level (2-tailed).

4. 17. Association between Air Qualities in Arab Quarry District

The results in Table 11 reveal the existence of positive and significant association between SO_2 and CO_2 ($r = 0.554$, $p<0.01$), NO_2 and SO_2 ($r = 0.441$, $p<0.01$), $PM_{2.5}$ and SO_2 ($r = 0.448$, $p<0.01$), $PM_{2.5}$ and NO_2 ($r = 0.463$, $p<0.01$), H2S and NO_2 ($r = 0.333$, $p<0.05$) and between H2S and $PM_{2.5}$ ($r = 0.366$, $p<0.05$). The positive association implies that an increase in the concentration of H_2S will result in a corresponding increase in the concentration of $PM_{2.5}$ and vice versa. It further shows that any anthropogenic factor responsible for the increase in the concentration of H_2S will also trigger the increase in $PM_{2.5}$ in the atmosphere.

Table 11. Zero order correlation matrix in Arab Quarry District.

Variables	**CO_2**	**SO_2**	**NO_2**	**NH_3**	**$PM_{2.5}$**	**PM_{10}**	**H_2S**
CO_2	1						
SO_2	0.554*	1					
NO_2	0.109	0.441*	1				
NH_3	0.172	0.122	0.037	1			
$PM_{2.5}$	0.200	0.448*	0.463*	0.210	1		
PM_{10}	0.078	0.253	0.118	0.158	0.247	1	
H_2S	-0.020	0.082	0.333^{+}	0.283	0.366^{+}	0.076	1

* Correlation is significant at the 0.01 level (2-tailed).
$^{+}$ Correlation is significant at the 0.05 level (2-tailed).

4. 18. Association between Air Qualities in the Control

The results in Table 12 revealed that positive and significant association existed between SO_2 and CO_2 ($r = 0.315$, $p<0.05$), $PM_{2.5}$ and NH_3 ($r = 0.354$, $p<0.05$), PM_{10} and CO_2 ($r = 0.355$, $p<0.05$) and between H2S and $PM_{2.5}$ ($r = 0.447$, $p<0.01$). It also showed that negative and significant association existed between $PM_{2.5}$ and CO_2 ($r = -0.307$, $p<0.05$), $PM_{2.5}$ and SO_2 ($r = -0.686$, $p<0.01$), PM_{10} and SO_2 ($r = -0.399$, $p<0.01$) and between H2S and SO_2 ($r = -0.320$, $p<0.05$).

The negative association implies that an increase in the concentration of H_2S will result in a corresponding decrease in the concentration of SO_2 and vice versa. It further shows that any anthropogenic factor responsible for the increase in the concentration of H_2S will cause the decrease in SO_2 in the atmosphere. The reverse is however the case for air qualities or pollutants with positive and significant associations.

Table 12. Zero order correlation matrix in the Control.

Variables	CO_2	SO_2	NO_2	NH_3	$PM_{2.5}$	PM_{10}	H_2S
CO_2	1						
SO_2	0.315$^+$	1					
NO_2	0.042	-0.239	1				
NH_3	-0.087	-0.288	0.265	1			
$PM_{2.5}$	-0.307$^+$	-0.686*	0.115	0.354$^+$	1		
PM_{10}	0.355$^+$	-0.399*	0.162	-0.019	0.286	1	
H_2S	-0.003	-0.320$^+$	-0.273	0.037	0.447*	0.210	1

* Correlation is significant at the 0.01 level (2-tailed).
$^+$ Correlation is significant at the 0.05 level (2-tailed).

4. 19. Classification and Identification of the Sources of Air Pollutants

Cluster analysis was employed to organize the pollutants into homogenous groups. In order to discriminate distinct groups of studied elements as tracers of natural or anthropogenic source, a hierarchical cluster analysis was performed on the 7 air quality parameters.

4. 20. Cluster Analysis

Cluster analysis yielded a dendrogram by grouping all 7 air quality parameters into two statistically significant clusters. From the Figure, Cluster I consisted of $PM_{2.5}$ and NH_3. This group (cluster) had two pollutants. These parameters showed similarities in sources of pollution, which are basically controlled by anthropogenic activities. The concentration of these pollutants in any environment is attributed to high fuel combustion from automobiles, heating of power plants, commercial and industrial activities resulting (Han, 2010). The two have similar environmental factors that favour their concentration in the atmosphere. This is affirmed by the positive Pearson's correlation between across the selected locations. Similar source of pollution was identified by Wang, Wang, Xu et al., (2016) when they reported that traffic intensity resulting in high fuel combustion was partially related to the formation of $PM_{2.5}$ and NH_3, suggesting that traffic pollution may be an important source of $PM_{2.5}$. Gu, Sutton, Chang et al., (2014) reported that NH_3 emitted from agriculture allows react more readily and form $PM_{2.5}$ to further deteriorate air quality near or within cities. Similarly, Ye *et al.,* (2011) cited in Yang and Jiao (2017) stated that NH_3 accounted for 30 per cent to 70 per cent of $PM_{2.5}$ mass concentration. These studies simply show that the increase in the emission of NH_3 brings about a corresponding increase in $PM_{2.5}$ mass concentration.

In addition, Cluster II identified PM_{10}, H_2S and SO_2 as the main group of pollutant. These parameters in the area of study are also controlled majorly by anthropogenic activities. The placement of these pollutants in the same group is further affirmed by the Pearson's correlation result. The result in many of the locations except in the control (with reduced human activities) shows positive association between the pollutants. The study of Lin, Liu, Chou et al., (2004) reported a significant relationship between PM_{10} and SO_2. The classification of PM_{10} and SO_2 is also justifiable as PM_{10} is emitted or formed when emissions of sulfur oxides (SO_x) and other gases react in the atmosphere. The two have similar environmental factors that favour their concentration in the atmosphere.

EPA (2016) stated that the principal source of SO_2 is the burning of fossil fuels and other industrial facilities. However, the two clusters identify anthropogenic activities as the chief source of ambient air pollutants in the area. This is so as the pollutants have anthropogenic inputs. Hydrogen Sulfide (H_2S) is easily recognizable by their strong odor (rotten egg for H_2S). It is mostly produced by industrial activities: extraction and treatment of gas/fuel, wastewater treatment plants, tanneries, paper mills, etc. SO_2 – Sulphur dioxide is created by the combustion of gas, fuel, coal, while for PM_{10}, emitting sources for such pollutants are again industrial or linked to the traffic (http://cairpol.com/en/expertise-autonomous-systems-for-monitoring-low-concentration-pollutants/measured-pollutants/).

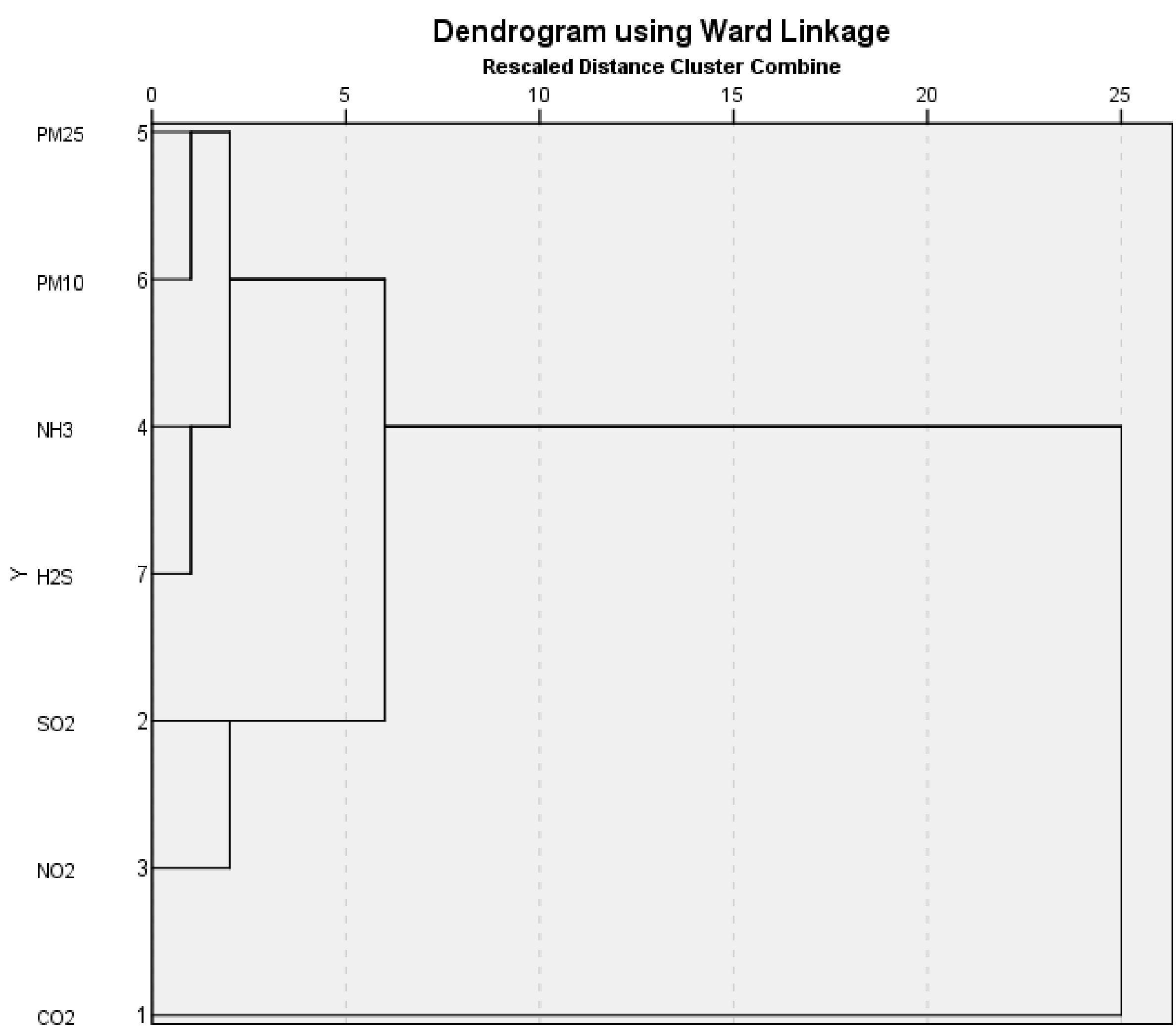


Figure 3. Cluster tree of pollutants in Mpape

The cluster analysis result above therefore classifies the principal pollutants of Mpape into two homogenous groups and also identifies anthropogenic activities (principally the combustion of fuel, agricultural and industrial activities) as the primary source of emission of these groups of gases or pollutants into the atmosphere.

4. 21. Identification of Most Varied Air Quality

This section of the study makes use of factor analysis (FA) to identify the most varied or significant air quality parameter in Mpape. It is also performed in order to know the sources (natural or anthropogenic) of air pollutants introduction into the atmosphere.

4. 22. Assessment of the Air Quality Data Set

Assessment of the air quality data set was carried out to know whether it was adequate to run FA making reference to the result of Kaiser – Meyer – Olkin measure of sampling adequacy and Bartlett's test of sphericity. The result in Table 13 showed that the Bartlett's test of Sphericity with 21 degree of freedom was observed to be 368.160 and significant at 1% alpha level. Since the Bartlett's test of Sphericity was significant at the 0.05, we reject the null hypothesis that the population correlation matrix was an identity matrix. This meant that there existed correlations among the variables. The significance of Bartlett's test meant that FA was appropriate for the air quality data set. Also, the value of KMO (Kaiser-Meyer-Olkin Measure of Sampling Adequacy) was observed to be 0.732 which was greater than 0.5. This result also meant that FA was a suitable technique to analyzing the air quality data set. This further implies that Kaiser's criterion of extracting factors with eigen values >1 is applicable for the set of data (Field, 2005).

Table 13. KMO and Bartlett's Test.

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		**0.732**
Bartlett's Test of Sphericity	Approx. Chi-Square	368.160
	df	21
	Sig.	0.000

Source: SPSS Window Output Version 22.0

4. 23. FA Result of Air Quality in Mpape

FA result using varimax normalized rotation produced two factors that explained 56.7% of the variation in the original data set (Table 14). Based on Kaiser criterion (Kaiser 1960 cited in Hu *et al.*, 2013), only two factor were extracted from the entire data set with eigenvalues >1. Hu et al., 2013) noted that in the interpretation of FA patterns, components greater than 0.71 are typically considered excellent, while those less than 0.32 are regarded as very poor. Hence, in the present study, factors of $\pm\geq0.8$ were identified and selected as significant variables for understanding the type and source of pollutants. Factor One (F_1) had strong and positive loadings on SO_2 (0.815). F_1 was responsible for 35.1% of total variance in the overall data set and symbolized anthropogenic pollution. F_2 had strong and positive loadings on NH_3 (0.809) and was responsible for 21.6% of total variance in the overall data set. F_2 also symbolized anthropogenic pollution. The two extracted factors therefore identify anthropogenic activities as the main sources of pollution of SO_2 and NH_3 in Mpape and environ. This further shows that SO_2 and NH_3 are essential pollutants with significant levels of pollution in the atmosphere. The increase concentrations of SO_2 and NH_3 are emitted via anthropogenic activities (such as agricultural activities and burning of fossil fuel in residential, commercial and industrial areas and heavy traffic congestion).

According to US EPA (2008) mobile sources which include both on-road vehicles (e.g., cars, trucks, motorcycles) and non-road vehicles and engines (e.g., farm equipment/activities, construction equipment, aircraft, marine vessels) are responsible for majority of the emission of air pollutants into the atmosphere. The result of cluster analysis discussed above agrees with the outcome of factor analysis. The clusters and result of FA have enabled us to identify the principal sources of emission of pollutants into the atmosphere. Since, only two factors were extracted explaining 56.7% of the variance in the data set and displaying significant dimension in air quality, the result of factor analysis confirms the positive relationship between the air pollutants of Pearson's Correlation (Ebong and Mkpenie, 2016).

The result presented above and displayed in Table 14 shows the pathway of pollutant emission in Mpape as well as identifies the significant set of pollutants that are frequently emitted into the atmosphere.

Table 14. Factor Loadings of Air Quality in Mpape[a].

Air quality parameters	**Factor loadings**	
	F_1	**F_2**
SO_2	0.815	0.129
CO_2	0.775	0.092
NO_2	0.719	0.290
PM_{10}	0.672	-0.108
NH_3	-0.237	0.809
H_2S	0.188	0.697
$PM_{2.5}$	0.365	0.570
Eigenvalues	**2.46**	**1.51**
% variance	**35.11**	**21.55**
Cumulative percentage	**35.11**	**56.65**

[a] the underlined coefficients are considered significant

4. 24. Temporal analysis of traffic volumes in across selected locations

The total traffic volume distribution shown in Table 15 and Figure 4 showed that the number of vehicles counted varies by the time of the day and across locations. It showed that in Angwan Powa, 4284 vehicles were enumerated with more of the vehicles counted or encountered in the morning hours followed by the evening hour with total number of vehicles of 1776 and 1626 respectively. ANOVA results showed that in Angwan Powa, there was significant temporal variation in vehicular flow ($F = 25.187$, $p<0.05$). This supports the earlier results which identifies morning and evening as peak hours or periods characterized by increased vehicular movement. In the morning, people rush for work, school, market and other places of engagement and in the evening, they retire back home. This makes the two time of the day to witnessed accelerated number of vehicles which increase traffic related situations. In Angwan Gwari, a total of 1994 vehicles were countered throughout the duration of the study with morning and evening accounting for 782 (39.2%) and 720 (36.1%) of the vehicles respectively. It simply means that more vehicles ply Angwan Powa than Angwan Gwari, but identifies morning and evening as periods with high vehicular movements in the area. ANOVA results showed that in Angwan Gwari, there was no significant temporal variation in vehicular flow ($F = 2.742$, $p>0.05$).

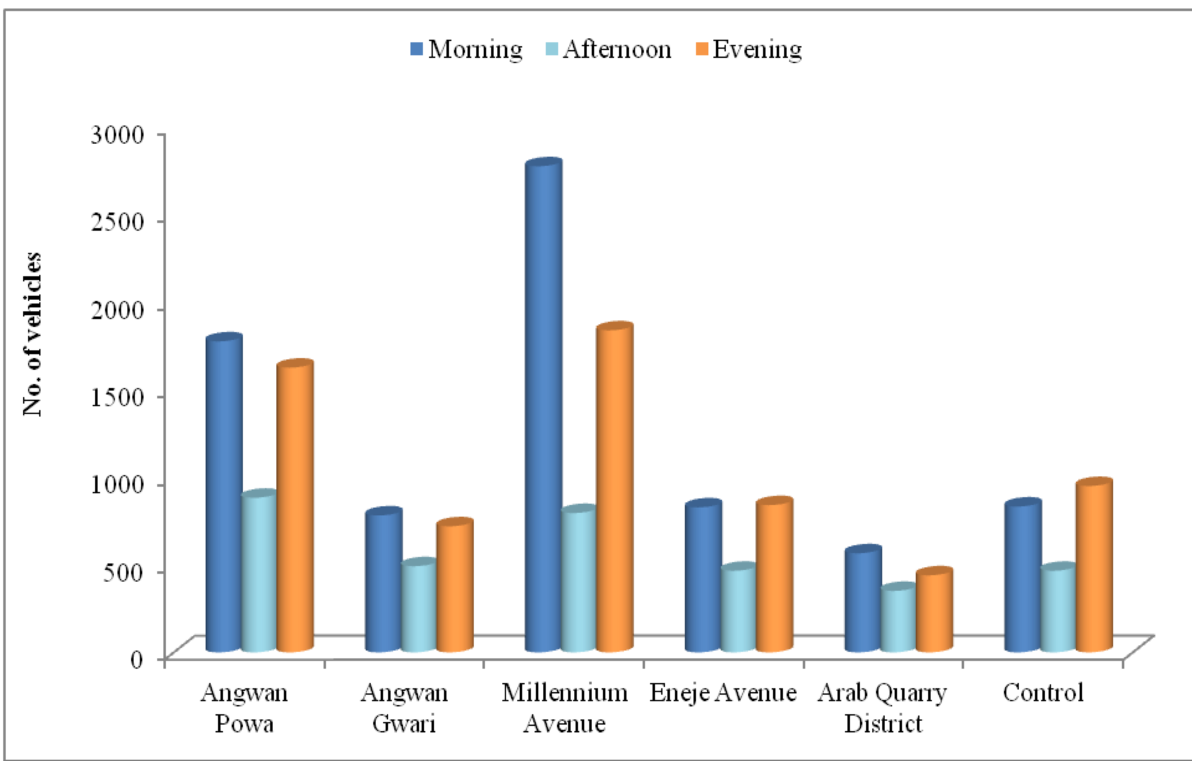


Figure 4. Temporal pattern of vehicular traffic

In comparison with the number of vehicles enumerated in Angwan Powa, there was 26.3% increase in the vehicular movement in Millennium Avenue with a total of 5411. The area recorded high number of vehicles in the morning followed by evening with values of 2776 and

1839 respectively. ANOVA results showed that in Millennium Avenue, there was a significant temporal variation in vehicular flow ($F = 30.00$, $p<0.05$). The increase number of vehicles could be attributed to the busy nature of the area and its proximity to social, economic and residential centres. In Eneje Avenue, 2135 vehicles were enumerated during the survey with high vehicular movement noticed in the evening followed by morning with volumes of 841 and 828 respectively. ANOVA results showed that in Eneje Avenue, there was a significant temporal variation in vehicular flow ($F = 10.804$, $p<0.05$).

On like in the other locations, high number of vehicles is found in the evening because it is the period a good number of residents in the area retire home. Eneje Avenue accounts for more vehicles than Angwan Gwari and this simply means that Eneje Avenue is busier and connects several places. In Arab Quarry District, a total of 1357 vehicles were counted with the morning period recording the highest vehicles followed by evening of 566 and 440 respectively. ANOVA results showed that in Arab Quarry District, vehicular flow varied significantly with time of the day ($F = 6.853$, $p<0.05$). In Katampe Estate being the control site, a total of 2249 vehicles were counted with evening recording the highest number of traffic flow followed by morning period with traffic volumes of 950 and 833 respectively.

Also, ANOVA results showed that in the control site, vehicular flow varied significantly with time of the day ($F = 10.090$, $p<0.05$). It could be seen that the traffic situation in Eneje Avenue and Katampe Estate (control) have similar pattern with high vehicular movement noticed or recorded in the evening. The traffic flow shows a discernible pattern which is attributed to land uses differentials resulting in the movement of people to the area. It shows that Millennium Avenue recorded the highest number of vehicles followed by Angwan Powa and then the control, while Angwan Gwari experienced the lowest vehicular movement. The order of vehicular flow in the selected locations is: Millennium Avenue> Angwan Powa> Katampe Estate (control)> Eneje Avenue>Arab Quarry District> Angwan Gwari. The results in Table 15 identify Millennium Avenue, Angwan Powa and Katampe Estate as locations with high vehicular traffic. The pattern of traffic flow reported in this study pays credence to the study of Etim (2016) in Ibadan Metropolis where morning and evening were identified as periods with high vehicular flow across 8 locations. It is therefore apparent from the results that the concentration of ambient air pollutants mostly CO_2 will be associated with the high vehicular volume during morning and evening peak hours.

Table 15. Temporal variation in the number of vehicles in Mpape.

Time of the day	Total number	Average
	Angwan Powa	
Morning	1776	1271
Afternoon	883	63
Evening	1626	116
	Angwan Gwari	
Morning	782	65

Afternoon	492	35
Evening	720	51
Millennium Avenue		
Morning	2776	198
Afternoon	796	57
Evening	1839	131
Eneje Avenue		
Morning	828	59
Afternoon	466	33
Evening	841	60
Arab Quarry District		
Morning	566	40
Afternoon	351	25
Evening	440	31
Control		
Morning	833	60
Afternoon	466	33
Evening	950	68

Source: Researcher's fieldwork, 2017

4. 25. Test of Hypotheses

The two hypotheses are tested using One-Way Analysis of Variance (ANOVA) and Pearson's correlation.

4. 25. 1. Hypothesis One

H_0: Ambient air pollutants do not vary significantly among the six selected locations.

H_1: Ambient air pollutants vary significantly among the six selected locations.

The first hypothesis was tested using ANOVA. The results obtained are shown in Table 16 and they showed that the concentrations of varied significantly among the six selected locations. This is because the probability values for the respective pollutants are lower than 5%

significance level. Since the probability values are lower than 5% significance level, the null hypothesis is rejected, while the alternative hypothesis is accepted which further implies that the concentrations of ambient air pollutants (particularly CO_2, SO_2, NO_2, NH_3, $PM_{2.5}$, and PM_{10}) varied significantly among the six selected locations.

This is expected considering the differences in land uses and human activities in the respective locations. Since human activities and their extent and intensity vary across the selected locations, it has implications on the quantities of pollutants released into the atmosphere. However, a look at the result in Table 16 showed that the concentration of H_2S did not vary significantly among the selected locations ($F = 1.445$, $p>0.05$). This is so as the probability value of 0.209 is greater than 0.05 (5%) significance level. It therefore means that irrespective of the varied locations and existing human activities, the emission level of H_2S happen to be the same. In general, the result in Table 4.16 simply indicates that ambient air pollutants vary significantly among the six selected locations. This is because 85.7% of the ambient pollutants are significant.

Table 16. ANOVA results of the variation in ambient pollutants.

Air pollutants	Source of variation	Sum of Squares	df	Mean Square	F	Sig.
CO_2	Between Groups	7.289	5	1.458	19.350*	.000
	Within Groups	18.532	246	.075		
	Total	25.821	251			
SO_2	Between Groups	3.647	5	.729	20.840*	.000
	Within Groups	8.611	246	.035		
	Total	12.258	251			
NO_2	Between Groups	3.757	5	.751	30.540*	.000
	Within Groups	6.052	246	.025		
	Total	9.809	251			
NH_3	Between Groups	.013	5	.003	1.445	.209
	Within Groups	.446	246	.002		
	Total	.459	251			
$PM_{2.5}$	Between Groups	.298	5	.060	10.758*	.000
	Within Groups	1.363	246	.006		
	Total	1.661	251			

PM_{10}	Between Groups	.272	5	.054	9.880*	.000
	Within Groups	1.353	246	.006		
	Total	1.625	251			
H_2S	Between Groups	.182	5	.036	3.798*	.002
	Within Groups	2.357	246	.010		
	Total	2.538	251			

*Significant at the 0.01 level (2-tailed)

4. 25. 2. Hypothesis Two

H_0: Vehicular volume is not positively and significantly related to SO_2 and CO_2.

H_1: Vehicular volume is positively and significantly related to SO_2 and CO_2.

The second hypothesis was tested using Pearson's correlation. This statistical tool was used to find out the association between vehicular volume and the level of SO_2 and CO_2**.** This was achieved by aggregating vehicular movement, SO_2 and CO_2 across the six locations. The result in Table 4.18 showed that there were positive and significant associations between vehicular volume and CO_2 (r = 0. 313, p<0.05) and also between vehicular volume and SO_2 (r = 0.349, p<0.05). This is so because the probability values of 0.000 are lower than 5% (0.05) significance level, which means that the null hypothesis is rejected and the alternative hypothesis accepted.

It therefore means that vehicular volume is positively related to SO_2 and CO_2; implying increase in the level of SO_2 and CO_2 with the increase in the volume of vehicle or vehicular flow. The results obtained are consistent with the finding of Etim (2016) who also reported a positive 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.

Table 17. Pearson's correlation coefficient for CO, SO2 and vehicular volume.

Pollutants	**Number of vehicle**	
	r-values	**P-values**
CO_2	0.313*	0.000
SO_2	0.349*	0.000

* Correlation is significant at the 0.01 level (2-tailed)

5. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary of Research Findings

The study assessed air quality along designated area of interest in the Mpape Area of the FCT, Nigeria. Particularly, it examined air quality variation in the heavily built areas, areas around the roads, areas around industrial areas, and control sites areas in Mpape. The experimental research was employed and air quality variables (NH_3, NO_2, SO_2, H_2S CO_2 and PM_{10} and $_{25}$) was 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 analysed using averages, ANOVA, Pearson's correlation, cluster analysis and Factor analysis.

Table 18. Permissible Limits of Parameters.

Parameters	FEPA Permissible Limit	WHO Permissible Limit
CO_2	10 ppm	90 ppm/15 Minutes
SO_2	0.10 ppm	20 ppm/24 Hrs
NO_2	0.06 ppm	200 ppm/1 Hr
NH_3	0.30 ppm	____
$PM_{2.5}$	0.25 μg/m^3	WHO limit of 20 μg/m^3 for 24 hrs mean concentration
PM_{10}	0.25 μg/m^3	WHO limit of 24 hrs mean concentration of 50 μg/m^3

The summary of major findings from the results obtained is given as follows:

1) The concentration of CO_2 in this study is within the 10ppm recommended by FEPA. It is also within WHO 90 ppm limit for 15 minutes. Across the studied locations, highest concentration of carbon monoxide (CO_2) was recorded in Arab Quarry District followed by Millennium Avenue and with mean values of 1.76 and 1.50 ppm respectively, while in the lowest concentration of CO_2 was recorded in the control with a mean value of 1.18ppm.
2) The range of SO_2 in the present study is above FEPA recommended level of 0.10 ppm. The range is also within WHO 24 hrs allowable limit of 20 ppm.
3) The concentration of nitrogen dioxide (NO_2) varied significantly among the different locations ($F = 30.540$, $p<0.05$). In all NO_2 ranged from 0.15 to 0.55 ppm which is above the limit of 0.06ppm recommended by FEPA (Ebong and Mkpenie, 2016). The range is however within WHO 1hr mean allowable limit of 200 ppm.
4) The concentration of ammonia (N_{H3}) in the present study ranged from 0.04 to 0.06 ppm. This range is in agreement with the value of 0.07 to 0.13 ppm reported by Magaji and Hassan (2015). Across the studied locations, high content of N_{H3} was recorded in

Angwan Powa and Angwan Gwari with a mean value of 0.06 ppm respectively, while in the lowest concentration was recorded in Eneje Avenue with a mean value of 0.04 ppm (Table 2 and Figure 1). NH_3 range of 0.04 to 0.06ppm is within the limit of 0.30 ppm recommended by FEPA.

5) In addition to this, it shows that, the contents of atmospheric particulate matters (PM), $PM_{2.5}$ and PM_{10} also varied among the selected locations. For $PM_{2.5}$, it value ranged from 0.18 to 0.27 μg/m^3 which is slightly above the threshold of 0.25 μg/m^3 recommended by FEPA, mostly for ambient air quality in Angwan Gwari and Millennium Avenue areas. The range of $PM_{2.5}$ is within WHO limit of 20 μg/m^3 for 24hrs mean concentration (WHO, 2006). Result of ANOVA showed that the concentration of $PM_{2.5}$ varied significantly among the various locations ($F = 10.758$ $p<0.05$). Furthermore, for PM_{10}, it value ranged from 0.16 to 0.26 μg/m^3 which is also slightly above the threshold of 0.25μg/m^3 recommended by FEPA (Magaji and Hassan, 2015), mostly in Arab Quarry District and to some extent Angwan Gwari/ Millennium Avenue. These areas have increased concentrations of PM_{10}. The range of PM_{10} reported in the present study is within WHO limit of 24 hrs mean concentration of 50 μg/m^3. Also, result of ANOVA showed that the concentration of PM_{10} varied significantly among the various locations ($F = 9.880$ $p<0.05$). The result therefore means that Arab Quarry District and Angwan Gwari/ Millennium Avenue have high PM concentrations. This is expected as these land uses experience high fuel combustion from automobiles, power plants, commercial and industrial activities resulting in the release of particular matter (Han, 2010).
6) Cluster analysis classifies the principal pollutants of Mpape into two homogenous groups (SO_2 and PM, and NO_2) and also identifies anthropogenic activities (principally the combustion of fuel) as the primary source of emission of these groups of gases or pollutants into the atmosphere.
7) FA identified anthropogenic activities as the main sources of pollution of PM, NO_2, SO_2, NO and CO in Mpape environs.
8) Positive association is observed between car, bus truck and level of SO_2 and CO as well as a negative association between bike and level of SO_2 and CO.

Conclusions

Pockets of high and low areas within the study area, but however the concentration is high in the core where there is high level of anthropogenic activities. 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 Mpape and its 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 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 Mpape are not safe from traffic related pollution threats.

Recommendations

Based on the research findings and the conclusion arrived at; it can be concluded that the level of air pollutant varies along the Mpape area. And that the volume of pollutant emitted, is positively related to the level of air pollutant, and that the volume of traffic also influences the level of pollution positively. Based on the research findings and conclusions arrived at, the following are suggested to minimize the Concentration level of pollutants in Mpape and its environs.

1) 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;
2) Government should assist in the development of these new technologies that will enhance engine efficiency and reduce fuel consumption through the funding of research.
3) 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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