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Spatio-Temporal Variations in Urban Vehicular Emissions in Uyo City, Akwa Ibom State, Nigeria

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Abstract

The increasing volume of road traffic and congestion strongly impact on air quality in most urban areas of the developing countries. This paper therefore investigates pollution from automobiles during traffic peak periods at intersections on some selected roads in Uyo, Nigeria. It estimates the level of some selected air pollutants which are largely products of internal combustion in motor vehicle engines, namely: Nitrogen dioxide (NO2), Carbon monoxide (CO), Sulphur dioxide (SO2), and Hydrogen sulphide (H2S), in six sample locations. Monitoring of ambient hourly concentration of NO2, CO, SO2 and H2S, took place at six major intersections in Uyo during morning and evening (peak traffic hours) and afternoon (off-peak hours), hence variations in concentration of these pollutants was determined. Emissions concentration for CO, was found to be higher during the peak periods due to traffic congestion and intersection, where long waiting time for vehicles were observed and however exceeded the Federal Ministry of Environment limits / Standards. Also, the concentration of SO_2 was alarmingly high, especially in location C. Levels of Nitrogen oxides (NO_2) and Hydrogen sulphide ($H2_S$) measured, varied in time and space and was also above the recommended municipal and international standards in all the six locations during the peak traffic period. This finding thus has implications for public health in the region under study as such calls for the need to control emissions of these obnoxious air pollutants in the city.

Keywords: air pollution, carbon monoxide, emission concentration, vehicular emissions, traffic congestion

1. Introduction

Air pollution at all levels is matter of concern the world over. Studies on the effect of air pollution have revealed high potential of suspended particulate matter and gaseous pollutants to cause health challenges on people, ranging from Respiratory infections, and cardiovascular diseases to cardio pulmonary mortality (Sobrata, Srimanta & Raj, 2010). For example NO_2 is responsible for immune system impairment, exacerbation of asthma and chronic respiratory diseases: reduced lung function and cardiovascular disease (Schwela, 2000). Semi permanent business operators are mostly at risk of the health challenges associated with these vehicular traffic based pollution. A prevalence of chronic bronchitis and asthma in street cleaners exposed to vehicle pollutants in concentrations higher than WHO recommended guidelines, thus leading to significant increase in respiratory problems (Rachou, 1995).

Modernization, urbanization and increased vehicular use have significantly contributed to air pollution around the world. The use of motor vehicles has increased enormously all around the world since the 1940's. On-road motor vehicles have dominated the markets for passenger and freight transport both in developed and developing countries. Thus, it is estimated that between the years 1950 and 1990, the world car population rose ten-fold, from around 40 million to 400 million (Lixin & Yang, 2003). Although a mixed mode of transport is encouraged, motorized road vehicles are likely to keep their overwhelming dominance of the transport sector in the foreseeable future. One consequence of this has been a growth in the importance of motor vehicles as a source of atmospheric pollution.

The tremendous increase in the mobilization of human society has resulted in phenomenal rise in vehicular traffic on the major roadways. The vehicles discharge an appreciable amount of exhaust emission which consists of poisonous gases like carbon monoxide (CO), sulphur dioxide ($SO_{X)}$), nitrous oxides ($NO_{X)}$), volatile organic compounds (VOCs) to mention but a few. The emissions from the vehicles cause adverse effects on plants, human beings, animals, soil and other environmental constituents. Excessive emissions are released by the vehicles if they are not well maintained and are not properly driven. This results in increase in fuel consumption, decrease in mileage, increased expense, wastage of precious fuel, and also the pollution of the environment.

Emission from vehicles is a deadly mixture of poisonous gases and particulates which affects the human beings, vegetation, agriculture and buildings. The problem is of much concern in Nigeria with increasing vehicular population and heavy traffic congestion on roads. The problem of vehicular air pollution is far more serious than one can imagine, and therefore, the assessment of the impact of this pollution on urban environment becomes imperative. Vehicles traveling in major metropolitan areas are estimated to account for 80% of all carbon monoxide, 50% of hydrocarbons, 30-40% of oxides of nitrogen and almost 100% of the lead present as air pollutant. Vehicular combustion sources include automobiles, trucks, buses, rail road locomotives, air craft and marine vessels. Pollutants from these sources contain both toxic compounds and organic materials that are not in themselves objectionable but which react in the atmosphere to form smog which is highly objectionable (Khitoliya, 2007).

The amount of pollutant emissions from motor vehicles are dependent on the vehicle population, age of the vehicles, the technologies used for emission control for in-use vehicles (i.e. the resultant composite emission factors of the fleet), and the mileage driven by each category of vehicle. This may vary a great deal from region to region, and from city to city. Owing to their rapidly increasing numbers and limited use of emission control technologies, motor vehicles are emerging as the largest source of urban air pollution in the developing world. In developing countries, non-attainment of urban air quality standards is still largely related to motor vehicle emissions. Although great efforts have been made to control these emissions, the continuously growing vehicle population and the growth in mileage driven by each vehicle have somewhat upset this benefits. Air pollution caused mainly by motor vehicle emissions is a common problem for large cities around the world.

Indeed, motor vehicles produce more air pollution than any other single human activity (WRI, 1992). Nearly 50% of global CO, hydrocarbon and NOx emissions from fossil fuel combustion come from gasoline and diesel-powered engines. In the city centres, especially on highly congested streets, traffic can be responsible for as much as 90-95% of the ambient CO levels, 80-90% of the NOx and hydrocarbons, and a large portion of the particulates, posing a significant threat to human health and natural resources (Savile, 1993).

Motor vehicle-related air pollutants are unevenly distributed in the urban areas and vary also with time period. Most of the direct emissions are concentrated along highways and major roads inside cities. This is especially the case where streets are surrounded by tall buildings on both sides (normally referred to as 'street canyons'). It also appears to be more during traffic peak hours when so many vehicles are on the road causing traffic congestion and increasing the length of steaming of stationary vehicles.

Air pollutants from road traffic such as CO, NOx, VOCs and Suspended Particulate Matter (SPM) will be transported virtually throughout the whole urban area, causing region-wide air quality deterioration. Furthermore, VOCs and NOx, in the atmosphere can form photochemical smog which when there is sufficient solar radiation, results in severe secondary air pollution.

Since the 1970s, there have been many studies on the dispersion and distribution of traffic-related air pollution. It was also reported that some chemicals found in polluted air could cause cancer, birth effects, brain and nerve damage, and long-term injury of the lungs and breathing passages in certain circumstances. The concentration of such chemicals beyond limits, and exposure over a certain period is extremely dangerous and can cause severe injury or even death (Weli, 2012).

2. The Problem

Hydrocarbon (HC) emissions can be influenced by ambient temperature which varies with the period of the day and season. Very low ambient temperatures (e.g., below 20 OF) can influence emissions at ignition and cause the catalytic converters, in vehicles that have it, to cool during short stops (Utang & Peterside, 2011). Very high ambient temperatures can also have a secondary influence on exhaust emissions because engine load is increased by air conditioner use. Although CO concentrations are generally high in areas with heavy traffic congestion, the emissions are substantially greater in cold weather because cars need more fuel to start at cold temperatures and some emission control devices such as oxygen sensors and catalytic converters operate less efficiently when they are cold (Tubal et al., 2002).

The city of Uyo, the capital/Headquarters of Akwa Ibom State, Nigeria is a rapidly growing city and state capitals in Nigeria. It has witnessed significant growth in urban population and vehicular in-flow in recent times. The rising influx/population of second-handed motor vehicles into the city has increased traffic congestion and prolonged length of stay in traffic. This has in turn increased the amount of emissions from these vehicles and consequent air pollution. A cursory assessment of air quality in Uyo city would reveal high level air pollution resulting mostly from emissions from incomplete combustion from aged vehicles operated within the city.

Little documentary evidence exists on the impact of these emissions on the micro-climate of the city. There is also dearth of data on the variations in the emissions from one part of the city to another and from one time period to another. Thus, the following fundamental questions arise: What is the level of vehicular emissions within the city of Uyo? Does the emission vary between time and location or is it uniform? At which part of the city is vehicular emission more?

3. Brief Description of the Study Area

Uyo city, the capital of Akwa Ibom state, lies between latitude $4^{0}59^{I}$ and $5^{0}04^{I}$N and longitude $7^{0}53^{I}$ and $8^{0}00^{I}$E. It is situated on an elevation of about 60.96 meters (2090ft) above sea (Njungbwen, 2011) and located at the centre of the Akwa Ibom state. The city lies within the tropical rain forest Region, and enjoys the tropical wet and dry climate with two distinctive seasons (dry and wet). The location of Akwa Ibom just north of the Equator and within the humid tropics and its proximity to the sea makes the state generally humid. On the basis of its geographical location the climate of Uyo, Akwa Ibom State can be described as a tropical rainy type which experiences abundant rainfall with very high temperature. The mean annual temperature of the state lies between 26°C and 29°C and average sunshine cumulates to 1,450 hours per year, while mean annual rainfall ranges from 2.000mm to 3.000 mm, depending on the area. Naturally, maximum humidity is recorded in July while the minimum occurs in January. Thick cloud cumulonimbus type is commonly experienced in the months of March to November. Evaporation is high with annual values that range from 1500 mm to 1800 mm. Two more or less distinct seasons are experienced in Uyo city, Dry & Wet season. The dry season occurs between November and march while the rainy season is between April and October, with occurrence of a short dry spell in august, known as ‘August Break.’

The city has a population of 309,573 persons (NPC report) and a land mass of 95km^2, 36.75sq.ml (Essien & Okpo, 2012). There has been a corresponding increase in industrial activities in Uyo. Major industries in the city include small agricultural processing industries, plastic manufacturing industries, confectioneries, pharmaceutical and surgical companies etc. On the other hand, there has been an increase in the number of vehicles for personal and commercial use in the town. Thus, traffic emission is expected to be a major source of air pollution in the town.

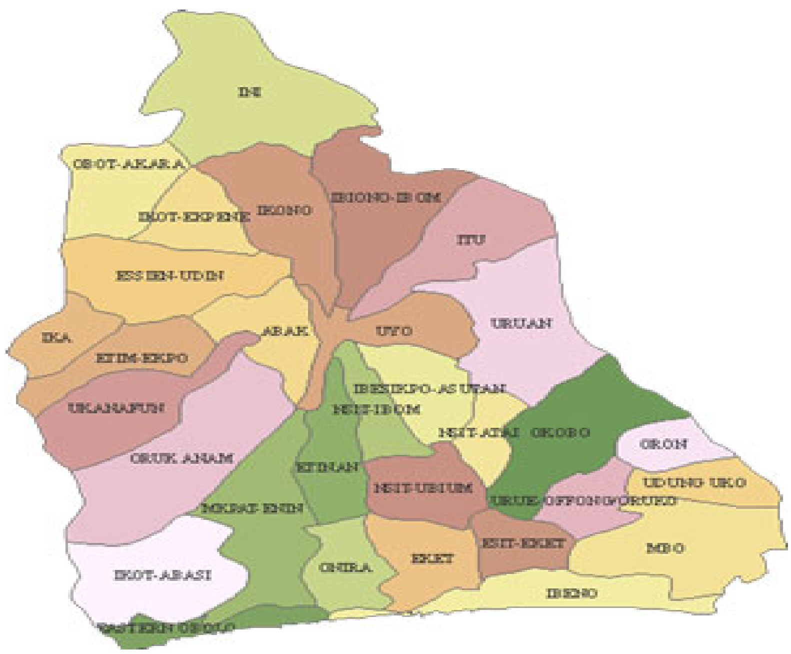

Figure 1. Administrative map of Akwa Ibom State showing Uyo

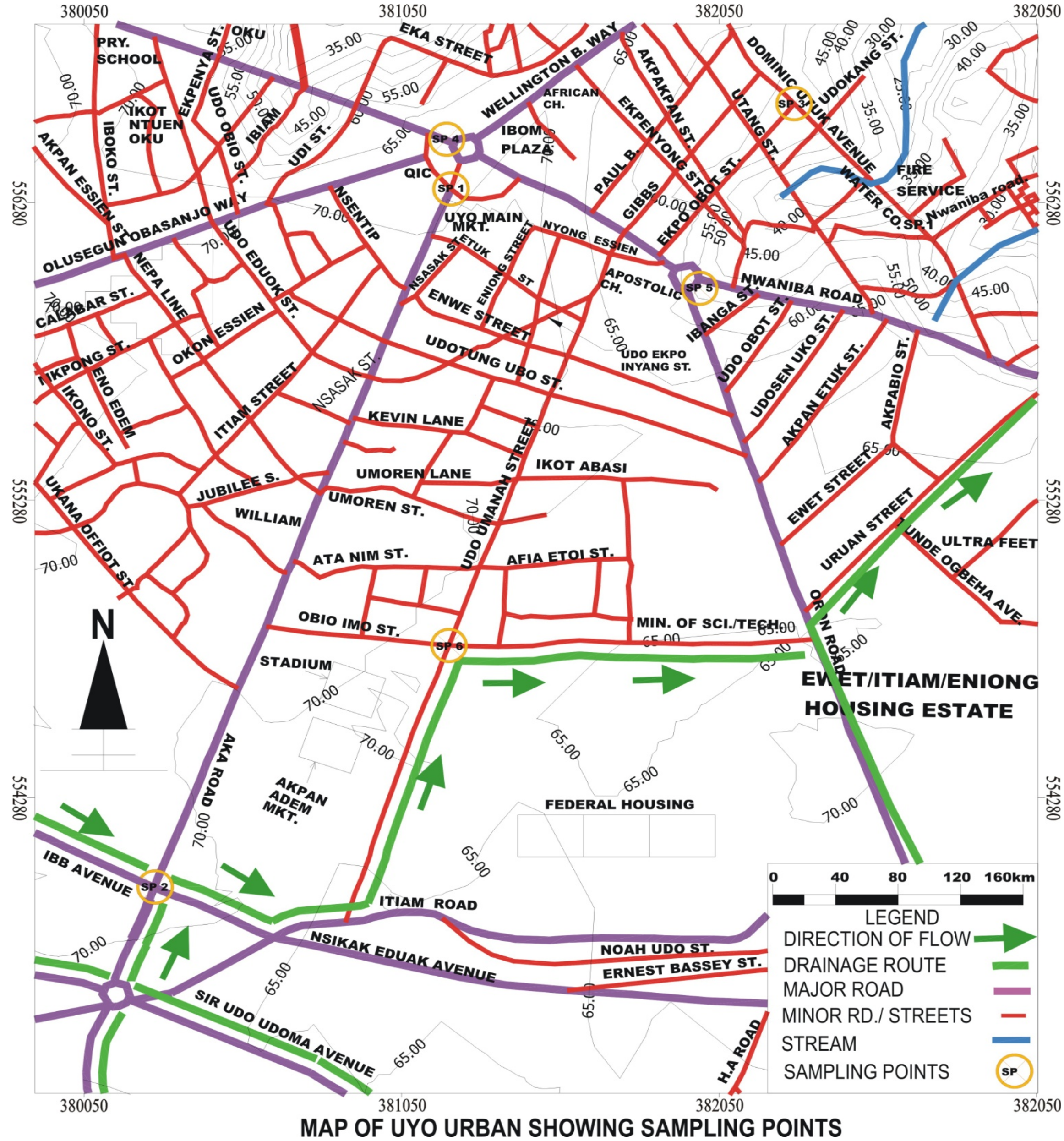

Figure 2. Map of Uyo Metropolis showing the sample points

4. Methodology

The study measured air pollutant concentrations and levels from automobiles at road intersections with high volume and frequent traffic congestion at some selected roads, and compared the values obtained with periods where the traffic is less congested regarded as off-peak periods.

Also, the assessment of all the sampling points was carried out in association with the atmospheric conditions of these points. The study was based on the propositions that there is variation in the concentration of vehicular emission during peak and off-peak periods. And that surface layer meteorological condition greatly determines the concentration of each air pollutant which varies in space and time.

A sample of six locations noted for heavy traffic congestion in the city was selected as the focus of this study. These six (6) locations were randomly selected from a pool of identified 26 locations/junctions with highly traffic density in Uyo metropolis. The sampled locations include; Aka road by Plaza, Aka road by IBB avenue, Ekpo obot street by Dominic Utuk avenue , Ikot Ekpene road by Plaza, Oron road by Nwanaiba road, Udo-umana street by Obio-Imo street.

The measurement of air pollutants from the selected sites were carried out three (3) times per day for the duration of five working days of the week Viz; 7:30am-9:30am (Morning peak hours). 1:00pm-3:00pm (Off-peak hours) and 5:00pm-7:00pm (Evening peak hours) respectively.

The air pollutants measured are: Nitrogen oxide (NOx), Sulphur dioxide (SO_2), Carbon monoxide (CO) and Nitrogen dioxide (H_2S). These were measured with the Testo 350XL Emission Analyzer.

Also, the climatic elements sampled were; wind velocity(ms^{-1}), ambient temperature and differential pressure also measured with the same instrument, while relative humidity data was derived using the kestrel 4000 weather tracker. The co-ordinates of the sampling points within the period were recorded with a hand-held Geographic Positioning Systems (GPS).

The data generated from the field work were presented both in graphs and in tables. Graphs were used as exploratory tool of analysis to explore and depict the concentration of the air pollutants at different locations and periods.

Simple descriptive statistics was also used to describe the nature of the data generated, while the analysis of variance (ANOVA) was used to validate the research assumptions.

Table 1. Showing sample routes, sampling points and coordinates

S/N	SAMPLING ROUTES	SAMPLING POINTS	Coordinates
1	Aka Road by Plaza	A	$05^0$01'59.6" $007^0$55'40.5"
2	Aka Road by IBB Avenue	B	$05^0$00'48.9" $007^0$55'09.4"
3	Ekpo Obot Street by Dominic Utuk Avenue	C	$05^0$00'36.2" $007^0$51'41.0"
4	Ikot Ekpene Road by Plaza	D	$05^0$02'06.0" $007^0$55'42.1"
5	Oron Road by Nwaniba Road	E	$05^0$00'03.0" $007^0$56'56.6"
6	Udo Umana Street by Obio imo Street	F	$05^0$01'14.5" $007^0$55'39.3"

Source: Authors' Filed Work 2013

Table 2. Average emissions estimates at Peak and Off-peak hours at six locations

LOCATION	AIR QUALITY PARAMETERS				METEOROLOGY		
	Morning Peak						
	NO_2(ppm)	SO_2(ppm)	CO(ppm)	H_2S(ppm)	Wind Speed(m/s)	Air Temp. (^oC)	R/H (%)
A	0.031	0.047	7.0	0.047	1.16	31.7	42
B	0.039	0.025	6.8	0.062	1.13	33.5	48
C	0.053	0.021	5.0	0.014	1.57	32.1	51
D	0.045	0.049	7.3	0.025	1.24	35.2	46
E	0.032	0.064	10.04	0.053	1.11	31.9	29.7
F	0.031	0.032	6.2	0.033	1.15	31.4	31
			EVENING PEAK				
A	0.082	0.051	14.5	0.064	1.25	30.1	31
B	0.051	0.048	13.4	0.031	1.12	32.2	45
C	0.037	0.023	8.8	0.048	1.42	31.4	43
D	0.067	0.034	16.1	0.057	1.21	35.1	28.2
E	0.042	0.071	17.6	0.066	1.09	35.3	50
F	0.046	0.046	8.5	0.037	1.17	31.2	42
			OFF PEAK				
A	0.018	0.059	2.6	0.031	1.14	36.8	67
B	0.029	0.014	4.2	0.022	1.11	33.4	62
C	0.016	0.027	2.8	0.006	1.16	35.7	63
D	0.027	0.021	3.7	0.009	1.18	35.4	74
E	0.042	0.043	9.2	0.046	1.12	35.9	71
F	0.049	0.018	4.1	0.021	1.24	36.2	61

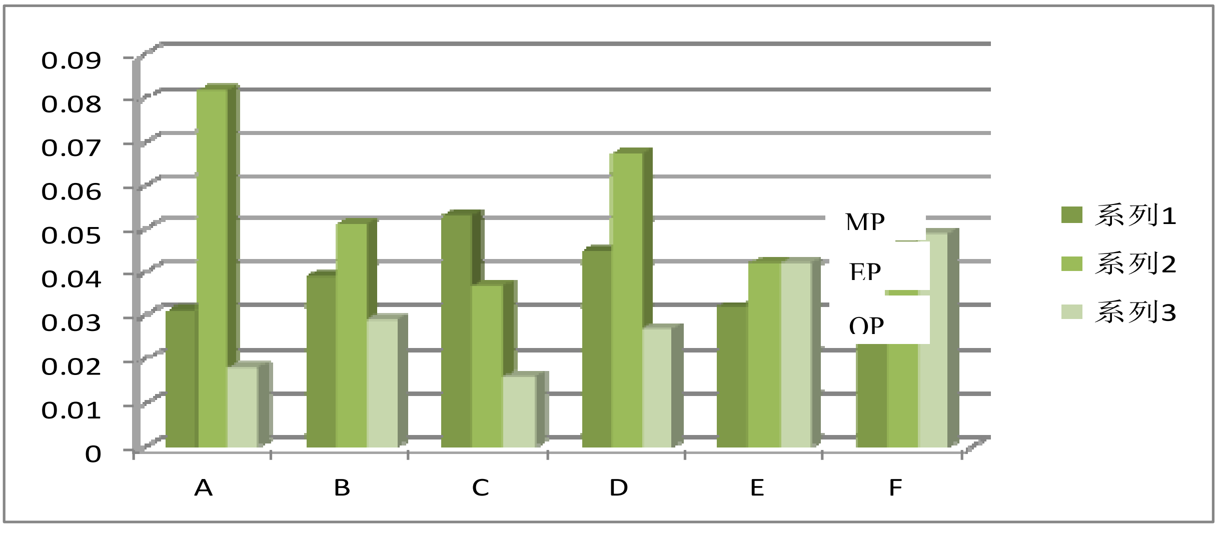

Figure 3. Average NO_2 concentration at different locations and periods

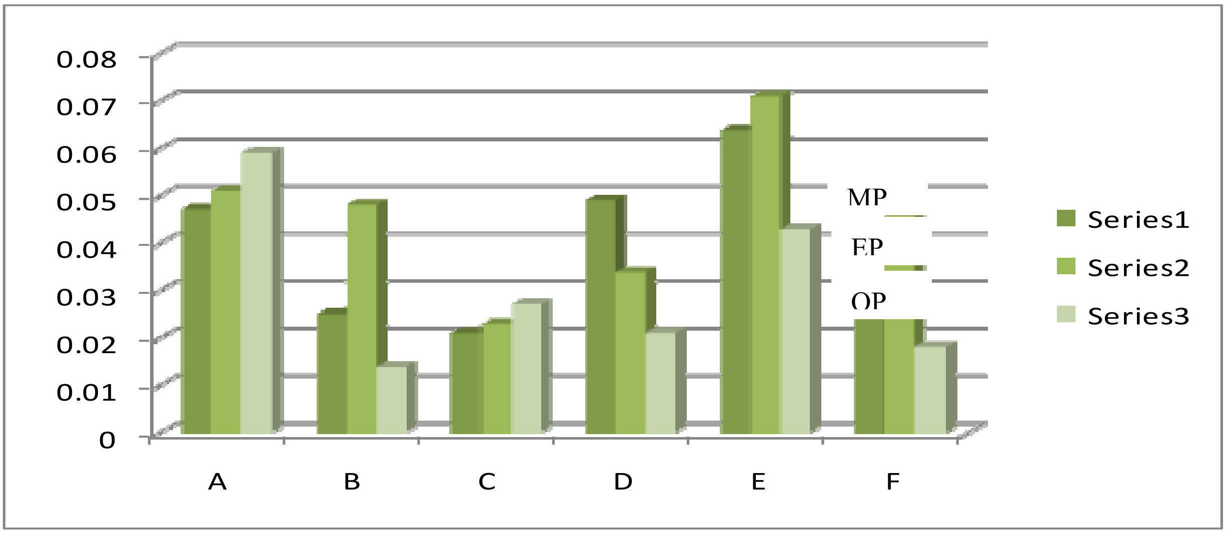

Figure 4. Average SO_2 concentration at different locations and periods

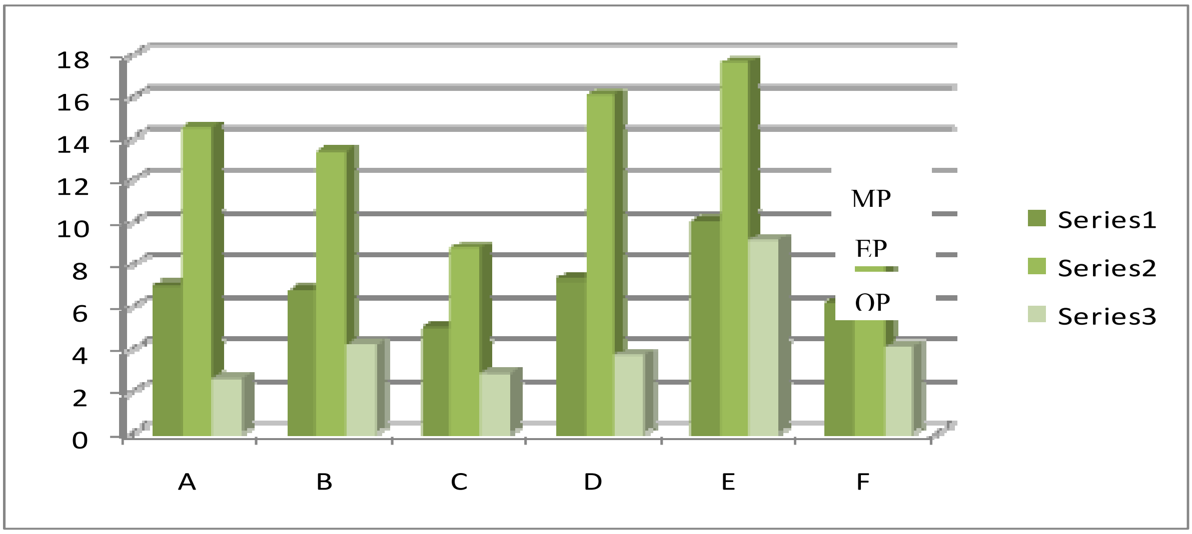

Figure 5. Average CO concentration at different locations and periods

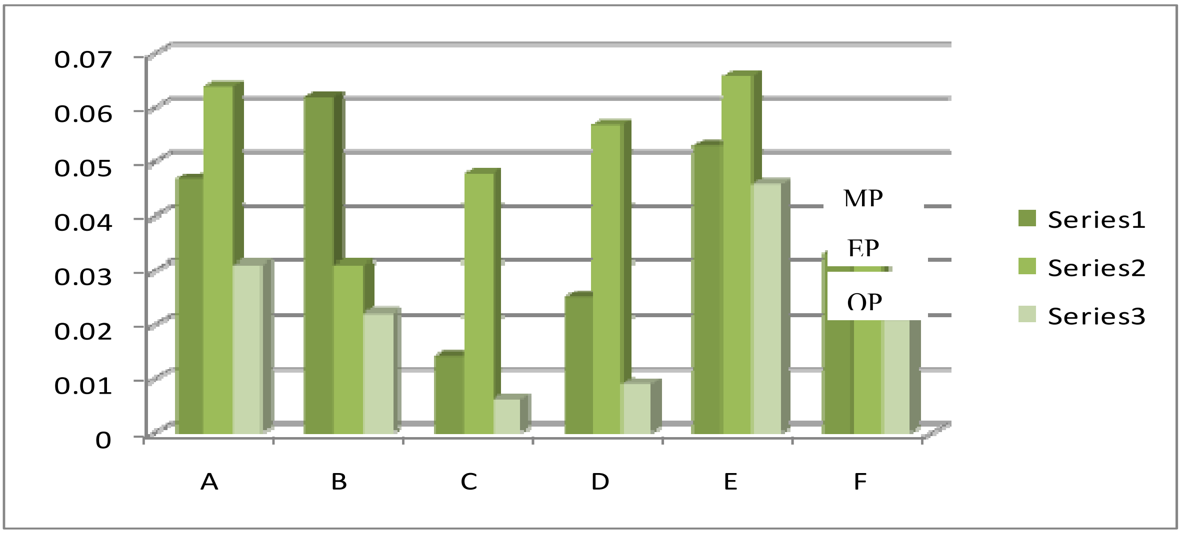

Figure 6. Average H_2S concentration at different locations and periods

Table 3. ANOVA table of variation in air quality between locations and peak and off peak periods

Comparison of Carbon Monoxide Values					
Source of variations	Sum of squares	Degree of freedom	Mean sum of squares	F Cal	Critical F
Between Sum of squares	239.98	2	119.99		
Within Sum of Squares	114.38	15	7.63	15.73	
Total Sum of Squares	354.36	17	20.84		
	Comparison of Sulphur dioxide				
BSS	0.0006	2	0.0003		
WSS	0.0043	15	0.00030	1.00	
TSS	0.0049	17	0.00028		
	Comparison of Hydrogen Sulphide values				3.68
BSS	0.0024	2	0.0012		
WSS	0.0038	15	0.00025	4.8	
TSS	0.0062	17	0.00036		
	Comparison of Nitrogen oxide values				
BSS	0.0022	2	0.0012		
WSS	0.0023	15	0.0002	6.0	
TSS	0.0045	17	0.00026		

5. Results and Discussion

As shown in table 1, the results of measurements of the concentration of CO over the sampling period shows that the highest concentration of CO was detected at Sp E, the least level of this pollutant were observed at Sp A and D. The concentration of CO was found in the range of 2.6-17.6ppm. At all locations, the results were within the limit of the international air quality standard (USEPA), while at some other locations they were above the limit of the Nigerian air quality standard.

The locations with relatively high value of CO are known to have heavy traffic at the peak period, and this could have accounted for the results obtained. The SO_2 concentration in all the sampling points was in the range of 0.014ppm-0.071ppm, the highest values was found at Sp E. The reason for the high value could be due to traffic congestion and road intersection, where long waiting time for vehicles is observed. Several works in literature

(Mage, et'al 1996, Ravindra, et'al, 2005, Utang & Perside, 2012) reported a corresponding high value of air pollutants in peak periods. Thus, our finding is in agreement that high concentration of air pollutants as associated with heavy traffic, especially areas with heavy traffic congestions. High level of emissions from the vehicles is associated mainly with the age of the vehicles. Most vehicles in use in city have average of about 12 years of age with incomplete combustion.

The concentration of NO_2 was highest at Sp A with 0.082 at evening peak and 0.016 at Sp C during (off peak), hence the concentration of NO_2 in all the stations and at peaks and off peaks was within the boundary of both USEPA and Nigerian ambient air quality standard.

Comparing the values Of H_2S, the highest values was seen at Sp E, A and B, and this was during the peak periods. This of course, can be attributed to traffic congestion and vehicle intersection at the points where long waiting time for vehicles was observed. Moreover, it was observed that there exist significant variations in all the air pollutant parameters during the days of emission inventory. This finding corroborates with Utang and Peterside (2011) study of spatial variations in vehicular emissions in the city of Port Harcourt. They discovered that variation exist in observed pollutants parameters within the state and between time perioids. The reason for this variation could be attributed to variation in vehicle operation modes, local meteorological conditions and variation in motor characteristics

6. Recommendations

From the above report, the following recommendations are advanced to improve air quality in the city and for environmental protection:

(i) There is need to disperse traffic at road intersections, through the constructions of multiple freeways or overhead bridges. These will help to free traffic in the city and reduce emissions.

(ii) There is need for the government to adopt sustainable emission control technologies aimed at reducing emission of pollutants and enforce legislation on the maximum age of imported seconded vehicles in the country.

(iii) Government should also improve the condition of link roads/inner roads to reduce the number of vehicles at intersections will reduce the concentration of pollutants, if there is minimal traffic situation in a given area.

(iv) It also recommended that there should be formulation of inspection and maintenance system for all vehicles operating in the state. This could however help to reduce pollution loads generated by vehicles through proper periodical inspections and maintenance of vehicles.

7. Conclusion

There is high level of air pollution in the city of Uyo, Akwa Ibom State occasioned by high level of emission of air pollutants from vehicular traffic. High vehicular traffic at peak periods has the potential to cause air pollution especially depending on these factors; viz: age of vehicle, type of fuel used, the operation characteristics, meteorology and many more. Hence, the study showed that pollution is usually high at traffic intersections particularly at peak periods (morning and evenings) and that motor vehicle remains the formal source of urban air pollution. The implication of this is that residents of the city, especially road-side traders are highly exposed to health risk associated vehicular emissions in the city. This study created the awareness that vehicular traffic at peak periods has the potential to cause pollution especially depending on the operation characteristics, meteorology, age of the vehicle and the type of fuel used in the vehicle. Although this study was restricted to traffic intersection /points, the findings suggest that the entire city of Uyo is not safe from traffic related air pollution threats. Thus, it is therefore pertinent to stem future air pollution problems through concerted efforts such as implementation of legislation, Engineering and economic measures as recommended earlier.

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