Impacts of improved traffic control measures on air quality and noise level in Benin City, Nigeria

[1]Ukpebor, Justina Ebehirieme, [2]Omagamre, Eguono Wayne [1]Abayode, Bamidele, [1]Unuigbe, Charles Akhadelor, [1]Dibie, Edward Nduka and [*1]Ukpebor, Emmanuel Ehiabhi

[1] Air Pollution Research Group, Department of Chemistry, University of Benin, Benin City, Nigeria
[2] Department of Natural Sciences, University of Maryland Eastern Shore, Princess Anne, MD 21853, USA.

* **Corresponding Author Email:** ukpebehi@uniben.edu

Abstract

This study has assessed the outcome of implemented traffic control measures within Benin City, Nigeria on the levels of suspended particulate matter (SPM), carbon monoxide (CO) and noise level. A positive effect of the measures was observed with a 49.4% reduction in SPM concentrations, and a decline in the baseline mean from 447.00 µg/m^3 (2006) to 226.06 µg/m^3 (2018). CO concentrations revealed an 89.7% reduction in the baseline concentration from an average of 19.4 ppm (2010) to 2.0 ppm (2018). This reduction was found to be statistically significant ($p<0.05$), however the decline in SPM concentration was not significant. Noise pollution has however remained unabated (6.41% reduction) with a baseline mean of 78.18 dB(A) in 2005 and a current average of 73.17 dB(A) (2018). The multivariate analysis conducted using Principal Component Analysis, Multiple Linear Regression and Varimax rotation, identified road traffic as the main noise source in Benin City.

Key words: Baseline, Carbon monoxide, Noise, Suspended particulate matter, Traffic control measures.

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1. Introduction

Air quality has been deteriorating especially in developing nations of the world in recent times with vehicular traffic being a major contributor with its adverse health effects (Zalakeviciute *et al.* 2017). Globally, about 7 million people die annually from illness induced and exacerbated by air pollutants (WHO 2018) and it has been predicted that premature deaths from outdoor air pollution could double by the year 2050 (Lelieveld *et al.* 2015). Nigeria ranks as one of the African countries with the highest level of air pollution and is reflected in her very low life expectancy of 54.3 years (WHO 2016, Etchie *et al.* 2018). According to IHME (2016) and WHO (2016), the toll of premature deaths attributed to air pollution in Nigeria is the largest in Africa and among the top 5 position in the world. IHME (2016) estimated that exposure to air pollution in Nigeria currently accounts for about 114,000 annual deaths. Most of the identified air pollution in Nigerian cities (inclusive of Benin City) is caused by vehicular traffic (Ogunsola *et al.* 1994, Baumbach *et al.* 1995, Ukpebor *et al.* 2006, Abam and Unachukwu 2009, Ukpebor *et al.* 2010). The high pollution from traffic in these cities generally andBenin City in particular, is as a result of road transport being the main form of transportation, with strong pollutants emitted from poorly maintained vehicles, overloading and age of these vehicles being a major factor. The above situation is further compounded by frequent traffic jams occasioned by undisciplined road users and numerous pot holes from poorly maintained roads. Some of the reported traffic related air pollutants data and noise for Benin city and some other cities in Nigeria include; NO_2 concentration of 3.60 – 12.45 µg/m^3 (Ukpebor and Ahonkhai 2000), and suspended particulate matter (SPM), levels of 240.00 – 675.00 µg/m^3 (Ukpebor *et al.* 2006) from Benin City; averaged noise level of 65.5 dB(A) and PM_{10} dose of 215.0 µg/m^3 from Calabar (Abam and Unachukwu 2009), and $PM_{1.0}$, $PM_{2.5}$,PM_{10} levels of 45.1 µg/m^3, 77.9 µg/m^3, 513.0 µg/m^3 respectively from Ilorin Metropolis (Adeniran *et al.* 2017).These values violated set threshold limits (Table 4). The above scenario notwithstanding, there are no federal traffic control policies enforceable in cities within Nigeria.

Conversely, the high – income cities have cleaner air even though the numbers of vehicles have increased significantly over the last two decades (Lana *et al.* 2016). For instance, decreasing trend in the concentrations of NO, NO_2, CO and PM_{10} have been observed in Madrid (Salvador *et al.* 2015) as a result of the pollution abatement policies promoted by the European Parliament. A similar trend of reduced particulate pollution has also been observed in Latin American populous cities during the last decade (Zalakeviciute *et al.* 2017). Quite remarkably, it has also been reported that significantly higher population cities and even megacities are not heavily impacted by atmospheric pollution (WHO 2014, UNEP 2015). A peculiarity of these megacities is the development and implementation of comprehensive vehicle pollution control measures, i.e. adopting strict emission standards, traffic control systems and stricter fuel regulations.

This study was therefore designed to use field measurements in a Nigerian city to assess the effectiveness of implemented traffic control measures on air pollution and noise level. The focus was on SPM, CO and noise in this research because they are closely related to traffic

(Mayer 1999). In recent times, traffic related particulates (and its fractions) have been profusely studied because of the overwhelming evidence that particulates generated from combustion processes, especially diesel exhaust particulates (DEP), are more potent in posing adverse health effects than those from non – combustion process (Janssen *et al.* 2002). Furthermore, traffic – generated emissions have been estimated to account for more than 50% of the emissions of particulate matter in the urban areas in highly industrialized countries (Wrobel *et al.* 2000, EEA 2012). Particulate matter has also shown consistent links with cardiopulmonary diseases, increased hospital admissions and mortality in both short and long-term studies (Pope 3rd *et al.* 2010, Thurston *et al.* 2016). Carbon monoxide (CO), which results from incomplete combustion of natural gas, diesel or gasoline in traffic engines, is another important pollutant in traffic – related studies and epidemiologic investigations (Han and Naeher 2006). Increased traffic volumes have also been associated with high noise levels (Babisch *et al.* 2005). Khan *et al*., (2018) reported that road traffic induces air and noise pollution in urban environments with direct negative impacts on human health.

Consequently, this research would in addition to its fundamental aim, provide current data on SPM, CO and noise level status of Benin City for policy re-alignment. It would also attempt to advance pragmatic reasons for the intractable high noise and air pollution challenge of the city, therefore by extension other Nigerian and West African cities. Additionally, appropriate mitigation measures would be recommended.

2. Materials and methods

2.1 Study area and schedule

The study was carried out in Benin City, southern Nigeria (longitude 5.3ºE and latitude 6.2ºN). The climate is equatorial with distinct wet and dry periods – dry period (October – March) and wet period (April – September), with an estimated land area of 500 km^2 (Erah *et al.* 2002) and a population of about 1,147,188 (NPC 1991), making it the fourth largest city in Nigeria. Benin City is commercial in nature with operations of petroleum based industries. Traffic volume is high in the city all year round, because the city is a gateway to the other parts of the country.

Sampling in this study was carried out in the months of May - July, 2018. Five monitoring sites were selected based on traffic hotspots. The sites were created at roadside verges, traffic intersections, roundabouts and close to locations where the initial baseline data was obtained. Figure 1 and Table 1 represent the monitoring sites and their characteristics. The sites were Geo – referenced by using GARMIN GPS MAP765 chart plotting receiver. Eleven – hours sampling duration was observed at each sampling site with air samples and noise level recorded every half – hourly from 8.00 am to 7.00 pm on the sampling days. Traffic census was also taken during the sampling period at all the sampling sites (Table 1). This exercise revealed an average traffic volume of 2,199 cars/hour for the city. The census represents various types of vehicles including motorcycles, tricycles, cars, Lorries and trucks that use the road for commercial, industrial activities and personal services.

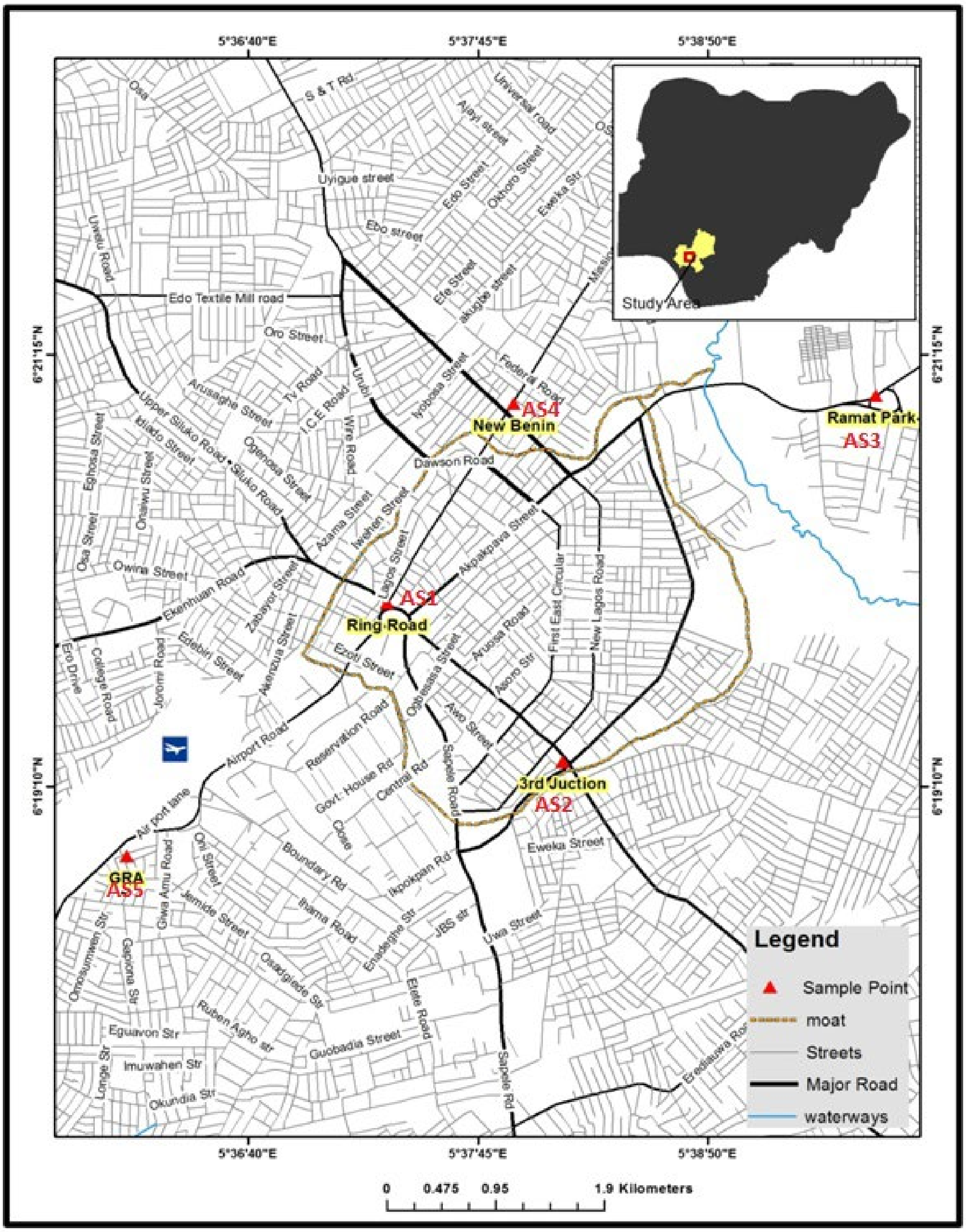


Figure 1. GIS base map of Benin City showing sampling locations and major routes.

Table 1: Sampling sites and characteristics

Site code	Coordinates	Elevation (m)	Traffic density (cars/hour)	Site description
AS1	N06º 20.020’ E005º37.352’	92	3246	10m from the city centre Ring Road (roundabout) with seven link roads/streets. Fast flowing traffic and human activities, with a building construction site about 20m away from the point of measurement.
AS2	N06º 19.289’ E005º38.181’	88	1594	15m from a traffic intersection at Upper Sakponba. Traffic volume is high and also human activities due to Ekiosa open market which is about 25m from the sampling point.
AS3	N06º 21.008’ E005º39.583’	83	3030	7m near a roundabout road at Ramat park. High, free flowing vehicular traffic and human activities. About 40m from Ikpoba Hill open market
AS4	N06º 20.980’ E005º37.886’	92	1590	5m from a traffic intersection at New Benin. 25m from the popular New Benin Market with moderate traffic and commercial activities.
AS5	N06º 18.893’ E005º36.087’	85	1534	4m from Airport Road, opposite the Benin Airport, low free flowing vehicular traffic, low commercial activities with few nearby residential and commercial buildings.

2.2 Measurement methods

Suspended Particulate Matter

The SPM concentrations were measured using a Casella CEL – 712 Microdust Pro Real – time Dust Monitor (Model HB 4048 – 01, Bedford, UK). The instrument uses a proven forward light scattering principle to make accurate and repeatable measurements of dust concentrations. The principle of the light – scattering method has been described in details elsewhere (Ukpebor *et al*., 2006). In brief, the instrument complies with EMC Directive 89/336/EEC of the European Union and uses a visible red semiconductor laser light (wavelength 635 nm, < 5 mW) as the sensing technique, with a measuring range of 0.001 mg/m^3 to 250 g/m^3.Prior to particulate measurements, the instrument was pre – calibrated by adjusting the zero and span settings using the correction factor obtained from the calibration exercise with the gravimetric sampler. Averaging time of 15 seconds was selected and the average particulate concentrations were recorded every half - hourly for 11 hours (inclusive of the rush and non – rush hours) sampling duration at each site. The Microdust Pro is factory calibrated in accordance with a method traceable to isokinetic techniques as prescribed by ISO 12103 – 1A2 fine test dust (Arizona road dust equivalent). However, prior to taking measurements in order to ensure optimal accuracy, the recommended four users– defined routine calibration dust type settings suitable for each particulate type was implemented.

After performing a zero adjustment and span check, a calibration factor for the dust type at the sampling location was carried out. The calibration factor was computed via gravimetry using a low volume pump (Casella Cel Tuff I.S, Bedford, UK) and a 37 mm microfibre filter inserted into the dust sampler. Further details on the working principle, detection efficiencies and quality control of the gravimetric sampling approach can be found in Ukpebor *et al*., (2006). Dust collection and measurements were carried out at the AS1 location over a 5 hour period (Figure 2). Comparison of the dust sampler reading and the weight of the collected dust on the microfibre filter was carried out at the end of the sampling. The respective dust measurements were 0.6431 and 0.6160 mg/m^3 from the filter gravimetric study and the forward light scattering of the dust sampler. The user – defined correction factor for the SPM was then calculated using the equation (1) below;

$$Correction factor\ (CF) = \frac{Gravimetric\ concentration\ (mg/m^3)}{Instruments\ measured\ average\ value\ reading\ (mg/m^3)} \quad (1)$$

$$CF = \frac{0.6431}{0.6160}$$

The correction factor of 1.044 obtained was subsequently applied automatically (via the instrument setup menu) for any measured value, to ensure optimal measurement accuracy.

Carbon Monoxide

The CO concentrations were measured using a CO dosimeter (model 627, BK Precision USA). This sampler measurement range is from 0 to 1000 ppm, with a sensitivity of 1 ppm, an accuracy of ±5%, operating temperature of 0 to 40°C and operating humidity of 15 to 90%. Additionally, it is equipped with a sensor that has an electrochemical sensing electrode and a counter electrode. The sensor has a permanent irreplaceable filter built inside the sensor to filter out trace concentrations of SO_2, NO_2 and most hydrocarbons. The effectiveness, efficiency and the details of this sampling approach have been reported earlier (Ukpebor *et al.* 2010). The CO monitor was calibrated before deployment and during the monitoring campaign by ensuring that the zero and span of the dosimeter were checked at regular intervals using zero air and a standard CO concentration. This sampling approach has been used by several authors (Osuntogun 2004, Wan-Kuen and Joan-Yeob 2006) because of the following positive attributes: low cost, high accuracy and sensitivity, no special training before usage, direct readout, wide special coverage and no dependence on electricity.

Noise Level

A pre – calibrated BK Precision 732A sound level meter (model IEC651 Type 2, ANSI S1.4 Type2) (B&K Precision Corp. Savi Ranch Parkway Yorba Linda, CA, USA.) was used to measure the noise levels in all the sampling locations. The noise dosimeter used has a frequency range of 31.5 Hz – 8 KHz, measuring level range of 30 – 130 dB, operation temperature of 0 – 40°C, operation humidity of 10 – 90% RH, and accuracy of ±1.5 dB (under reference conditions of 94 dB, 1 KHz). The equipment measures noise level via a microphone probe that generates signals approximately proportional to located sound waves. Measurements were carried out by directing the probe towards the direction of the prevailing sound and the reading recorded from the digital meter in decibels dB(A). Prior to measurements, the dosimeter was calibrated using a standard acoustic calibrator B&K model CAL73 (94dB, 1 KHz sine wave). The noise dosimeter was set to 1 second time resolution and A – weighting for general noise sound level was selected.

Site Meteorology

Temperature, humidity and wind speed were simultaneously measured daily, during the monitoring exercise with the aid of a humidity/temperature meter, with resolutions of 0.1%RH and 0.1°C (model RS 1364, RS components Ltd, UK). At the same time, wind speeds were measured using an LM – 8000 anemometer with a resolution of 0.1 ms^{-1} (Heatmiser UK Ltd).

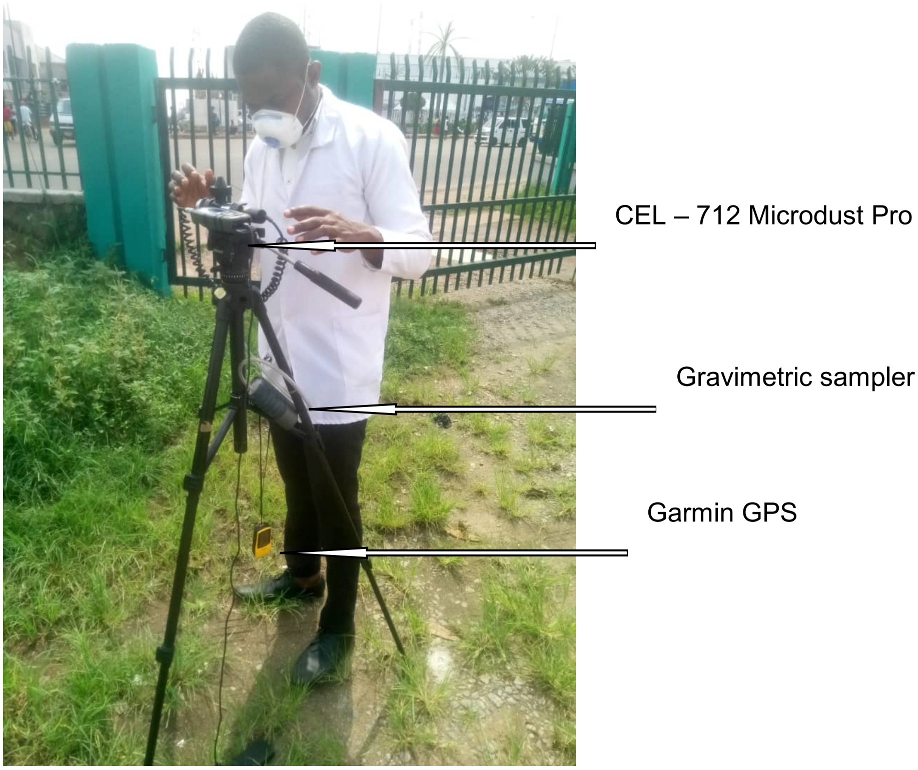


Figure 2: Measurement and calibration exercise of PM Real-time Dust Monitor (Casella, Bedford, UK).

2.3 Method of Data Analysis

The data were analysed using descriptive and inferential statistics. Descriptive statistics used were mean, standard deviation, range (minimum and maximum) and percentage distribution. Inferential statistics involved the use of Analysis of Variance (ANOVA) to assess spatial variations. Additionally, t – test was used to compare the means of each parameters between the two periods. Principal Component Analysis (PCA) using Varimax rotation as well as Hierarchical Cluster Analysis were the multivariate analyses employed in this study. Though in literature there are quite a number of methods of performing Source Apportionment and Identification, this study used the PCA and Multiple Linear Regression (MLR) vis – a – vis PCA – MLR method. The level of significance in the study is set at $p<0.05$. All data analysis were performed using the IBM Statistical Package for Social Sciences (SPSS) version 26.0 for windows.

3. Results and Discussions

Results obtained for the assessment of the impact of implemented traffic control measures (installation of traffic light, relocation of various commercial bus terminals from the city centre, parking restrictions, road maintenance and the establishment of a special traffic control unit to ensure adherence to traffic regulations) on air pollution and noise level in Benin City, Nigeria are presented below:

3.1 Impacts of traffic control measures on SPM emissions

The obvious physical changes in the city that influenced this study are; apparent orderliness in the traffic situation (Fig. 3 and Fig. 4.), significant reduction in the traffic gridlock from hour(s) to very few minutes and the advertised slight improvement in life expectancy from 44 years in 2010 (Ukpebor *et al.* 2010) to the current 54.3 years (UNDP 2018). Analysis of the SPM data, revealed a reduction (-61.75% to 87.72%) in its concentration and distribution (Table 2), when compared with the baseline data obtained previously (Ukpebor *et al.* 2006) using a similar sampling procedure. The reduction was however found to be statistically insignificant ($p>0.05$) (Table 3). That study reported a particulate matter range of 240.00 – 600.00 $\mu g/m^3$ with a mean value of 447.00 $\mu g/m^3$.

Table 2. Baseline concentration (BLC) and Concentrations after traffic control measures (CAC) of SPM and CO; Baseline levels (BLL) and Levels after traffic control (LAC) measures of Noise, and the Reduction Rate (RR%).

Location	SPM (μgm^{-3})			CO (ppm)			Noise (dB(A))		
	BLC	CAC	RR%	BLC	CAC	RR%	BLL	LAC	RR%
AS1	240.00	388.20	-61.75	20.30	1.30	93.60	78.74	70.04	11.05
AS2	400.00	105.00	73.75	18.70	3.20	82.89	79.08	79.82	-0.94
AS3	675.00	387.40	42.61	15.00	2.00	86.67	75.07	72.26	3.74
AS4	320.00	176.00	45.00	28.30	1.80	93.64	77.00	70.98	7.82
AS5	600.00	73.70	87.72	14.80	1.50	89.86	81.00	72.74	10.20
Mean	**447.00**	**226.06**	**37.47**	**19.42**	**1.96**	**89.33**	**78.18**	**73.17**	**6.37**

Table 3: Mean comparison of SPM (μgm^{-3}) between data obtained in 2006 and 2018

Locations	2006 Mean	2018 Mean	2018 Std.	Mean difference	t	p
AS1	240.0	388.20	300.28	147.93	0.853	0.483
AS2	400.0	105.00	35.36	295.00	11.800	0.054
AS3	675.0	387.40	163.20	287.60	2.492	0.243
AS4	320.0	176.00	39.600	144.00	5.143	0.122
AS5	600.0	73.70	9.120	526.45	81.620	0.008

The current study conducted after the implementation of the traffic control measures, gave SPM levels which varied from 73.70 – 388.20 $\mu g/m^3$ with a mean of 226.06 $\mu g/m^3$ (Table 2). There was SPM reduction at 80% of the sampling sites, except at site AS1 where the SPM concentration rather increased from 240.00 $\mu g/m^3$ in 2006 to 388.2 $\mu g/m^3$ in 2018. At the other sampling sites (AS2 to AS5) we observed the lowest SPM reduction of 42.6% at AS3 and the highest reduction of 87.7% at AS5. The observed anomaly of an increase in SPM concentration at AS1 could be due to the characteristics of that sampling site (Table 1). Site AS1 is a roundabout with adjoining 7 link roads (Fig. 1). Also, it is at the city centre where all the traffic going through the city to the other 35 states of the country must pass through. Consequently, the traffic intensity at that location is the highest and particularly high all day long which apparently causes intermittent congestions as well as the construction site located close to the sampling site could have led to the observed SPM increase. It has been reported that emissions of air pollutants (such as PM) in a city vary depending on thetraffic speed (EEA 2012), traffic intensity (HKEPD 2015), vehicles maintenance, street configuration (Aliyu and Botai 2018), engine type and condition, fuel type, driving habits and loads of vehicles (Autrup 2010) andtraffic congestion (Yao *et al.* 2013).

Figure 3: Traffic light signals at busy road junctions and intersections

Figure 4: Commercial bus terminals from the city centre

Of the above factors, traffic congestion is the most apparent traffic challenge in Nigeria cities (Baumbach *et al.* 1995), and the reasons for its intractability are traffic intensity, unfavourable traffic handling and inadequate traffic discipline. The positive impacts of these simple traffic control measures are better appreciated; when the current Benin City averaged SPM value of 226.06 µg/m^3 is compared with other Nigerian cities devoid of similar interventions. Examples are averaged SPM levels of 1484.95 µg/m^3 measured in Ilorin (Adeniran *et al.* 2017), a range of between 100 - 2000 µg/m^3 in Lagos and between 120 - 720 µg/m^{3}in Ile – Ife (Ogunsola *et al.* 1994). The above high particulate matter load reported for these other cities have been attributed to heavy traffic density. In Benin City, traffic intensity is also very high (ESIRS 2020) and increasing. But what has changed in the city is better traffic management (from the introduced traffic control measures) that has led to traffic decongestion and faster traffic flow. Previous studies have shown that pollutants emissions during traffic congestion are 2- 4 times manifolds of those obtainable during the free flow traffic periods (Zhang *et al.* 2012, Shirmohammadi *et al.* 2017).

In a similar study in Quito, Ecuador, a 27% decrease in particulate matter concentration was reported for an 11 year period (Zalakeviciute *et al.* 2017). Reduced particulate pollution have also been reported in other Latin American populous cities (AQICN 2015), 45 – 50% reduction rate in the west coast of U.S.A (Kotchenruther 2015), 21% and 20% reduction in coarse and fine particulate matter respectively from 2009 to 2014 in Hong Kong (Ai *et al.* 2016), 52% and 30% coarse particles emission reduction in Beijing and Guangzhou (Zhou *et al.* 2010, Yao *et al.* 2013).
Comparison of the SPM values obtained in Benin City with the World Health Organization (WHO 2000) and Nigerian Federal Environmental Protection Agency (FEPA 2000) threshold limits for particulates (Table 4) was done in order to assess the health and safety effects.

Table 4: Threshold limit of selected air pollutants, modified after (FEPA 2000, WHO 2000)

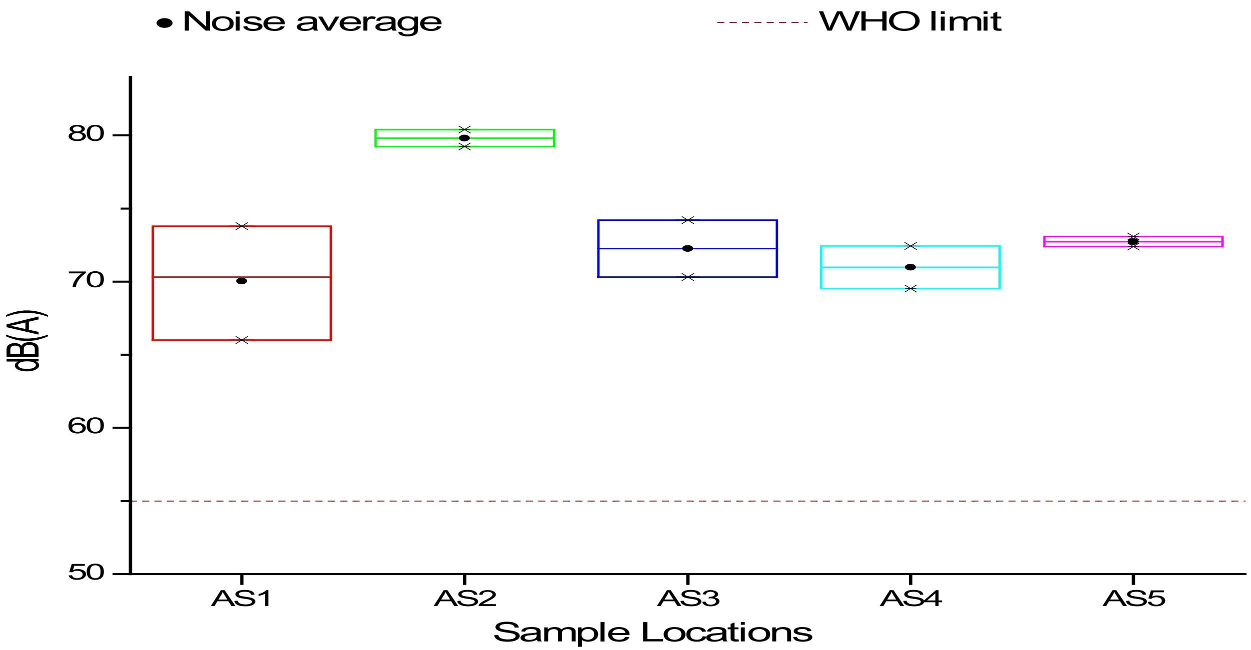
Pollutant	**FEPA[a]**	**WHO[a]**
Suspended Particulate Matter (µgm^{-3})	250	150 - 230
CO (ppm)	10	9
Noise dB(A)	-	55

[a] 24-hour time weighted average for listed pollutants

The city average SPM value of 226.06 µg/m^3 was within the 250.00 µg/m^3 national limits and the WHO limit of 150 – 230 µg/m^3. There were statistically insignificant ($p>0.05$) (Table 5) spatial variations in the measured SPM data. However, the highest SPM levels were measured at AS1 and AS3 with average concentrations of 388.2 µg/m^3 and 387.4 µg/m^3 respectively (Table 2) and the available regulatory limits were exceeded at these locations (Fig. 5). At the other sampling sites (AS2, AS4, AS5), a SPM mean range of 73.7 – 176.0 µg/m^3 was reported. These values were within the available threshold limits (Fig. 5). Of major concern is the nearness to unity (0.9) of the ratio of the city averaged SPM value and the SPM national threshold limit. Airborne particles have been known to adversely affect human health, provoking a wide range of respiratory diseases and exacerbating heart disease and other conditions (Autrup 2010, Katheeri *et al.* 2012). Consequently, there is a need for additional measures to further reduce particulate pollution in Benin City and such should include policies on fuel quality improvement and the reduction in traffic volume.

Table 5: Mean comparison of SPM, CO and Noise at the different locations (2018).

	Mean(SD)	Range	F	P
SPM (μgm^{-3})				
AS 1	387.93±300.28	141.00-722.20	1.495	0.314
AS 2	105.00±35.36	80.00-130.00		
AS 3	387.40±163.20	272.00-502.80		
AS 4	176.00±39.60	148.00-204.00		
AS 5	73.55±9.12	67.10-80.00		
CO (ppm)				
AS 1	1.33±0.31	1.00-1.60	3.953	0.066
AS 2	3.30±0.99	2.60-4.00		
AS 3	2.00±0.85	1.40-2.60		
AS 4	1.80±0.28	1.60-2.00		
AS 5	1.50±0.14	1.40-1.60		
Noise (dB(A))				
AS 1	70.04±3.91	66.00-73.80	4.460	0.052
AS 2	79.82±0.82	79.24-80.40		
AS 3	72.26±2.74	70.32-74.20		
AS 4	70.98±2.06	69.52-72.44		
AS 5	72.74±0.48	72.40-73.08		


Noise average
WHO limit
dB(A)
80
70
60
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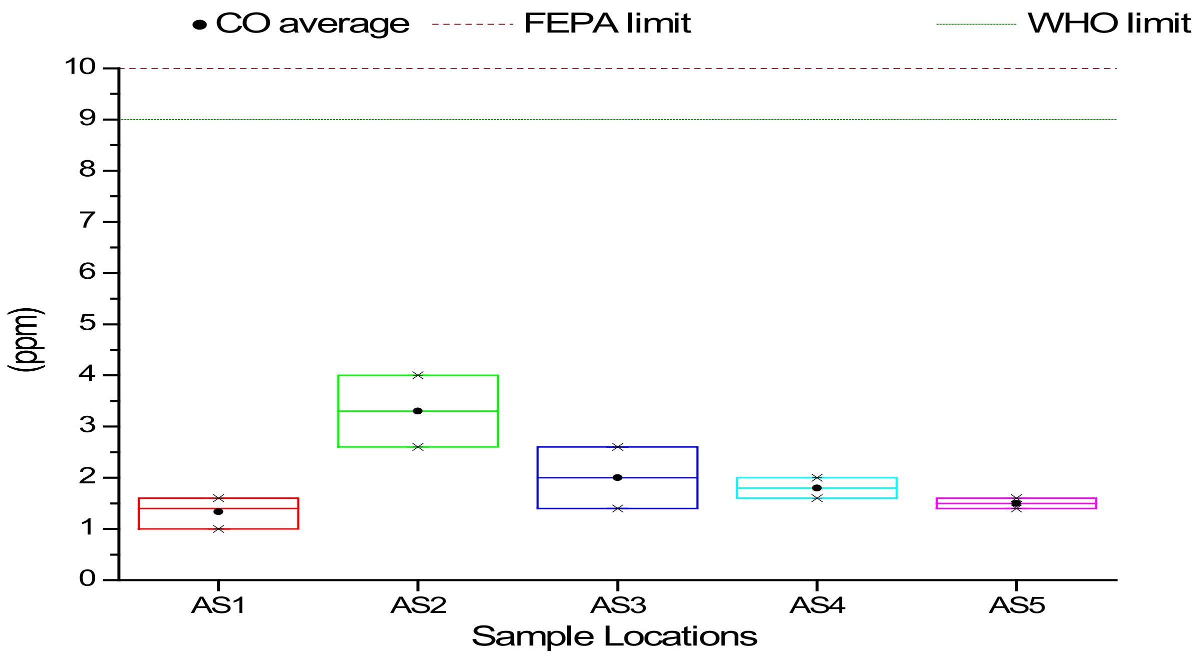
AS1
AS2
AS3
AS4
AS5
Sample Locations


CO average
FEPA limit
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10
9
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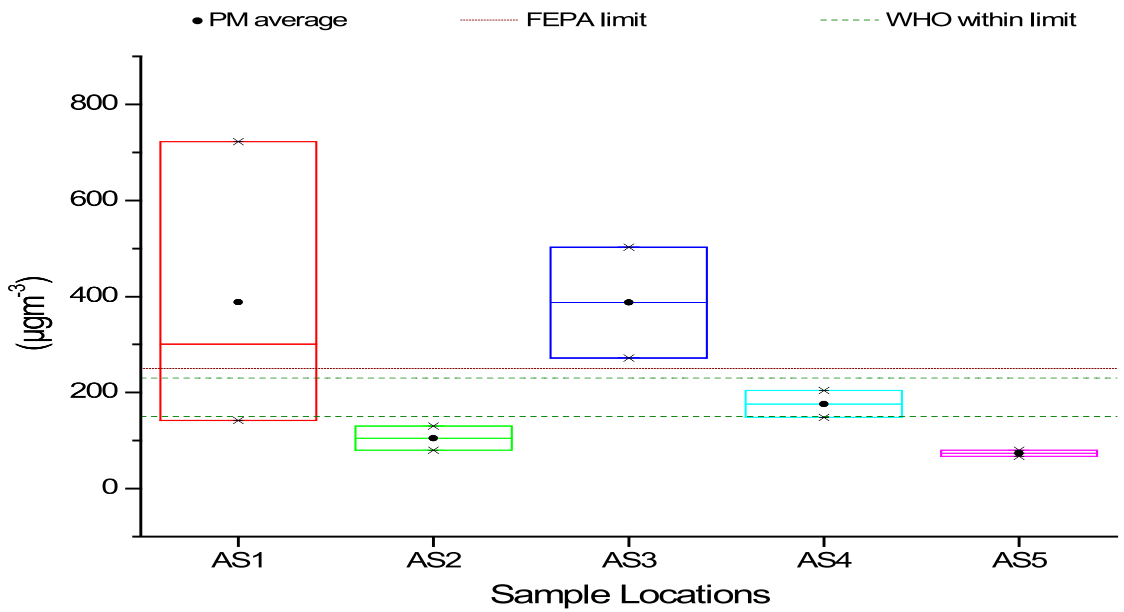
PM average
FEPA limit
WHO within limit
800
600
400
200
0
(μgm-3)
AS1
AS2
AS3
AS4
AS5
Sample Locations

3.2 Impacts of traffic control measures on CO emissions

In the last 2 decades, CO has gained the highest notoriety in Nigeria amongst the criteria air pollutants because of the high mortality rate (Ukpebor *et al.* 2010, Akindele and Adejumobi 2017, Elenwo and Ebe 2019, Punch 2019). Outdoor sources have been reported to contribute to the levels of indoor CO in Nigeria. At elevated concentrations, CO can have large negative impacts on human health (Forbes and Garland 2016). When inhaled, CO can bind to haemoglobin, thus reducing the oxygen carrying capacity of the blood (WHO 2010)which can result to premature death. Carbon monoxide poisoning is a leading cause of death in many countries, although the number of fatal cases are thought to be underestimated (Prockop and Chichkova 2007).

A major source of CO in the environment is vehicular exhaust (Han and Naeher 2006, Abam and Unachukwu 2009, Inchaouh and Tahiri 2017). The introduced traffic control measures in Benin City have resulted in statistically significant ($p< 0.05$) CO concentration reduction in the city (Table 6). The baseline CO values obtained in 2010 was a city range of 14.8 – 28.3 ppm and a mean value of 19.4 ppm (Table 2).

Table 6: Mean comparison of CO between data obtained in 2010 and 2018

	2010	2018				
Locations	**Mean (ppm)**	**Mean (ppm)**	**Std.**	**Mean difference**	**t**	**p**
AS1	20.3	1.33	0.31	18.97	107.531	0.000
AS2	18.7	3.30	0.70	15.40	22.000	0.029
AS3	15.0	2.00	0.95	13.00	21.667	0.029
AS4	28.3	1.80	0.28	26.50	132.500	0.005
AS5	14.8	1.50	0.14	13.30	133.000	0.005

A mean CO concentration of 2.0 ppm was obtained for this study, with minimum and maximum values of 1.33 ppm and 3.3 ppm respectively. At all the sampling sites, CO concentration reduction was observed with a minimum of 82.4% at AS2 and the highest reduction rate of 93.64% at AS4.This translated to an 89.3% reduction rate in the CO spatial distributions in the city from 2010 to 2018. Carbon monoxide has an atmospheric life time of 2 – 3 months (Forbes and Garland 2016) and has been reported as one of the most sensitive pollutants to traffic congestion and meteorological conditions (Han and Naeher 2006, Inchaouh and Tahiri 2017). Previous CO build up as a result of incessant traffic gridlock that runs into hours was prevalent within the city. Magaji and Hassan, (2015) have on records that CO concentrations as low as reported in our study abound in environment where traffic density is low and congestion scanty. CO levels of between 1.83 and 2.17 ppm have been recorded around Gwagwalada, Abuja Nigeria, (Magaji and Hassan 2015), 3.3 – 8.7 ppm CO levels obtained in Calabar, Nigeria (Abam and Unachukwu 2009), 0.17 – 4.20 ppm in Accra, Ghana (Nerguaye-Tetteh 2009) and a maximum CO level of 4.68 ppm measured at an arterial road in Noida, India (Barnawal 2017) (Barnawal, 2017). In contrast, CO concentrations violating the Nigerian FEPA and WHO threshold limits of 10 ppm and 9 ppm respectively have also being reported in some other Nigeria cities for example Uyo Metropolis, Nigeria (24.00 – 60.00 ppm) (Ebong and Mkpenie 2016); Ebute – Meta, Lagos, Nigeria(30.0 – 70.0 ppm) (Adelagun *et al.* 2012). Averaged CO level of 271.0 ppm at Ibadan, Nigeria (Koku and Osuntogun 2007); 1 – year averaged CO value of 29.22 ppm in Zaria, Northern Nigeria (Aliyu and Botai 2018); and average CO concentration of 19.27 ppm along Oba Akran road, Lagos Nigeria (Olajire *et al.* 2011) where traffic density and congestion are high.

Chow and Chan, (2003) and Shendell and Naeher, (2002) reported that CO pollution were generally higher in developing countries when compared with developed countries. This observation has been attributed to several factors including poor traffic management, poor vehicle maintenance and insufficient use of vehicle emission control systems. Reported identical studies on the effectiveness of introduced measures to reduce CO emissions in some urban cities in the World, include a 42% CO reduction reported in Guangzhou, China (Yao *et al.* 2013). Wang and Xie, (2009) also reported a 19.3% CO reduction linked to 32.3% traffic flow reduction in Beijing. A close view of the CO emission reduction rate suggests that the traffic control measures introduced in Benin City were more effective than the measures introduced in Guangzhou and Beijing. A plausible explanation for the above observation could be the higher traffic volume in Guangzhou and Beijing compared to this study area. However, Han and Naeher (2006) had noted that study outcomes from different regions and countries may not be completely comparable due to differences in sampling method, sampling date, time and duration, sampling technique, traffic profile and meteorological conditions.

There was no significant ($p>0.05$) spatial distribution of CO concentrations in the city with a maximum of 3.3 ppm measured at AS2 and a minimum of 1.33 ppm obtained at AS1 (Table 5). This observation has been attributed to the obvious significant traffic decongestion and faster traffic flow in all the sampling sites. The CO concentrations in all the sampling sites complied with the FEPA and WHO regulatory limits (Fig. 5).

3.3 Impacts of traffic control measures on Noise Pollution.

Noise pollution is the most neglected and normalized form of pollution in Africa, inclusive of Nigeria. High - pitch sounds are seen as normal and this attitude stems largely from lack of enlightenment. However, there is evidence of the relation between traffic noise and heart diseases like myocardial infarction and ischemic heart diseases (Babisch *et al.* 2005, Babisch 2006). The average life expectancy (ALE) of Nigeria is 54.3 years and some of the few published noise studies done in Nigeria (Oyedepo and Saadu 2010, Oloruntoba *et al.* 2012, Oguntunde *et al.* 2019) have also reported the above noise impacts and even more. Unfortunately, the introduced traffic control measures do not seem to have remarkably improved the noise pollution in Benin City, though they have resulted in massive traffic decongestion and faster/smoother traffic flow. Slight noise reduction was only observed at locations AS1, AS3, AS4 and AS5, with a minimum of 3.74% at AS3 and a maximum of 11.05% at AS1. At AS2, the noise level has remained completely unabated. The statistical evaluation of the averaged noise baseline value of 78.18 dB(A) (Odeh 2005) and the current averaged noise level of 73.17 dB(A), only amounted to 6.41% noise reduction in the city (Table 2) which was statistically insignificant ($p. > 0.05$) (Table 7). The data suggests that the introduced mitigation measures did not impact positively on the noise levels within the city because of the peculiar nature of anthropogenic noise generation from vehicular traffic in Nigeria, inclusive of Benin City. Like every other city in Nigeria (Oyedepo and Saadu 2010, Oloruntoba *et al.* 2012) and most other high - income cities globally (Andersson *et al.* 2020), our multivariate analysis using PCA, MLR and Varimax rotation identified vehicular traffic as the main noise source. The PCA, MLR analysis identified two components for the noise pollution in the City (Fig. 7). This suggested two main noise sources in the sampling locations that were confirmed by the hierarchical cluster analysis (Fig. 8). Our field observation led to the suggestion that 55.8% of the noise pollution was from road traffic and the remainder coming from commercial activities (Figure 9).

Table 7: Mean comparison of Noise between data obtained in 2006 and 2018

	2006	2018				
Locations	**Mean (dB(A))**	**Mean (dB(A))**	**Std.**	**Mean difference**	**t**	**p**
AS1	78.70	70.04	3.91	8.66	3.839	0.062
AS2	79.10	79.82	0.82	-0.72	1.241	0.432
AS3	75.10	72.26	2.74	2.84	1.464	0.382
AS4	77.00	70.98	2.06	6.02	4.123	0.151
AS5	81.00	72.74	0.48	7.26	21.353	0.030

However, unlike the high – income cities where urbanization with increasing road traffic has been proposed as the main reason for the rising noise pollution, Benin City noise is more of the quality of the vehicles and indiscriminate use of car horns and sirens. Obioh *et al.,* (1994) observed that quite a number of vehicles that failed emission tests in Europe and other countries dominated the cars found in Nigerian cities. Aliyu and Botai (2018), also reported that aged automobiles from import/recycle still dominate the Nigerian automobile fleet creating high air and noise pollution. A combination of the above noise causing factors have led to outrageous noise levels in Nigerian cities which are evidenced in the studies by Oyedepo and Saadu (2010) that reported a noise levels of 68 – 89 dB (A) for Ilorin metropolis; averaged morning, afternoon, evening noise levels of 90.78 dB(A), 90.60 dB(A), 90.72 dB(A) respectively at Ota metropolis (Oguntunde *et al.* 2019); 71 – 92 dB(A) in Abuja (Ibekwe *et al.* 2016) and a range of 71.5 – 97.5 dB(A) measured along Oba Akran road, Lagos (Olajire *et al.* 2011). In all of the above reported studies and inclusive of this study, the WHO regulatory limit of 55 dB(A) (Table 4) for residential environments have been clearly violated. This trend of high noise levels is prevalent in most other African countries (Haq and Schwelo 2012) and some of the reasons adduced for our findings, applies to them too. Reportshave indicated higher risks (~20%) of heart diseases for those living in streets with average noise levels above 65 – 70 dB(A) (Babisch 2006) than those living in more serene areas. The current average noise level in Benin city is ~73.17 dB(A) similar to other Nigerian and African cities. It is estimated that over half of Europe's population is exposed to unacceptable noise levels (den Boer and Schroten 2007) and exposure to traffic noise has increased in recent times (Andersson *et al.* 2020). However, the reported noise data for these high – income cities are relatively lower than the values reported in this study. In a study on theprevention and control measures of China's urban road traffic noise pollution (Wu *et al.* 2019), the noise data reported varied from 54.5 – 68.5 dB(A). Adherence to prescribed regulations on car maintenance, emission control and legislations on the use of horns, sirens etc. accounts for the lower noise levels in the high – income cities.

Uniformly high noise data were reported for the entire sampling sites within the city during this study (Table 5). A minimum noise level of 70.04 dB(A) was obtained at location AS1 and a maximum value of 79.82 dB(A) reported at AS2. The other 3 sampling sites reported noise values in - between the above levels. The similarities in the noise levels at all the sampling locations, is an indication of the similarities of anthropogenic noise sources within the city. The evaluated spatial variability in the measured noise data was found to be statistically insignificant ($p>0.05$) (Table 5).

3.4 Microclimatic Parameters during the study

The climatic parameters obtained during the sampling are shown in Figure 6. As expected for a tropical climate, high atmospheric temperatures were measured with a maximum of 37.3 ºC and a minimum of 28.2 ºC**.** A relatively humid atmosphere was observed during sampling with a mean of 58.9%. The mean wind speed was between 0.5 and 2.3 m/s. The obtained climatic data are consistent with the historical microclimatic parameters of the study area(NIMET 2011).

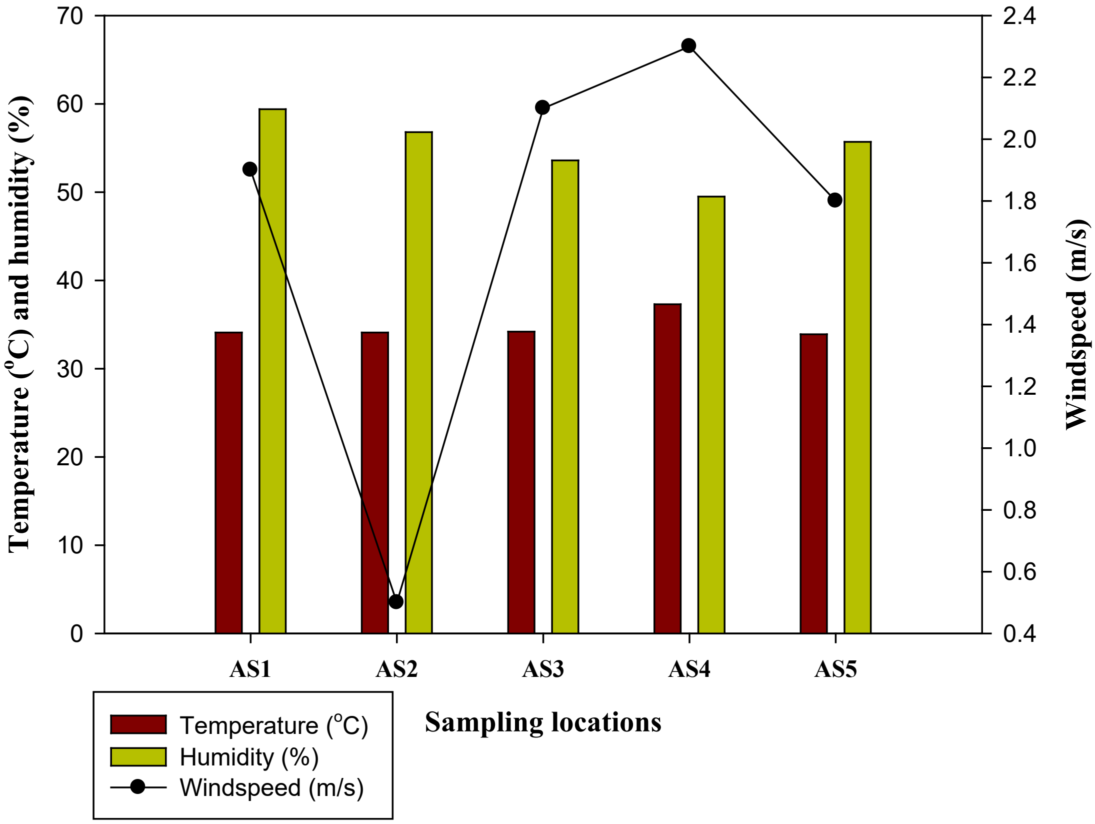

Figure 6. Measured micro-climate parameters during sampling

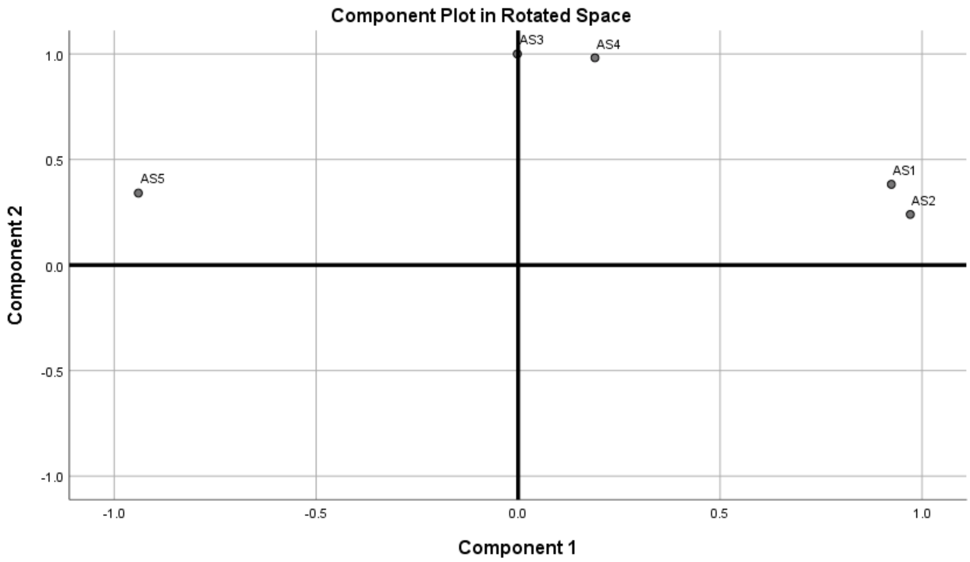

Figure 7: Component plot in rotated space

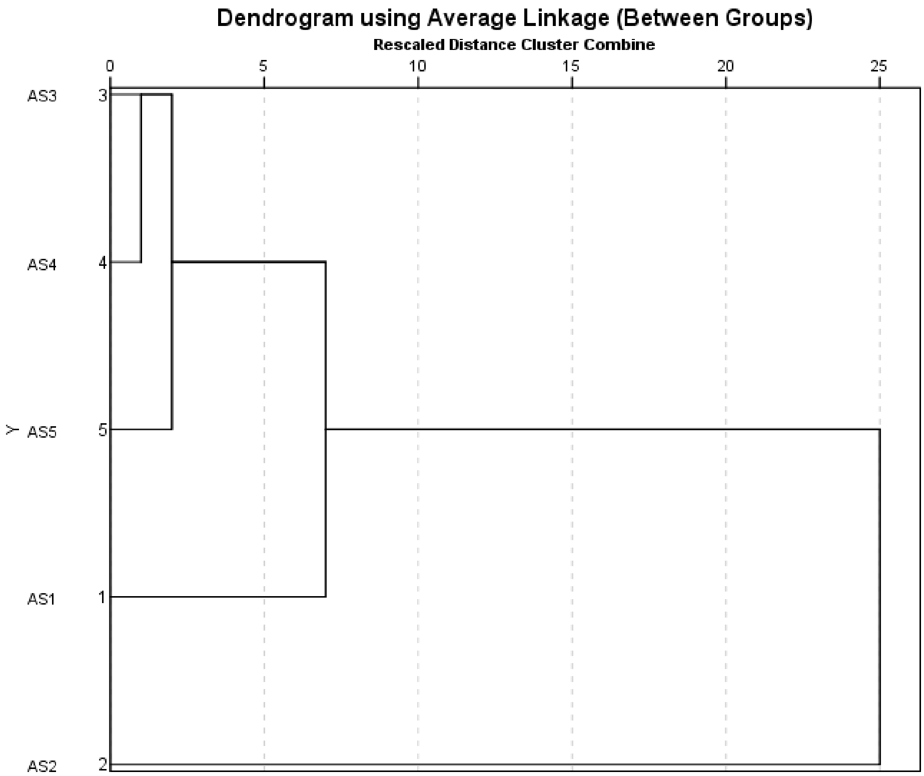

Figure 8. Dendrogram using average linkage (between groups) of noise levels obtained in Benin City. (Hierarchical cluster analysis confirms a two-cluster arrangement of noise level and distribution at the five monitoring sites).

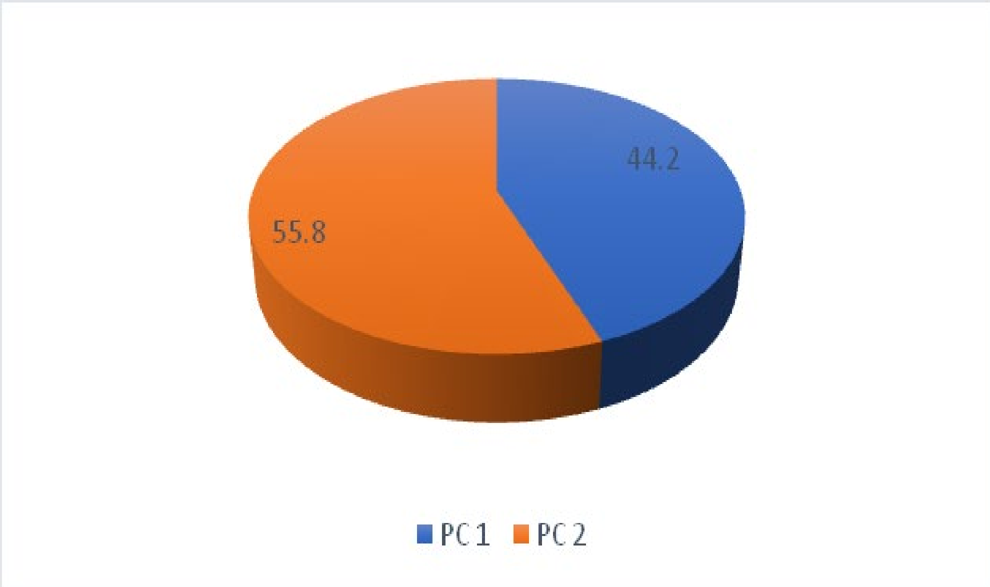

Figure 9: Source apportionment of Principal component of noise at the different locations. (Figure shows that source 1 contributes 44.2% of the noise the different locations, while source 2 contributes 55.8% of the noise).

3.5. Strengths and weaknesses

This study provides the most up-to-date data on SPM, CO and Noise levels in Benin City with a population of over a million people. It was also able to use solely field data to assess the impact of introduced simple traffic control measures on atmospheric distribution of SPM, CO and Noise level in the City; first of its kind in the West African region – to the best of our knowledge. Finally, this study was able to establish the most probable reasons for the intractable noise pollution in Benin City and most Africa countries. The first weakness of this study is the sampling period (May – July; wet season), which could not be extended to cover the dry season, because the baseline study was not seasonally based. Secondly, is the sample size which was equally done to tally with the baseline sampling sites. The last weakness was our inability to evaluate the impact of climate parameters on the reduction observed in the pollution indicators.

3.6. Conclusions

The introduced traffic control measures have led to a remarkable improvement on traffic congestion and traffic flow within the city. The co – effects of traffic congestion and traffic flow improvement resulted in 37.47% reduction rate in particulate matter distribution in the city. Carbon monoxide benefitted the most from the introduced measures with a massive 89.3% reduction rate in the CO spatial distributions in the city. However, the impact of the implemented measures on noise pollution in the city was completely negligible with only a 6.41% noise reduction in the city. As a result of the nearness to unity (0.9) of the ratio of the city averaged SPM value and the SPM national threshold limit, and the outright breach of the WHO noise threshold limit of 55 dB(A) for the city, we recommend the following measures to improve on the air quality status and noise pollution; development of urgent policies/measures on fuel quality improvement, ban on the flagrant use of siren, horn, establishment of emission standards and traffic reduction. Finally, we envisage that the positive outcomes from these simple traffic improvement measures on air quality would trigger a country – wide adoption and implementation of same. This study is assumed novel, because to the best of our knowledge, it is the first of its kind in Nigeria and Western Africa particularly on the use of field data to quantify the efficacy of implemented traffic control measures on SPM, CO and noise pollution in a tropical urban city.

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