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Spatio-Temporal Variations in Carbon Monoxide and Carbon Dioxide Levels in Three Motor Parks in Ibadan, Nigeria

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Abstract: Carbon monoxide (CO) and carbon dioxide (CO_2) emissions arising from vehicles and combustion processes in motor parks predisposes to adverse health outcomes and associated health risks. There is dearth of studies and data on air quality in motor parks in Nigeria, hence, the need to assess the levels of CO and CO_2 and their relationship with meteorological parameters in three major motor parks in Ibadan, Nigeria. A cross-sectional comparative design was adopted for this study. Akinyele Motor Park (AMP) in Akinyele Local Government Area (LGA), Iwo Road Motor Park (IMP) in Ibadan North East LGA and New Garage Motor Park (NMP) in Ibadan South West LGA were purposively selected and levels of CO and CO_2 were monitored for 2 months with appropriate gas meters, meteorological parameters were also monitored using Ventus W155 wireless weather station. Values obtained were compared with WHO and ASHRAE guideline limits. Descriptive and inferential statistics were used for data analysis at p=0.05. CO concentrations (ppm) for AMP, IMP and NMP ranged from 2.0-106.0, 2.0 – 83.0 and 2.0 – 90.0 respectively while the mean CO_2 concentrations (ppm) were 395.4 ± 30.5, 356.3 ± 57.1 and 388.1 ± 42.1 respectively. There was a significant positive correlation between CO and CO_2 (r=0.258, p=0.000) and also with four meteorological parameters; temperature (r=0.164), rainfall (r= 0.105), heat index (r= 0.134) and dew point (r= 0.127) (p<0.05). A positive correlation was also found between CO_2 and four meteorological parameters; temperature (r= 0.276, p=0.000), rainfall (r=0.125), heat index (r= 0.232, p=0.003) and dew point (r=0.028). For the three motor parks, CO concentrations (ppm) were 80% higher than WHO guideline of 9 ppm for 8 hour monitoring. Mean CO_2 concentrations (ppm) were within ASHRAE guideline limit of 400 ppm. The study showed that meteorology has influence on CO and CO_2 concentrations and motor park users are exposed to high levels of CO. Routine monitoring of CO and CO_2 is recommended in order to ensure these emissions do not exceed guideline limits.

Keywords: Vehicles, Emissions, Meteorology, Motor Parks, Routine Monitoring

1. Introduction

The global vehicular fleet has increased ten-fold over the last 40 years, and it is predicted to increase even more over the next three decades. The United Nations estimated that more than 600 million people living in cities and towns all over the world are exposed to unhealthy and dangerous levels of air pollutants generated by vehicles [1]. Vehicular emissions account for 51% of carbon monoxide, 34% of nitrogen oxides and 10% of particulate matter released each year in the United States [2].

Carbon monoxide (CO) is a colourless, odourless, non-irritating gas produced as a byproduct of incomplete combustion of carbonaceous materials. These materials include petroleum products, coal, natural gas, wood, and plastics. CO can be produced at toxic levels by internal combustion engines, structural fires, industrial operations, and improperly vented heating or cooking appliances [3]. Most of CO emissions (95 - 98%) in a region can be related to anthropogenic activities [4].

When inhaled, CO binds to haemoglobin in red blood cells passing through the lungs, forming carboxyhemoglobin (COHb). Because CO binds to haemoglobin more tightly than oxygen does, CO occupies the sites normally used to bind and carry oxygen from the lungs to the tissues. One mechanism of

CO toxicity is that it decreases the oxygen content of arterial blood which reduces peripheral oxygen delivery [5].

Carbon dioxide (CO_2) is a dominant greenhouse gas [6]. Elevated levels of CO_2 in the atmosphere and its relationship with global climate change have attracted interests from scientific communities, becoming a topical issue posing both political and economic challenges worldwide [7]. CO_2 has drawn global attention due to its impact in terms of global warming as combustion of fuels in the power, transport and household sectors produce CO_2 and a wide range of short-lived air pollutants constituting directly or indirectly a substantial proportion of climate change and the bulk of adverse effects on human health from global energy use [8].

Road transportation is the second biggest source of greenhouse gas emissions in countries of the European Union (EU) where it contributes about one-fifth of the EU's total emission of CO_2 while passenger cars are responsible for 12% of EU's CO_2 emissions [9]. The most recent energy use and emission inventories indicate that China surpassed the United States as the world's largest carbon emitter in 2006 [10]. Most of the assessments carried out on anthropogenic CO_2 emissions were done in developed countries and emerging economies in Asia, which cumulatively account for 80% of CO_2 emissions [11]. Africa also contributed to emission levels as fossil fuel emissions for Africa were 285 Tg C (teragrams of carbon) accounting for 3.7% of the global emissions in 2005, however, fossil fuel emissions per capita in Africa are among the lowest in the world. Emissions from traffic are significant sources of air pollutants, especially in densely populated areas. CO_2 is the main product of fuel burning, but a wide range of other gases are emitted concurrently [12].

The weather of a place represents the state of the atmosphere over a brief period of time [13]. The weather conditions of any given location is often described in terms of meteorological elements which include the state of the sky, temperature, winds, pressure, precipitation, and humidity. These factors initiate and influence atmospheric processes [14]. The atmosphere is affected by direct and indirect energy releases *via* human activities such as burning of fossil fuel, industrial emissions and other phenomenon like El Nino and La-Nina [15]. It is believed that synoptic weather is an important driver of air pollution episodes via certain physical and chemical processes such as turbulent mixing, long-range transport, photochemical production and deposition [16-18]. Data are available on the influence of air pollutants on regional and global climate but very few studies have assessed the impact of air pollutants to every day weather [19].

The importance of transportation cannot be overemphasized as it is responsible for the movement of people in and around the city and it is also vital to the survival of such cities [20]. Motor parks are widespread and common public spaces in urban areas in Nigeria because many people use public transport systems, however, they differ in design, nature and services [21]. The goal of establishing of motor parks is to provide satisfaction to its users and commuters [21-22]. Several motor parks in developing countries are in deplorable state and their settings

are not consistent with standards and best practices, hence incapable of delivering comfort and serenity to users [21]. Motor parks in Nigeria are public areas where various activities take place. In addition to vehicular emissions, there are other sources of emission in motor parks that release CO, CO_2 and other gases into the motor park ambient environment. Hence, this study was carried out to assess the levels of CO and CO_2 and their relationship with meteorological parameters in three major motor parks in Ibadan, Nigeria.

2. Materials and Methods

2.1. Study Area

The study area was Ibadan. Ibadan is the capital of Oyo State, one of the thirty six states in Nigeria. Strategically, positioned on longitude 3°53' east of Greenwich Meridian and latitude 7° 23' north of the equator, this ancient city is located near the forest grassland boundary of south western Nigeria. The distance from Lagos is about 145 km North East [23]. As described by [24], Ibadan is situated close to the boundary between forest and grassland, which makes it a meeting point for people and products of both the forests and grassland areas.

This research was carried out in three major motor parks in Ibadan: Akinyele Motor Park (AMP) in Akinyele Local Government Area (LGA); Iwo Road Motor Park (IMP) in Ibadan North East LGA and the 'New Garage' Motor Park (NMP) located in the Ibadan South West LGA, within Ibadan municipal area. AMP caters for transport linking northern region which includes Kaduna, Abuja, Kano and other major cities. IMP caters for transport needs of passengers going towards eastern region comprising Benin, Warri, Port Harcourt, Uyo, Calabar and others. NMP links other major cities in the south west which includes Lagos, Abeokuta, Epe, Ijebu- Ode, and other coastal towns. These study sites were chosen purposively as they are the major exit points to reach northern, eastern and other western parts of the country. Many transportation devices such as taxis, mini-buses and buses originate and terminate at these points [25].

2.2. Description of Sampling Points

Garmin GPS 60 was used to capture co-ordinates and elevation of three points in each motor park where monitoring of CO and CO_2 were done. Table 1 shows the sampling points in the motor parks and their corresponding co-ordinates and elevation.

Table 1. *Co-ordinates and elevation of sampling points at the motor parks.*

	Sampling points	Longitude	Latitude	Elevation
AMP, Ojoo	Point 1	N07.46704°	E003.91339°	243m
	Point 2	N07.46731°	E003.91332°	229m
	Point 3	N07.46757°	E003.91288°	231m
IMP, Iwo road	Point 1	N07.40205°	E003.94246°	239m
	Point 2	N07.40185°	E003.94242°	213m
	Point 3	N07.40152°	E003.94212°	230m
NMP, Apata	Point 1	N07.39480°	E003.81088°	213m
	Point 2	N07.39448°	E003.81087°	180m
	Point 3	N07.39436°	E003.81103°	175m

2.3. Data Collection

CO monitoring was done using Extech CO 10 meter. 8-hour CO measurement was taken in each motor park twice a week for two months (August and September, 2014). The measurements were taken at 1hour intervals in three strategic points (front, back and centre) in order to obtain the average CO measurement from 8am-4pm. CO_2 monitoring was done using Telaire 7001 carbon dioxide and temperature monitor at the motor parks. 8-hour CO_2 measurement was taken in each motor park twice a week for two months (August and September, 2014). The measurements were taken at 1hour intervals in three strategic points (front, back and centre) in order to obtain the average CO_2 measurement from 8am-4pm. Meteorological parameters such as temperature, humidity, rainfall, heat index, dew point and sea level pressure were monitored using Ventus W155 wireless weather station. 8-hour monitoring of weather parameters was done twice a week in each motor park for 2 months (August and September, 2014) from 8am-4pm at 1hour interval.

2.4. Data Management and Statistical Analysis

Data was entered and analysed using statistical package for the social sciences (SPSS) version 20. Descriptive and inferential statistics were used in this study. Descriptive statistics was used to summarize data. Mean ± Standard Deviation (SD) and range was calculated for CO levels of the motor parks and compared with WHO guideline of 9ppm for 8-hour monitoring [26]. Mean ± SD and range was also calculated for CO_2 levels of the motor parks and compared with ASHRAE guideline of 400 ppm [27]. Mean ± Standard Deviation (SD) and range was calculated for meteorological parameters such as temperature, humidity, rainfall, heat index, dew point and sea level pressure. ANOVA was used to test for any significant differences in the levels of CO and CO_2 recorded at the motor parks. Pearson correlation test was carried out to check for relationships between CO, CO_2 and the meteorological parameters.

3. Results

3.1. Mean CO Concentration at the Sampling Points

Table 2 shows the mean CO concentration (ppm) of sampling points for morning and afternoon at the motor parks. Generally, afternoon mean CO concentrations were higher than morning. At AMP, Ojoo, for morning and afternoon, sampling point 3 recorded the highest concentration (15.4 ± 7.5 and 19.5 ± 10.9) while sampling point 2 recorded the lowest (11.7 ± 2.7 and 13.8 ± 6.6) respectively.

At IMP, Iwo road, during the morning period, sampling point 3 recorded the highest value (15.1 ± 8.3) while sampling point 2 recorded the lowest (12.0 ± 5.2). During the afternoon period, sampling point 1 recorded the highest concentration (24.0 ± 16.0) while sampling point 2 recorded the lowest (16.2 ± 11.1). At NMP, Apata, during the morning period, sampling point 3 recorded the highest concentration (15.5 ± 8.0) while sampling point 2 recorded the lowest (9.74 ± 3.13). During the afternoon period, sampling point 1 recorded the highest concentration (26.3 ± 16.9) while sampling point 2 recorded the lowest (9.6 ± 3.5).

For the three motor parks, sampling point 3 at NMP, Apata recorded the highest concentration (15.5 ± 8.0) for morning while sampling point 2 at NMP, Apata recorded the lowest (9.7 ± 3.1). For afternoon, sampling point 1 at NMP, Apata recorded the highest concentration (26.3 ± 16.9) while sampling point 2 at NMP, Apata recorded the lowest (9.6 ± 3.5). All the mean concentrations were higher than WHO guideline of 9 ppm.

3.2. Mean CO_2 Concentration at the Sampling Points

Table 2 also shows the mean CO_2 concentration (ppm) of sampling points for morning and afternoon at the motor parks. Generally, afternoon mean CO_2 concentrations were higher than morning. At AMP, Ojoo, during the morning and afternoon periods, sampling point 3 recorded the highest concentration (397.7 ± 38.9 and 410.9 ± 17.4) while sampling point 2 recorded the lowest (371.4 ± 37.4 and 396.0 ± 24.0) respectively.

At IMP, Iwo road, during the morning and afternoon periods, sampling point 1 recorded the highest concentration (361.4 ± 61.0 and 407.9 ± 47.6) while sampling point 2 recorded the lowest (327.7 ± 46.9 and 350.0 ± 51.6) respectively. At NMP, Apata, during the morning period, sampling point 3 recorded the highest concentration (381.1 ± 35.2) while sampling point 2 recorded the lowest (365.3 ± 26.6). During the afternoon period, sampling point 1 recorded the highest concentration (419.9 ± 44.4) while sampling point 2 recorded the lowest (388.8 ± 41.5).

For the three motor parks, sampling point 3 at AMP, Ojoo recorded the highest concentration (397.7 ± 38.9) for morning while sampling point 2 at IMP, Iwo road recorded the lowest (327.7 ± 46.9). During afternoon period, sampling point 1 at NMP, Apata recorded the highest concentration (419.9 ± 44.4) while sampling point 2 at IMP, Iwo road recorded the lowest (350.0 ± 51.6).
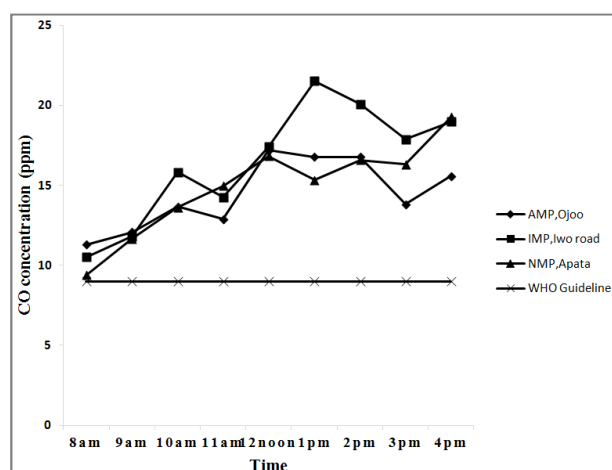
3.3. Temporal Variations in the Levels of CO

Fig. 1 shows the pattern of CO levels during the 8 hours of monitoring. For AMP, Ojoo, the chart shows that CO concentration (ppm) was lowest at 8am (11.3 ± 4.2) and highest at 12noon (17.2 ± 17.2). At IMP, Ojoo, CO concentration (ppm) was lowest at 8am (10.5 ± 3.1) and highest at 1pm (21.5 ± 15.0). At NMP, Apata, CO concentration (ppm) was lowest at 8am (9.4 ± 2.9) and highest at 4pm (19.3 ± 17.2). There was a statistically significant difference in the levels of CO across the 8 hours

of monitoring at the three motor parks (p<0.05).

*Table 2. CO and CO$_2$ mean±SD of the sampling points for morning and afternoon for the motor parks.*

	AMP, Ojoo					
	Point 1		Point 2		Point 3	
	Morning	Afternoon	Morning	Afternoon	Morning	Afternoon
CO	13.2±13.4	14.0±9.5	11.7±2.7	13.8±6.6	15.4±7.4	19.5±11.0
CO$_2$	396.4±22.9	404.9±13.5	371.4±37.4	396.0±24.0	397.7±38.9	410.9±17.4
	IMP, Iwo Road					
	Point 1		Point 2		Point 3	
	Morning	Afternoon	Morning	Afternoon	Morning	Afternoon
CO	14.8±7.0	24.0±16.0	12.0±5.2	16.2±11.1	15.1±8.3	18.7±13.1
CO$_2$	361.4±61.0	407.9±47.6	327.7±46.9	350.0±51.6	338.5±58.9	362.3±41.4
	NMP, Apata					
	Point 1		Point 2		Point 3	
	Morning	Afternoon	Morning	Afternoon	Morning	Afternoon
CO	14.7±9.3	26.3±16.9	9.7±3.1	9.6±3.5	15.5±8.0	14.8±5.0
CO$_2$	380.0±44.0	419.9±44.4	365.3±26.6	388.8±41.5	381.1±35.2	402.8±41.4

Figure 1. Concentration of CO during the 8 hours of monitoring.

3.4. Temporal Variations in the Levels of CO$_2$
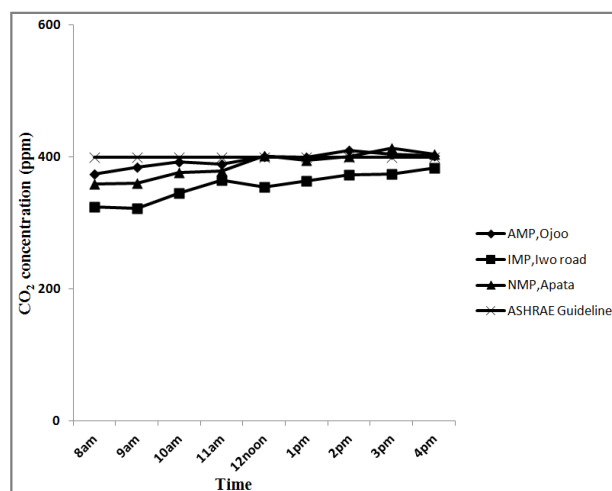
Figure 2. Concentration of CO$_2$ during the 8 hours of monitoring.

Fig. 2 shows the pattern of CO$_2$ levels during the 8 hours of monitoring. For AMP, Ojoo, the chart shows that CO$_2$ concentration (ppm) was lowest at 8am (374.6 ± 37.2) and highest at 2pm (409.9 ± 12.7). At IMP, Iwo road, CO$_2$ concentration (ppm) was lowest at 9am (322.3 ± 55.0) and highest at 4pm (383.5 ± 52.2). At NMP, Apata, CO$_2$ concentration (ppm) was lowest at 8am (358.9 ± 23.6) and highest at 3pm (413.9 ± 55.9). There was a statistically significant difference in the levels of CO$_2$ across the 8 hours of monitoring at the three motor parks (p<0.05).

3.5. Spatial Variations in the Levels of CO and CO$_2$

Table 3 shows the comparison of mean concentrations of CO and CO$_2$ at the three sampling points in each motor park, and the result of ANOVA shows that there were differences in the levels of CO and CO$_2$ at the sampling points in each motor park and the differences were statistically significant. (p<0.05).

Table 3. Comparison of levels of CO and CO$_2$ at sampling points of each motor park.

		Point 1	Point 2	Point 3	p-value
CO	AMP, Ojoo	13.6±11.8	12.6±4.9	17.2±1.4	0.000
	IMP, Iwo road	18.9±12.6	13.9±8.5	16.7±10.8	0.000
	NMP, Apata	19.9±14.4	9.7±3.3	15.2±6.8	0.000
CO$_2$	AMP, Ojoo	400.2±19.6	382.3±34.2	403.6±31.7	0.000
	IMP, Iwo road	382.1±59.7	337.6±49.9	349.1±52.8	0.000
	NMP, Apata	397.7+48.1	375.7±35.7	390.8+39.3	0.020

3.6. Mean and Range of CO and CO$_2$ for the Motor Parks

Table 4 shows the overall mean and range for CO and CO$_2$ in the motor parks. The overall mean CO concentration (ppm) for AMP, Ojoo, IMP, Iwo road and NMP, Apata were 14.5 ± 9.3, 16.5 ± 11.0 and 14.9 ± 10.2 respectively (p=0.009) while the range were 2.0-106.0, 2.0-83.0 and 2.0-90.0 respectively. For AMP, Ojoo, IMP, Iwo road and NMP, Apata, CO (ppm) concentrations were 82%, 83% and 75% higher than WHO guideline of 9ppm for 8hour monitoring
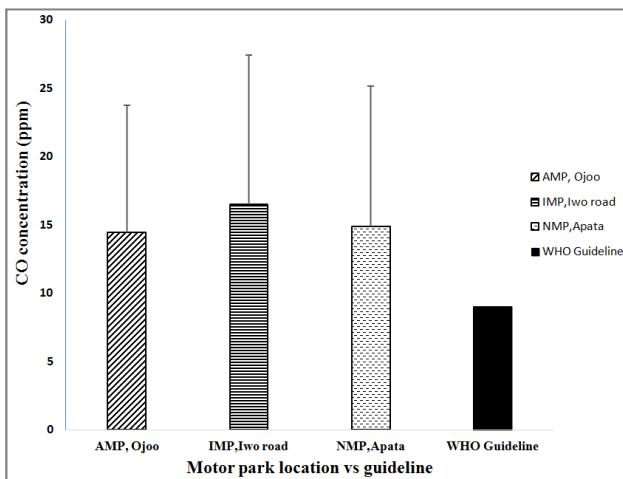
respectively. Generally, CO (ppm) concentrations were 80% higher than WHO guideline of 9 ppm for 8 hour monitoring across the motor parks.

Mean CO_2 concentration (ppm) for AMP, Ojoo, IMP, Iwo road and NMP, Apata were 395.4 ± 30.5, 356.3 ± 57.1 and 388.1 ± 42.1 respectively (p=0.000) while the range were 290.0-450.0, 255.0-524.0 and 320.0-560.0 respectively. These mean CO_2 concentrations are lower than ASHRAE guideline of 400 ppm.
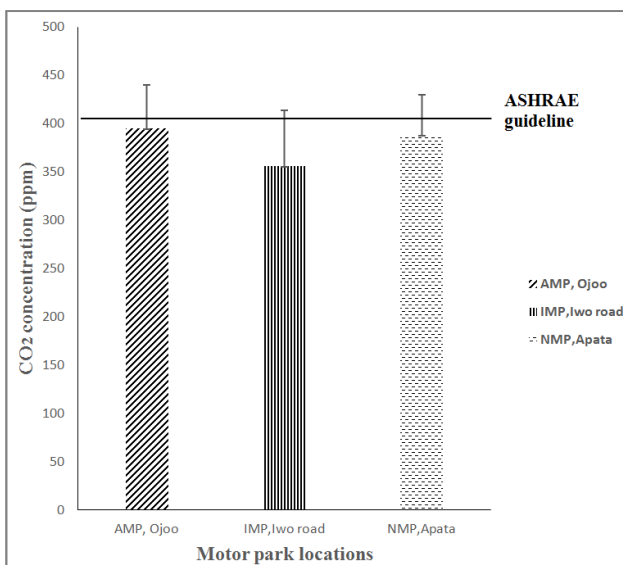
Figures 3 and 4 show the mean±SD of CO and CO_2 across the motor parks respectively.

Table 4. Mean and range of CO and CO_2 for the motor parks.

	AMP, Ojoo	IMP, Iwo road	NMP, Apata	p-value
CO(ppm)	14.5 ± 9.3	16.5 ± 11.0	14.9 ± 10.2	0.009
	2-106	2-83	2-90	
CO_2(ppm)	395.4 ± 30.5	356.3 ± 57.1	388.1 ± 42.1	0.000
	290-450	255-524	320-560	

Figure 3. Mean CO concentrations across the motor parks compared with WHO guideline.

Figure 4. Mean CO_2 concentrations across the motor parks compared with ASHRAE guideline.

3.7. Meteorological Assessment

Table 5 shows the mean ± SD and range of meteorological parameters assessed at the motor parks. AMP, Ojoo recorded the highest mean temperature (28.5 ± 2.6) while IMP, Iwo road recorded the lowest (28.4 ± 2.0). NMP, Apata recorded the highest mean humidity (82.0 ± 9.3) while AMP, Ojoo recorded the lowest (79.3 ± 9.8). AMP, Ojoo recorded the highest mean rainfall (278.0 ± 404.8) while NMP, Apata recorded the lowest (144.4 ± 206.6). NMP, Apata recorded the highest mean heat index (33.8 ± 8.4) while IMP, Iwo road recorded the lowest (32.9 ± 4.1). NMP, Apata recorded the highest mean dew point (25.1 ± 1.5) while AMP, Ojoo recorded the lowest (24.4 ± 1.4). NMP, Apata recorded the highest mean sea level pressure (1012.6 ± 2.0) while IMP, Iwo road recorded the lowest (1011.7 ± 4.3).

Table 5. Mean and range of meteorological parameters for the motor parks.

	AMP, Ojoo	IMP, Iwo road	NMP, Apata
Temperature (°C)	28.5 ± 2.6	28.4 ± 2.0	28.4 ± 2.3
	22.3-35.0	25.2-33.3	22.8-34.2
Humidity (%)	79.3 ± 9.8	79.5 ± 9.0	82.0 ± 9.3
	54.0-95.0	55.0-91.0	55.0-96.0
Rainfall (mm)	278.0 ± 404.8	205.1 ± 361.9	144.4 ± 206.6
	0.0-2309.0	0.0-2511.0	0.0-997.7
Heat Index(°C)	32.9 ± 5.5	32.9 ± 4.1	33.8 ± 8.4
	19.8-54.9	26.0-45.0	22.8-47.2
Dew point(°C)	24.4 ± 1.4	24.5 ± 1.3	25.1 ± 1.5
	21.4-30.5	22.3-28.0	19.3-28.8
Sea level pressure (hpa)	1012.1 ± 2.2	1011.7 ± 4.3	1012.6 ± 2.0
	1004.0-1018.0	993.0-1017.0	1005.0-1017.0

3.8. Relationships Between CO, CO_2 and Meteorological Parameters

Pearson correlation test was carried out between CO, CO_2 and the meteorological parameters as shown in Table 6. The table shows that there was a significant positive correlation between CO and CO_2 (r=0.258, p=0.000). Fig. 5 shows the strength of the linear relationship between the levels of CO and CO_2 (R^2=6.7%). A significant positive correlation was also recorded between CO and four meteorological parameters namely; temperature (r=.0164), rainfall (r= 0.105), heat index (r= 0.134) and dew point (r= 0.127) (p<0.05) while there existed a negative correlation between CO and the remaining two meteorological parameters, i.e, humidity (r= -0.114, p=0.018) and sea level pressure (r= -0.002).

A positive correlation was also found between CO_2 and four meteorological parameters namely; temperature (r= 0.276, p=0.000), rainfall (r=0.125), heat index (r= 0.232, p=0.003) and dew point (r=0.028) while a negative correlation was recorded between CO_2 and the remaining two meteorological parameters i.e humidity (r= -0.286, p=0.000) and sea level pressure (r= -0.172, p=0.035).

There existed a significant negative correlation between temperature and two other meteorological parameters namely humidity (r= -0.795, p=0.000) and sea level pressure (r= -0.230, p=0.000), while temperature correlated positively with rainfall (r=0.155, p=0.001), heat index (r= 0.706, p=0.000) and dew point (r=0.413, p=0.000).

There was a significant positive correlation between humidity and two other meteorological parameters, namely; dew point (r= 0.210, p=0.000) and sea level pressure (r= 0.219, p=0.000), while a significant negative correlation existed between humidity and heat index (r= -0.431, p=0.000).

A significant positive correlation was observed between rainfall and two other meteorological parameters, namely; heat index (r= 0.163, p= 0.001) and dew point (r= 0.188, p=0.000). A positive correlation existed between heat index and dew point (r= 0.651, p= 0.000) while a negative correlation was noticed between heat index and sea level

pressure (r= -0.223, p= 0.000).
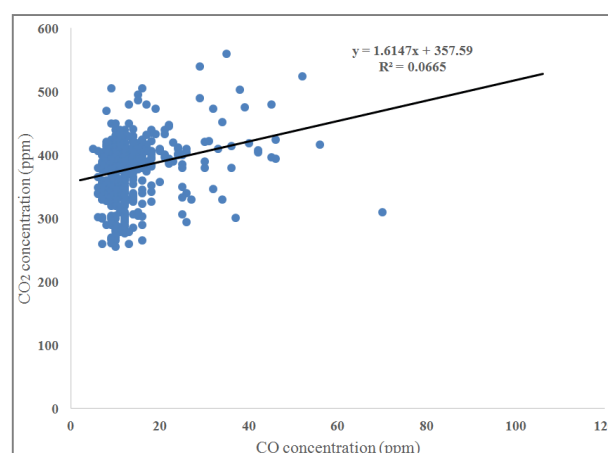

$y = 1.6147x + 357.59$
$R^2 = 0.0665$

Figure 5. Relationship between levels of CO and CO_2 at the motor parks.

Table 6. Correlation between CO, CO_2 and meteorological parameters.

Pearson Correlation coefficient Sig (2 tailed)	CO(ppm)	CO₂(ppm)	Temperature (°C)	Humidity (%)	Rainfall (mm)	Heat index(°C)	Dew point (°C)	Sea level pressure (hpa)
CO(ppm)	1							
CO₂(ppm)	0.258** 0.000	1						
Temperature (°C)	0.164** 0.001	0.276** 0.000	1					
Humidity (%)	-0.114* 0.018	-0.286** 0.000	-0.795** 0.000	1				
Rainfall (mm)	0.105* 0.029	0.125 0.113	0.155** .155**	-0.048 0.319	1			
Heat index(°C)	0.134** 0.005	0.232** 0.003	0.706** 0.000	-0.431** 0.000	0.163** 0.001	1		
Dew point (°C)	0.127** 0.010	0.028 0.735	0.413** 0.000	0.210** 0.000	0.188** 0.000	0.651** 0.000	1	
Sea level pressure (hpa)	-0.002 0.970	-0.172* 0.035	-0.230** 0.000	0.219** 0.000	-0.003 0.945	-0.223** 0.000	-0.048 0.346	1

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

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

4. Discussion

Generally, afternoon mean CO concentrations were higher than morning. This may be due to increased influx of vehicles into the motor parks in the afternoon. This result is in line with the study by [28] in Enugu, Nigeria but at variance with studies by [29] in Lafia metropolis and [30] in Benin City where CO concentration was higher in the morning but lower in the afternoon.

There were variations in the mean CO concentration at the sampling points in the motor parks. This was due to the fact that, at each sampling point in the motor parks, activities that emit CO differ in degree and frequency. The pollution level at these sampling points varied as observed during CO monitoring in the motor parks and the difference in mean CO level across the sampling points was significant for the motor parks, hence, there were spatial variations in CO levels for the motor parks. The pattern of CO emissions during the 8 hours of monitoring revealed that there were temporal variations in CO concentrations across the three motor parks.

This result is supported by [31] who stated that ambient CO concentrations have daily and seasonal variations, as well as complex spatial distributions.

IMP, Iwo road recorded the highest mean CO concentration (ppm) (16.5±11.0) while AMP, Ojoo recorded the lowest (14.5±9.3). There was significant difference in the mean CO concentration of the motor parks (p=0.009), hence, the motor parks vary in CO levels. The highest mean CO concentration recorded at IMP, Iwo road may be attributed to high vehicular density in the motor park than others. According to a study by [32], mean CO concentration at Iwo road near overhead bridge was 86 ppm while it was 32.5ppm at Ojoo trailer park. These mean CO concentrations were higher than the mean CO concentrations recorded in this study.

There were spatial and temporal variations in CO concentrations across the three motor parks and this is corroborated by the study by [30]. All the mean CO concentrations across sampling points, during the 8 hours of monitoring and overall mean for the motor parks were above the WHO guideline of 9 ppm [26].

The CO range (ppm) for AMP, Ojoo, IMP, Iwo road and NMP, Apata were 2.0-106.0, 2.0-83.0 and 2.0-90.0 respectively and generally, these CO concentrations (ppm) were 80% higher than WHO guideline of 9 ppm for 8hour monitoring across the motor parks. Hence, motor park traders are exposed to high concentration of CO in the motor parks. This finding is supported by a study that investigated the ambient carbon monoxide and carboxyhaemoglobin levels in Ibadan City, Nigeria by [33], it was reported that ambient carbon monoxide levels in Ibadan city were between 3.0 and 55.0 ppm with a mean value and standard deviation of 20.12 ± 1.40ppm. The study indicated that Ibadan city dwellers were generally exposed to higher levels of CO than WHO permissible guideline limit. Vocations and occupations requiring workers to spend long periods on the highways are at higher risk of exposure. Potential exposures that exceed the existing guideline may be of greater concern to public health because they increase the total body burden for CO [34].

Generally, afternoon mean CO_2 concentrations were higher than morning. This may also be due to increased influx of vehicles into the motor parks in the afternoon, and also increase in air pollution related activities in the motor parks. This could also be explained by stating that CO is co-emitted with CO_2 from combustion sources [7], hence, increase in CO concentration in the afternoon when compared to morning will result in increased CO_2 concentration in the afternoon as compared to morning.

There were variations in the mean CO_2 concentration at the sampling points in the motor parks. This is due to the fact that at each sampling point in the motor parks, CO_2 emitting activities vary. The emission levels at these sampling points differ as observed during CO_2 monitoring in the motor parks and the difference in mean CO_2 levels across the sampling points was statistically significant for the motor parks, hence a spatial variation in CO_2 level was observed for the motor parks. The pattern of CO_2 emission during the 8 hours of monitoring revealed that there were temporal variations in the CO_2 concentration across the three motor parks.

AMP, Ojoo recorded the highest mean CO_2 concentration (395.4 ± 30.5) while IMP, Iwo road recorded the lowest (356.3±57.1). This result is similar to that reported in a study by [8] where the mean CO_2 concentration in traffic area TA (TA comprised of Ojoo park, Mokola round about, Agbowo complex area, Challenge park and Oluyole Industrial area) was highest at 390 ± 64 ppm during the rainy season. However, the result of this study is lower than that reported by [35], in which CO_2 concentration was as high as 1710 ppm at Kawo motor park in Kaduna.

There was significant difference in the mean CO_2 concentration across the motor parks (p=0.000), hence, the motor parks vary in CO_2 concentrations. All the mean CO_2 concentration of the motor parks are below ASHRAE guideline of 400 ppm [27]. There was a significant positive correlation between CO and CO_2 (r=0.258, p=0.000, R^2=6.7%). CO is co-emitted with CO_2 from combustion sources, leading to a significant positive correlation between them when combustion is a significant source of observed CO_2 [7]. There was a significant positive correlation between CO and temperature (r= 0. 164, p= 0.001). This could be attributed to the fact that internal combustion engines of vehicles perform better in cold temperature and emit less CO but as temperature increases, the engine efficiency reduces, hence, releasing more CO into the motor park ambient environment. A study by [36] at Gaza strip reported a positive correlation between outdoor CO and outdoor temperature during winter.

CO concentrations in the motor parks have significant relationships with meteorological parameters, hence, meteorology has influence on the levels of CO in the motor parks. This assertion is corroborated by [31] who noted that meteorological conditions highly influence CO levels in urban regions. There was also a significant positive correlation between CO_2 and temperature. This is expected as CO is co-emitted with CO_2 from combustion sources [7]. However, in a study by [37] in Poland, significant negative correlation was found between CO_2 and air temperature. This is further corroborated by a study by [19] in Eastern China that showed that intense air pollution significantly affects local synoptic weather by influencing certain weather parameters indicating clear air pollution–weather interactions. Generally, for the motor parks, temporal variations were observed for all meteorological parameters and there were marked relationships between them.

5. Conclusion and Recommendations

This study assessed levels of CO and CO_2 and their relationships with meteorological parameters in three major motor parks in Ibadan, Nigeria. Mean CO concentration for afternoon was higher than that of morning at the motor parks due to increased influx of vehicles into the motor parks in the afternoon, and also increase in air pollution related activities. There were temporal variations in CO concentration across the 8 hours of monitoring and spatial variations across the sampling points for the motor parks. IMP, Iwo road recorded the highest mean CO concentration while AMP, Ojoo recorded the lowest. Generally, CO (ppm) concentrations were 80% higher than WHO guideline of 9 ppm for 8 hour monitoring across the motor parks. Therefore, motor park users are exposed to high concentrations of CO and are susceptible to effects of CO exposure.

Mean CO_2 concentration for afternoon was higher than that of morning at the motor parks due to increased influx of vehicles into the motor parks in the afternoon, and also increase in air pollution related activities. There were temporal variations in CO_2 concentration across the 8 hours of monitoring and spatial variations across the sampling points for the motor parks. AMP, Ojoo recorded the highest mean CO_2 concentration while IMP, Iwo road recorded the lowest. The mean CO_2 concentrations for the motor parks were lower than ASHRAE guideline of 400 ppm.

There was a significant positive correlation between CO and CO_2. Generally, CO and CO_2 concentrations in the motor parks have significant relationships with the meteorological

parameters, hence, meteorology has influence on the levels of CO and CO_2 in the motor parks. Temporal variations were observed for all the meteorological parameters across the 8 hours of monitoring at the motor parks and there were marked relationships between them.

Fixed site CO and CO_2 monitoring equipment should be installed at the motor parks to ensure regular assessment of these gases at the motor parks so that they do not exceed guideline limits.

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