ASSESSMENT OF CARBON DIOXIDE EMISSION AT ROAD JUNCTIONS IN THE SOUTHEAST OF NIGER STATE, NIGERIA

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ABSTRACT

This study assesses the levels of atmospheric carbon dioxide (CO2)emission at road junctions in three major cities in the southeast of Niger State in Nigeria, namely: Minna, Bida and Suleja, and identifies measures that improve traffic operations while reducing the emission levels that could have implications on global warming, and hence, climate change. For the study, handheld Crowcon Gasman CO2 gas meter was used to record the CO2 emission readings in parts per million (ppm) during peak (8.00am – 9:00am and 4:30pm – 6:30pm) and off-peak periods (11.30am – 12.30pm and 7:30pm – 8:30pm) of traffic flow at the selected locations within these cities. During peak periods in these locations, the highest emission values of 3236ppm (Park and Garden Junction, Suleja), 3043.5ppm (Mobil Roundabout, Minna) and 3036ppm (BCCC Junction, Bida) were recorded at the road junctions ("hotspots") with the highest average traffic volume (i.e. motor bikes, buses, trucks and cars) of 4511, 4529 and 3479 respectively. On the average, the level of emission of CO2 recorded at the major road junctions in Suleja, Minna and Bida were 2,856.6ppm, 2,731.1ppm and 2,518.1ppm respectively. The results established that the emission levels in these three cities was approximately eight times more than the internationally accepted safe limits of 350ppm for atmospheric CO2, but less than the Occupational Safety and Health Administration (OSHA) permissible exposure limits of 5,000ppm which has adverse health effects, and may contribute to climate change, in the long term, if unmitigated. The immediate enforcement of traffic congestion mitigation measures for the road junctions in Suleja, the closest to the FCT, Abuja is recommended.

Keywords: Minna, Federal Capital Territory, Carbon dioxide emissions, Climate change, Road transportation, Traffic Congestion Mitigation Measures

1   INTRODUCTION

It has been proven scientifically that atmospheric CO2 concentration has increased from approximately 280 parts per million (ppm) in pre-industrial times to 397ppm in 2005, a 42% increase (IPCC 2007). In order to reduce the ongoing climate change caused by this increase, Hansen et al. (2008) had proposed, using paleoclimate evidence, that global atmospheric CO2 concentration will need to be reduced from this current level to at most 350 ppm. This has become the internationally accepted target that may be required to stabilize global average temperatures within a likely range of 0.6–1.4°C above pre-industrial values and preserve the state on which civilization developed and to which life on Earth is adapted. Consequently, to prevent further increase in CO2, developed and emerging economies are intensifying efforts to develop and utilize alternative sources of fuel for their energy sector, which includes transport. Recent studies have shown that transportation is a major contributor to the emission of the key greenhouse

gas; carbon dioxide (CO2), whose increasing levels of concentration has been attributed to be the major cause of global warming. According to Environment Canada (2010), transportation was responsible for 27% of the total GHG emissions in 2007, and 69% of this was accounted for by road transportation. Furthermore, compared with the 1990, emissions level in 2007 had gone up to 35% for private vehicles, almost doubling the growth rate of Canada's population during the same period.

In 2011, 83.7% of the total greenhouse gas emissions in the US were from CO2 obtained mainly from fossil fuel combustion. Transportation activities accounted for 33% of these emissions; with the highest contribution coming from road transportation (light duty vehicles represented 61% of CO2 emissions, while medium- and heavy-duty trucks represented 22%). From 1990 to 2011, an increase in 18% was recorded (EPA 2013). In the EU, road transportation contributed about one-fifth of the total emissions of carbon dioxide (CO2), whose emission had increased by nearly 23% between 1990 and 2010; In South Africa, road transportation contributed greatly to the increase in CO2 in the transport sector 12 % in 1990 to 14.8 % in 1994 (Naude et al., 2000), while in India, 12% of the transport sector's emissions was CO2 in 2000 and an increase of 37% was recorded between 1990 and 2000. Road transportation is such a high contributor of CO2 because the complete combustion of petrol produces carbon dioxide (13%) and water (13%), while nitrogen from the air comprises most of the remaining exhaust (73%). The latter is converted to nitrogen oxides and some nitrated hydrocarbons. Thus, implying that, a larger percentage of the tailpipe exhausts are carbon dioxide and carbon monoxide (Pedersen et al, 2003). Therefore, given the fact that as economies develop, there is the increasing need to travel, WBCSD (2001) reported that emissions from this sector is still growing. In fact, it was further emphasized that the global emissions from different transport sectors in the year 2000 will affect the future temperature and this includes emissions from the 'wells to wheels' approach of fuel production and distribution (Weiss et al, 2000; Mizsey and Newson, 2001; Johannsson, 2003).

In Federal Republic of Nigeria (2006), it was reported that CO2 emissions in Nigeria increased by about 54 percent (from 68.5 million metric tons to 105.2 million metric tons) within two and half decades (1980-2005) and a steady rise had been recorded since 1997. They attributed this steady increase to the utilization of fossil fuel in the transport sector, especially because of the importation of old and fairly used vehicles ('tokunbo') and the increasing use of motorcycles ('okada') for public transportation. Consequently, road congestion increased and aggravated transport-related pollution in the country. Statistics on vehicle registration showed an increase from 38,000 to 1.6 million registered vehicles between 1950 and 1992 (Enemari, 2001). Abam and Unachukwu (2009) have also reported that the Federal Road Safety Commission of Nigeria (FRSC) had registered about six million (6,000,000) vehicles between 1999 and 2004 and that 70% of these were cars while 30% were buses and trucks. On the average, these have increased emissions from road transportation in Nigeria.

However, empirical studies on this observation are few as most studies that have been conducted emphasize oil industry pollution (Faboya, 1997; Iyoha, 2000; Magbagbeola, 2001, and Orubu et al., 2002). While other studies focus on the health implications of the magnitude of the problem of air pollution from road transportation and not the contribution to global warming (World Bank, 1995; Garba and Garba, 2001). For example, Abam and Unachukwu (2009) studied the concentration of total suspended particles (TSP), nitrogen oxides (NOx), sulphur dioxide (SO2) and carbon monoxide (CO) in Lagos and Port Harcourt and discovered that the limit recommended for Nigeria had been exceeded. In this study, the TSP concentration for both cities was rather high in comparison to the 24-hour mean of 50 micrograms per cubic meter (μg/m3) recommended by World Health Organization (WHO). Osuntogun and Koku (2007) assessed the impacts of urban road transportation on the ambient air pollutants, namely CO, SO2, and NO2 in three cities in the southwest region in Nigeria: Lagos, Ibadan and Ado- Ekiti. The results obtained for each city exceeded the Federal Ministry of Environment of Nigeria's recommended upper limits of 10ppm, 0.01ppm and 0.04 to 0.06ppm for CO, SO2, and NO2 respectively (Anonymous 1991). Abam and Unachukwu (2009) conducted a similar investigation of vehicular emissions in selected areas in Calabar, Nigeria, which indicated that the results of CO, NO2, SO2, and PM10 were within the range of 3.3-8.7ppm, 0.02 – 0.09ppm, 0.04 – 0.15ppm and 170 - 260μ

g/m3 respectively. Although this study did not include CO_2 in the sampled gases, the concentration of pollutant gases sampled was high due to the volume of traffic. Jerome (2000) conducted a comparative analysis of emission levels of TSP, NOx, SO2, and CO in Lagos and the Niger Delta cities of Port Harcourt and Warri. The results obtained for CO levels for Lagos ranged between 10ppm to 250ppm. The levels of these pollutants were higher than those obtained in the Niger Delta and cannot be adopted for other cities in Nigeria. However, this observation is contrary to the recommendation made by Orubu (2001) that the pollution levels in Lagos and the Niger Delta are comparable to those from automobile sources in different cities and zones in Nigeria. Furthermore, the levels obtained exceeded the minimum stipulated standard for the country.

The results of the above mentioned studies generally indicate that there are increasing risks of traffic-related problems that require serious measures to be implemented in order to curb air quality problems. It is noteworthy that most of the studies highlighted above focused on air pollution and not the contribution of these greenhouse gases to global warming. This includes the study conducted by Akpan and Ndoke (1999) in Northern Nigeria which showed higher values of CO_2 concentration (1780ppm- 1840ppm) in heavily congested areas in Kaduna and (1160ppm-1530ppm) in Abuja. Furthermore, in its Fourth Assessment Report, the Intergovernmental Panel on Climate Change (IPCC) had projected that world transport energy use will increase at the rate of about 2% per year with carbon emission projected to increase over current levels by approximately 80% by 2030 (IPCC 2007).

This study was conducted in response to the above mentioned grave projection by IPCC (2007). Therefore, the purpose of this paper is to carry out an empirical study on emissions of the key greenhouse gas, CO_2, across the study area. This is in addition to the fact that the proximity of Niger State to Abuja, the Federal Capital Territory of Nigeria has impacted both negatively and positively on the socio-economic development of Niger State and road transportation is a major driver of this development. With this development, comes the negative consequence of increasing levels of CO_2 in key destinations in the State. It also assesses the levels of CO_2 emission at selected major road junctions in three major towns in the southeast of Niger

State, namely Minna, Bida and Suleja and identifies measures that improve traffic operations while reducing the emission levels that could have implications on global warming, and hence, climate change. Furthermore, it is expected that the results will serve as a pilot for developing a more comprehensive database for future comparative analyses of CO_2 emission levels within the study area, and across Nigeria.

2   METHODOLOGY

2.1   Description of Study Area

Figure 1 (a) and (b) show the location of Nigeria in Africa and Niger State in a map of Nigeria. Niger State covers approximately 8.6 million hectares (86,000km2) of land (about 9.6% of Nigeria's land mass) and shares its western border with the Republic of Benin, while Kebbi, Zamfara, Kaduna, Kwara, and Kogi States are located at the north western, north, north eastern, south western and southern border respectively. The Federal Capital Territory (FCT), Abuja, which is located at the centre of the country, occupies the south eastern border of Niger State. According to the 2006 population census, the population of Niger State was 3, 950,249 which spreads across 26 Local Government Areas.

Figure 1(c) shows the three Local Government Areas (LGAs) selected for this study, namely, Minna (Latitudes 9° 36' 50"N and Longitude 6° 33' 25"E), Bida (Latitude 9° 05' 00" N and Longitude 6° 01' 00" E) and Suleja (Latitude: 9° 10' 33 N, Longitude: 7° 10' 51 E) with areal coverage of 74km2, 51km2 and 154km2 respectively. While Minna is the capital of Niger State with a population of 201,429 in 2006, Bida and Suleja are major towns with historical significance in the development of the State, with a population of 188,181 and 216,578. Thus, in comparison to other LGAs, the population density of Minna, Bida and Suleja rank 2nd, 1st and 3rd.
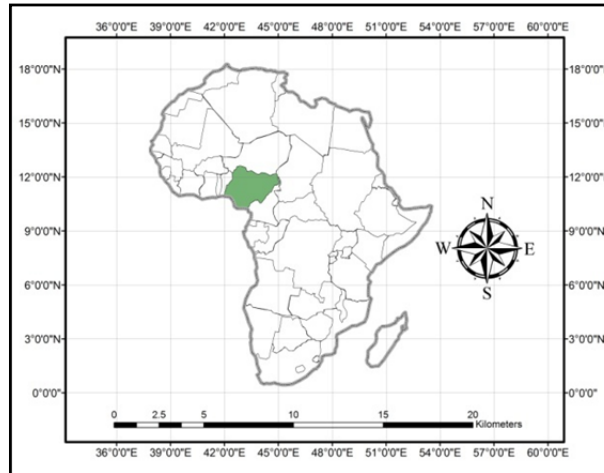
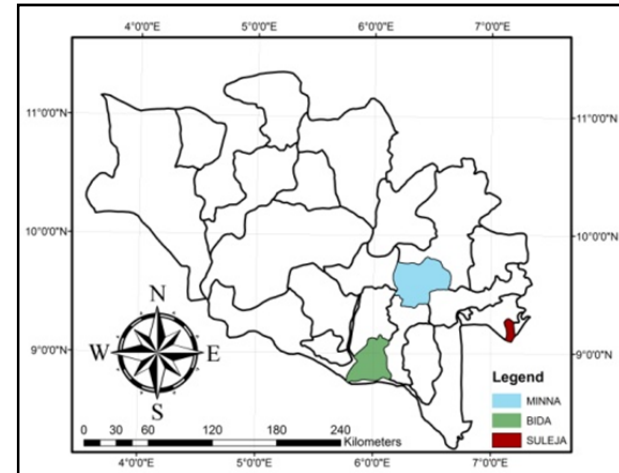Figure 1a: The Location of Nigeria in a Map of Africa (Adapted from www.mapsofworld.com)

Figure 1c: A map of Niger State showing the three selected cities: Minna, Bida and Suleja (Adapted from http://nationalmirroronline.net)
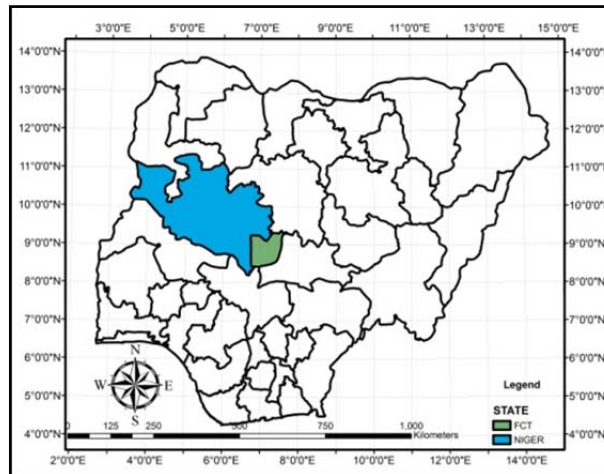

Figure 1b: A map of Nigeria showing Niger State and the Federal Capital Territory, Abuja (Adapted from www.wadoo.org)

Physical development in the three cities is poorly planned. Generally, the major mode of transportation in the State is road transportation. The network of roads comprises about 1384 km of asphalt, 207 km of surface dressing and 1731km of earth roads. In 2008, the total length of Federal Government roads was 2,189km comprising 1,586 Trunk A roads and 603.2 secondary routes. Although, specific breakdown of this statistics for the three locations selected for this study are unavailable, Minna, the capital of Niger State fares better, in terms of quality and quantity. However, like in most Nigeria roads, there are no routes specifically designed for use by motorcyles. The most commonly used mode of public transportation in three cities is mainly motorcycles, followed by cars and then buses. Generally, in Nigeria, motor vehicle ownership is about 31 per 1000 people (World Bank, 2007), while motorcycle ownership is rapidly rising amongst the low income group because it is used for commercial purpose. In Niger State, specifically, the number of registered vehicles increased from 5,766 to 1,561,699 in 2004 to 2009. Within this period of 5 years, the number of registered cars, buses, trucks and motorcycles increased from 1,868; 1,468; 214 and 2,126 to

568,512; 10,396; 20,413 and 962,288 respectively. Respectively, they are 160km, 212km and 56 km away from the Federal Capital Territory of Nigeria, Abuja, one of Africa's rapidly developing, European style cosmopolitan cities. In terms of city planning, the major urban areas in Niger State are experiencing growth that is unplanned and uncontrolled. Characterized by this spontaneous development of large and rapidly growing slums and squatter settlements, roads, among other infrastructure, are grossly inadequate.

2.2 Data Collection and Analysis

The sampling points for the measurement of CO_2 emissions were eight (8) major road junctions in each of the three locations of interest. These road junctions connect the major residential and commercial areas, while those observed to be the busiest in terms of traffic volume (hotspots) were identified from a pre-field data collection phase. Vehicular count for each of the hotspots was recorded for cars, motorcycles, buses and trucks. Bar graphs were plotted to show the distribution of each type of vehicle recorded within the period of study. The traffic volume was determined by manually counting the observed frequency of movement of each vehicle type over a period of four hours daily. These four hours were spread to include morning (AM) and evening (PM) peak periods of traffic flow between 8.00am – 9:00am and 4:30pm – 5:30pm as well as morning (AM) and evening (PM) off-peak periods of 11.30am – 12.30pm and 7:30pm – 8:30pm.The data collected were used in describing the impact of traffic congestion on CO_2 emissions within the southeast of Niger State. Based on this, the realistic traffic congestion mitigation measures that could be enforced across the State were identified.

To collect data on CO_2 emissions, Crowcon Gasman carbon dioxide handheld gas meter was used for recording the levels of emission in parts per million at the pre-selected sampling points. It was also fully calibrated by the suppliers of the instrument. A handheld CO_2 gas meter was used because of its high sensitivity to outdoor CO_2 detection as demonstrated by the study conducted by Akpan and Ndoke (1999). For each of the cities, three readings were taken at each of the eight selected road junctions and the average level of CO_2 emission at each point was calculated and recorded. These readings were taken during the dry season month of November, in order to ensure that similar weather conditions were maintained during the period of data collection. Although, the measurements were not taken simultaneously at the selected locations, efforts were made to ensure that the above mentioned time periods were strictly adhered to. Subsequently, bar graphs were plotted to compare the levels of CO_2 emissions recorded at the selected road junctions within the selected towns, the internationally accepted safe limit of 350 ppm for atmospheric CO_2 and the OSHA stipulated limit of 5000ppm.

Further statistical analysis was undertaken using INSTAT version 3.36 Statistical Software to calculate the variance of the emission levels across each of the selected locations using Single Factor Analysis of Variance (ANOVA One Way) at 0.05 significant levels. This test was conducted using:

(a) The null hypothesis that "there are no significant differences between the mean values of the levels of CO_2 emission under the assumption that the variances of the three samples are all equal"

(b) The hypothesis that "there are significant differences between the mean values of the levels of CO_2 emission under the assumption that the variances of the three samples are all equal".

3 RESULTS AND DISCUSSION

3.1 Traffic Volume and CO2 Emissions at the Selected Major Road Junctions

Although, traffic congestion increases fuel consumption, costs of vehicle operation, time and loss of productivity and congestion related accidents; the emphasis of this aspect of the study is on its impact on level of emissions of CO_2. The road junctions with the highest traffic volume in Minna, Bida and Suleja, namely, Mobil Roundabout, BCCC Junction and Park and Garden Junction were congested with traffic during peak periods (AM and PM)

being important links to major parts of the three towns. Considering the fact that nearly all roads in many cities as well as many inter-city expressways and highways in Nigeria have become impassable due to lack of maintenance (French et al.,1998), critical and cost effective measures must be taken to reduce the level of CO_2 emissions. The fact that in 2004 to 2009 in Niger State, the number of registered vehicles had increased from 5,766 to 1,561,699, underscores the urgent need for these measures to be implemented.

Figure 2 (a-c) shows that the average number of motorcycles plying the selected routes during AM and PM peak and off-peak periods was higher than any other type of vehicle, with the exception of off-peak hours in Suleja. This is explained by the fact that the Park and Garden road junction in Suleja city is strategically located at the very busy entrance into the city and well as the FCT, Abuja from Minna and other sub-urban areas in the outskirts of the city. During PM off-peak periods, most of these motorcycles are already within the busy Suleja city centre, not the outskirts of the city, where Park and Garden road junction is located. Motorcycles are a very convenient means of transportation on non-motorable roads found in the nook and crannies of the city.

Furthermore, the FCT, Abuja is the administrative capital of Nigeria, but most of the civil servants reside in satellite towns around the city and in Suleja (Ejaro and Abdullahi, 2013). During peak periods in Suleja, the rate of vehicular and distance covered by inter- and intra-city commuting increases. Hence, the volume of vehicular traffic is also high. Therefore, traffic congestion has become the norm during the AM and PM peak periods as workers commute to and from work during the week; as well as when they undertake various socio-economic activities.

Evidently, on the average, the high values of CO_2 emission recorded at AM and PM peak and off-peak periods are closely linked to traffic congestion at the selected road junctions. This is mainly because of "acceleration and deceleration" events associated with stop-and go-traffic situations at the road junctions, a problem that also leads to increased fuel consumption.
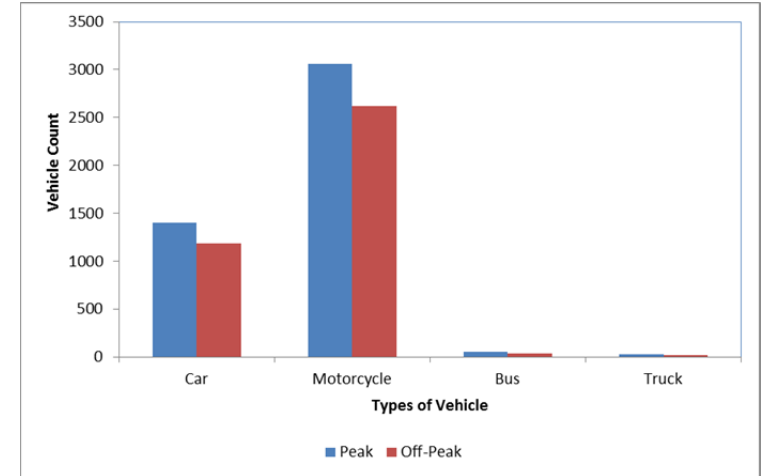

Figure 2a: The distribution of types of vehicles plying Mobil Roundabout during peak and off-peak periods in Minna, southeast of Niger State
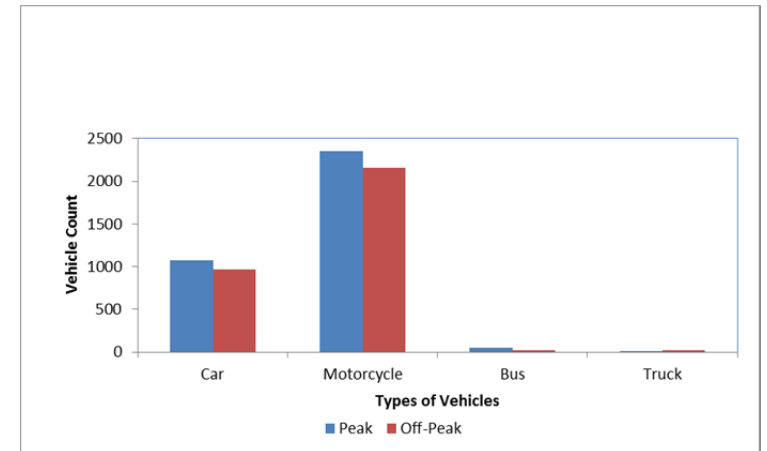

Figure 2b: The distribution of types of vehicles plying BCCC roundabout during peak and off-peak periods in Bida, southeast of Niger State
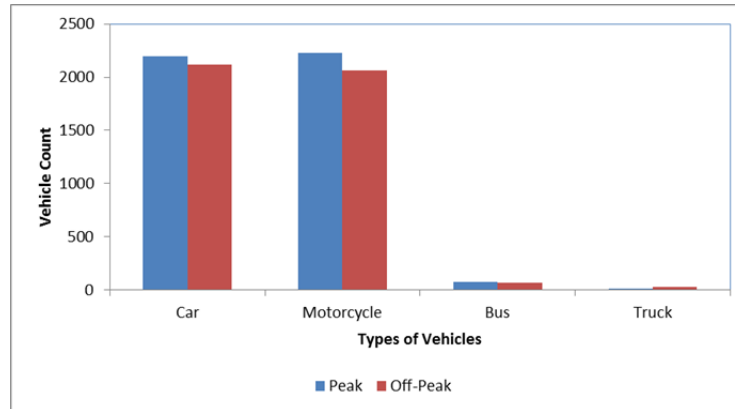
Figure 2c: The distribution of types of vehicles plying Park and Garden roundabout during peak and off-peak periods in Suleja, southeast of Niger State

Sometimes, these congestions cover a distance of at least one kilometer long for at least one hour, with bumpers almost touching. For additional emphasis on the relationship between traffic volume and CO2 emission levels, Table 1 indicates the average traffic volume and associated CO2 emission levels recorded at Mobile roundabout, BCCC junction and Park and Garden roundabout. It also shows clearly that Park and Garden roundabout in Suleja city has the highest average traffic volume of 4394 with average CO2 emission value of 3043ppm recorded within the period of study.

Table 1: The average traffic volume and associated CO_2 emission levels recorded at the road junctions with the highest volume of traffic in Minna, Bida and Suleja during the period of study

	City	The Selected Road Junction	Average Traffic Volume for the Peak Periods	Average CO_2 Emission for Peak Periods (ppm)	Average Traffic Volume for the Off-peak periods	Average CO_2 Emission for Off-Peak Periods (ppm)	Average Traffic Volume for the Peak and Off-Peak Periods	Average CO_2 Emission for Peak and Off-Peak Periods (ppm)
1	Suleja	Park and garden junction	4511	3236	4276	2850	4394	3043
2	Minna	Mobil roundabout	4529	3043.5	3857	2870	4193	2956.8
3	Bida	BCCC Junction	3479	3036	3159	2570	3319	2803

From the previous description of the composition of vehicles that ply Park and Garden roundabout, the greatest contributors to this high emission level are the duration, extent, intensity and reliability of congestion rather than the vehicle type. This is attested to by studies conducted by Chan et al. (1995), whose results show that not only is the fuel economy of motorcycles three to four times that of passenger cars, but also that the emissions of CO_2 of one car is equivalent to those of about three to eight motorcycles' emissions (Vasic and Weilenmann, 2006); and also by Yao et al. (2009), in his conclusion that CO_2 emission is lowest for the four-stroke motorcycles. Based on these, it is apparent that the greatest contributor to the high levels of CO_2 was mostly emitted by the cars that ply the road junctions rather than the large number of motorcycles recorded. Though outside the scope of this paper, it is worthy of mention that emissions from motorcycles contribute to serious pollution problems through their emission of as much as 40% of particulate matter and CO_2, 50% of carbon monoxide, and 70% or more of volatile organic compounds (VOCs) in some Asian cities (Darido et al., 2013), and thus, may constitute serious health hazards to motorists at road junctions.

3.2 CO2 Emissions at the Selected Road Junctions in the Southeast of Niger State

Figure 3 summarizes the variation of the levels of CO_2 emissions at the selected road junctions in the three cities in the southeast of Niger State, namely Minna, Bida and Suleja. In Minna (see Figure 3a), the road junction with the highest level of emission during peak periods (AM and PM) is Broadcasting road, while Mobil roundabout has the highest off peak emission. The explanation for this difference is that the former is located in a densely populated part of the city, and traffic congestion is more intense on the narrow, single lane T-junction when commuters leave for work on weekdays.
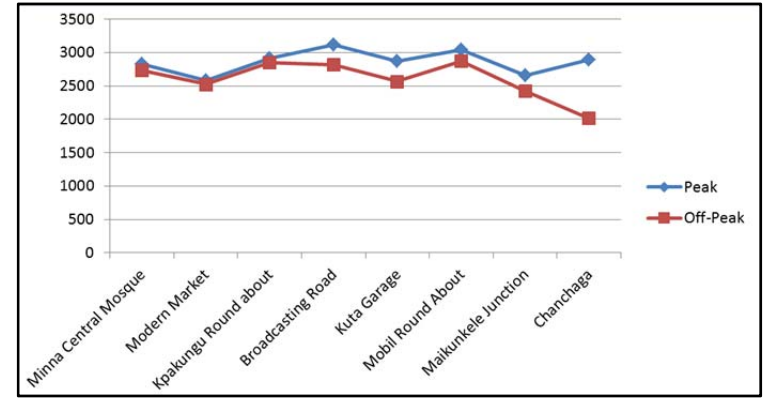

Figure 3a Varying levels of peak and off-peak CO2 emission at the selected road junctions in Minna, southeast of Niger State
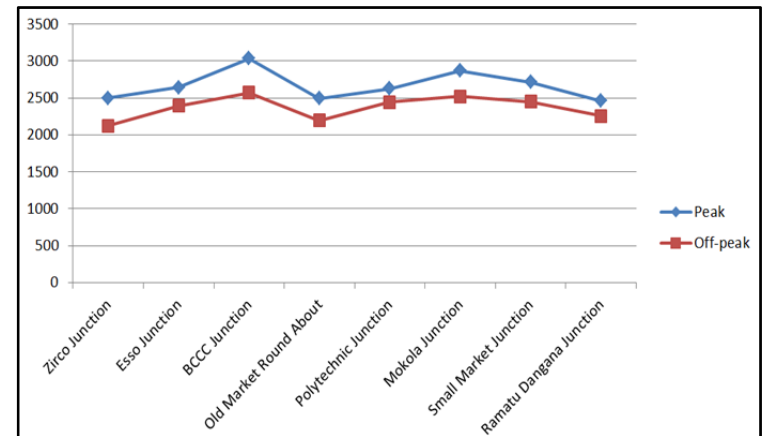

Figure 3b Varying levels of peak and off-peak CO2 emission at the selected road junctions in Bida, southeast of Niger State
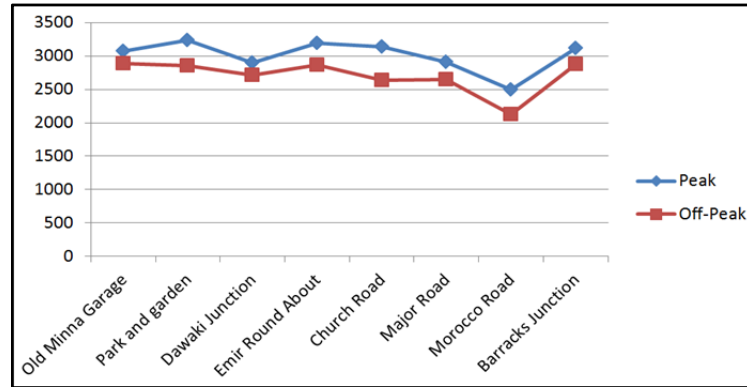
Figure 3c Varying levels of peak and off-peak CO2 emission at the selected road junctions in Suleja, southeast of Niger State

The situation in Bida (see Figure 3b) was slightly different as highest levels of emission for both peak and off peak are 3000ppm and 2550ppm respectively were recorded at BCCC junction within the city centre. To reduce CO2 emission at this road junction, measures to improve traffic operations such as traffic congestion mitigation are applicable. In Suleja (see Figure 3c), the highest level of CO2 emission (3236ppm) during peak period was recorded in Park and Garden junction, while Old Minna Garage junction had the highest off peak emission (2888ppm). The situation is similar to what was obtained in Minna, where the highest peak and off peak values of 3100ppm and 2900ppm respectively were recorded at two different road junctions.

3.3   Analysis of Variance (ANOVA) of the three CO2 Emission Samples

The computation of Single factor Analysis of Variance (ANOVA One Way) was used to hypothetically test for significant difference between the levels of CO2 emission in the selected locations and the result is shown in Table 2. It can be observed that the computed value of F (39.84774) is greater than the critical value of F (3.0274). This sets up a critical region for rejecting the null hypothesis. Thus, the hypothesis that there are significant differences between the mean values of the levels of CO2 emission under the assumption that the variances of the three samples are all equal is accepted. This difference is justifiable as traffic conditions differ because of the land use and socio-economic characteristics (e.g. commercial and industrial activities) of the cities. Suleja, the closest in proximity to the FCT, Abuja has busier traffic conditions, with the associated high level of CO2 emissions, on the average, than Minna and Bida respectively. Consequently, the aggressive enforcement of the traffic congestion mitigation measures identified in sub-section 4.1are applicable.

Table 2 Single Factor ANOVA of levels of CO_2 emissions in Minna, Bida and Suleja.

Source of Variation	Sum of Squares	Degree Of Freedom	Mean Square	F-value	P-value	F critical
Between Groups	5617617	2	2808809	39.84774	5.5E-16	3.027443265
Within Groups	20089232	285	70488.53			
Total	25706850	287				

3.4 Analysis of Carbon dioxide (CO2) Emissions in Minna, Bida and Suleja

Figure 4 summarizes the average emission levels of CO2 obtained from eight (8) road junctions in each of the selected cities, namely Minna, Bida and Suleja during average peak and off-peak periods in comparison with the internationally acceptable safe limit of 350ppm and the OSHA limits of 5000ppm. For both periods, the highest levels were 3005.38 and 2698ppm recorded in Suleja. The proximity of this city to FCT, Abuja, contributed to the high vehicular movements recorded because intra-city commuting and socio-economic activities have increased. Minna and Bida are basically regarded as "civil servants" domain characterized by low intensity of commercial activities because government employees are generally perceived to earn low personal income. Most importantly, they are both at least two hours away from the FCT, Abuja by road. The emission levels obtained in this study are significantly higher (by at least 1643ppm) than the results obtained from a similar study conducted about a decade ago in similar locations in North Central Nigeria by Akpan and Ndoke (1999). By implication, as number of vehicles and motorcycles increase, the emission level also increases.
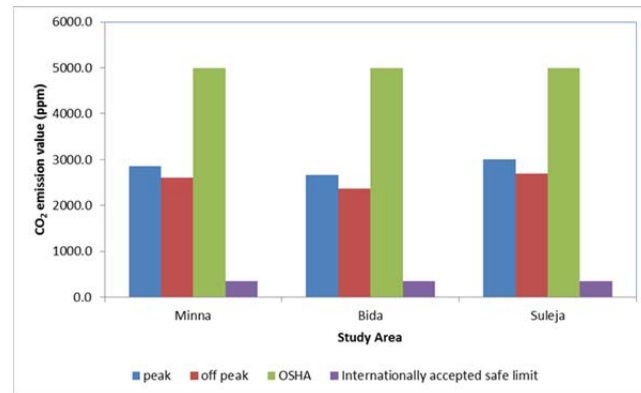

Figure 4: Deviation of Average Emission Levels of CO2 from the Internationally Acceptable Safe Level of 350ppm and the Occupational Safety and Health Administration (OSHA) limit of 5000ppm

In comparison with the internationally acceptable safe limit of 350ppm for atmospheric CO2, the three (3) cities have CO2 emission levels approximately eight (8) times higher than the limit. As a contribution towards stabilizing global average temperatures within a likely range of 0.6–1.4°C above pre-industrial values, efforts must be made to reduce these local sources of vehicular emission of CO2. On the other hand, however, the emission levels obtained are, at least, half of the Occupational Safety and Health Administration (OSHA) permissible exposure limits of 5,000ppm time weighed average that could cause adverse health effects on the populace. According to Greiner (1995), these emission quantities are not high enough to cause adverse health effects such as nausea and headaches, but as vehicular traffic grows in number and age, the quantity of CO2 that will be released in the near future will continue to increase. However, in these locations, this may contribute to climate change, in the long term, if unmitigated.

4 CONCLUSION AND RECOMENDATIONS

This study has established that the level of CO2 emissions from road transportation is approximately eight times higher than internationally acceptable safe limit of 350ppmin the southeast of Niger State, and its implication on global warming, hence climate change, cannot be overemphasized. Furthermore, the need to travel will continue to grow as economies develop, and emissions from this sector have been projected to continue increasing and contributing further to global warming. The results from this study identified Suleja as the city with the highest level of peak and off peak CO2 emissions, because of its proximity to the intense socio-economic activities of FCT, Abuja. Thus, emphasizing the need to implement and enforce measures that improve traffic operations across the State. The measures identified (e.g. congestion mitigation strategies, speed management techniques and traffic flow smoothing techniques) are relatively inexpensive to implement in comparison with vehicle improvement measures and the use of alternative fuels; and are more likely to have greater impact on CO2 emission reduction from road transportation in the short term. More importantly, they are realistic and enforceable as

they involve mainly the training and re-training of the officials responsible for road safety in Nigeria, and above all, involve promoting the adoption of "green" behavioural attitudes by drivers. However, it is worthy of mention that other relatively expensive measures could be adopted to reduce the emission of CO2 from road transportation, but these are likely to be medium and long term initiatives at policy (e.g. adoption of a reward system to encourage car owners to utilize eco-friendly 'zero carbon' options of walking and cycling for short distance travel, abolishing the importation of used vehicles of a certain age category etc.), strategic (e.g. improving the existing urban mass transit services, well managed urban afforestation programmes along major routes in the cities, introduction of high occupancy vehicle lanes or side lanes for motorcycles and bicycles etc.) and tactical levels (e.g. Advanced Traffic Management Systems etc.). It is worthy of mention that the most notable limitation of this study is the fact that the focus is on CO2 emissions from vehicular (motorized) sources only, excluding emissions from non-motorized modes of transportation. Future areas of research should expand the scope of coverage to improve on the frequency of data collection to cover a longer duration that spans both wet and dry seasons in Niger State. It should also involve the simultaneous collection of levels of atmospheric CO2 emission from the selected hotspots across the State using a combination of handheld and mobile gas meters as well as gas detection tubes.

Finally, the key recommendation from this study is that hotspots in each location, e.g. Broadcasting road, in Minna, should be converted to double lane roads by the State Government in order to minimize congestion and reduce the level of CO2 emission from vehicles plying the route. On the other hand, hotspots located at city centres, which link different routes to residential and commercial areas at the city centre, require the regular presence of traffic wardens and officials of Federal Road Safety Corps to enforce strict congestion mitigation measures e.g. Mobil roundabout in Minna. Studies have recommended measures that are more likely to have greater impact in the short term because they involve improved traffic operation (Barth and Boriboonsomsin, 2008; Varlhelyi et al., 2004). These measures include: congestion mitigation strategies (e.g. ramp metering and incident management), speed management techniques (e.g. traffic police

enforcing speed limits, use of radar and cameras) and traffic flow smoothing techniques (e.g. reduction of frequent speed fluctuations in slow moving traffic through the use of variable speed limits such as keeping traffic flowing at speeds of between 72 – 80km/h in road bypasses within town and at 100km/h on highways and enforcing this speed limit for cars, buses and trucks or synchronization of traffic signals). The measures highlighted are inexpensive and more importantly, are enforceable as they require the training and re-training of the paramilitary forces such traffic wardens, Vehicle Inspection Officers (VIO) and Federal Road Safety Corps (FRSC). Furthermore, "green" behavioral attitudes could be promoted through awareness creation e.g. keeping tyres correctly inflated to reduce friction, removing roof racks from cars when not in use, keeping the car trunks as light as possible, staying under speed limits as much as possible, carpooling and sharing, using the urban mass transit as often as possible etc.

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