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Full Length Research Article

ANALYSIS OF SPATIO-TEMPORAL EMISSIONS FROM ROAD TRANSPORT IN KADUNA METROPOLIS, KADUNA STATE, NIGERIA

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ABSTRACT
The study analyzed the spatial and temporal concentrations of road transport the spatial variation in the concentrations of road transport emissions at specific periods (off peak and peak periods of traffic). ToxiRAE monitor was used to measure the amount of carbon-monoxide (CO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2) and Ammonia (NH_3) while the MultiRAE plus monitor was used to measure volatile organic Compounds (VOCs) at different times and locations. These devices were used to ascertain the ambient concentration of selected gas emissions at road junction's corridors in the study area. Sample sizes of 10% of road junctions in the study area (Kawo, Ahmadu Bello Way, Yakubu Gowon Way, Sabo Junction and NNPC Junction) were selected for emission measurement. The result showed that carbon monoxide is above the 20ppm stipulated by FEPA (Federal Environmental Protection Agency) base line while the remaining gases (NH_3 .889ppm, SO_2 .0836ppm, VOCs 1.628ppm, NO_2 .203ppm) has not gone beyond the local and international safe limits. The study concluded that it is pertinent to emphasize that, continuous exposure of urban residents to these emissions could have cumulative negative impacts on the health of urban residents and calls for concerted effort to be put in place to ensure that carbon monoxides from various road transport modes are within acceptable safe limit.

INTRODUCTION
The need to control air quality in the cities is one of the main issues which has attracted the attention of public opinion and governments at all levels with a view to safeguarding human health and improving their quality of life (Giorgio et al., 2009). Despite the technological progress made towards cleaner engines and fuels, traffic emission still remains very high and accounts for a large proportion of air pollution in our urban areas today (Giorgio et al., 2009). Emission from various automobiles significantly contributes up to 90% of urban air pollution which largely deteriorates air quality in urban areas (USEPA, 1995).
Also, traffic induced emission accounts for 77% of carbon-monoxide (CO), 80-90% of nitrogen oxides (NO), 36% of Volatile Organic Compounds and 22% of particulate matter (PM), an average concentration of nitrogen dioxide (NO_2) is found to have increased by 25% as a result of increase in vehicular emission (USEPA, 2000). At micro level such as city centers and congested streets, traffic can be responsible for 80-90% pollution, a scenario particularly aggravated in cities in developing countries (Odhiambo et al., 2010).
The urban environment largely depends on an effective transportation system for its social and economic transformation (Ogunsanya, 2002; Filani, 2000). However, in view of the high level of over dependence on the use of petrol and diesel fuels to power the engine of their vehicles, the urban environment is highly endangered with harmful air pollutants (IPCC, 2007).
The choice of road transport emissions (air pollution), as singled out in this study is a step in the right direction particularly now with increasing rate of urbanization. The rapidity in the growth of urban centres has stimulated increase in the level of motorization to meet the mobility challenges of ever increasing urban residents. This may still continue for a long time because of increasing rates of rural urban migration through which urban population have experienced monumental growth (Babatimehin, 2012); a phenomenon occurring because of inadequate development of rural areas, which makes the rural areas so unattractive to many who eventually resolve to settle in urban areas (Adesanya, 1991). This is certainly one of the factors responsible for the rapid expansion of Nigerian cities in the past three decades and consequently, transport infrastructures especially roads and transport services; encompassing cars, buses and other conventional modes. This also includes motor cycles, which has just been recently accepted as alternative solution for mobility problem in many cities in Nigeria (Olawole, 2012).
Basically, transport continues to be highly relevant especially in urban areas where there is always a concentrated level of industrial, educational, commercial, economic, administrative, social and recreational activities. The ability of transport to exhibit both positive and negative effects in a typical urban area justifies its description as 'maker' and 'breaker' of cities (Ogunsanya, 2002; Filani, 2000).
The recent upsurge of scholar's interest in vehicular emission related studies is not unconnected with the increasing awareness of the dangers associated with the release of emission especially as it impacts negatively on human health and global environment. The need to provide both short term and long term solutions to this problem in order to improve human quality of life therefore, has tremendously influenced the present increase in scholar's interest in vehicular emissions related studies. Therefore, this study analysed road transport emissions at specific locations and time at traffic corridors along Kaduna urban roads.
Studies have shown that the rapid growth of urban population has increased the flow of vehicles in urban areas. This has tremendously increased road transport emissions in urban areas and its associated dangers on the environment and human health. This situation calls for urgent attention. Although few related studies on urban transport emission have recently been conducted, for instance, (Ndoke and Akpan, 1999) investigated the contribution of vehicular traffic to carbon dioxide emission in Kaduna and Abuja. Despite the fact that the study discovered a strong influence of traffic congestion on carbon dioxide emission; the focus on only carbon dioxide is a limitation of the study. Also,

the study by (Ndoke and Jimoh 2007) in Minna focused on the impacts of traffic emissions on air quality. Similarly, the study of Okelola and Okhimamhe (2013) also in Minna, Niger State Nigeria specifically emphasized the spatio-temporal variations of carbon dioxide and other greenhouse gases. The study equally considered the influence of some weather elements especially temperature and its effects on climate change. Additionally, Utang and Peterside (2011) conducted a study on the spatio temporal variations of urban vehicular emissions in Port Harcourt; emphasizing on vehicular emissions. These studies have only limited their study to either only one gaseous emission (carbon dioxide). Additionally, the studies are limited to relatively fewer urban centers, among some other limitations. Therefore, this study will help to bridge these missing gaps.

MATERIALS AND METHOD

Emission measuring equipment's known as ToxiRAE monitors and MultiRAE plus emission analysers were used as road transport emissions inventory. These devices are in-situ gas monitors with a capability for an instantaneous direct read out displays through which current concentration of selected gases were monitored in parts per million (ppm). These were used to ascertain the ambient concentration of selected gas emissions at road junction's corridor in the study area. ToxiRAE monitor was used to measure the amount of carbon-monoxide (CO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2) and Ammonia (NH_3) while the MultiRAE plus monitor was used to measure Volatile Organic Compounds (VOCs) at different time of the day designated as morning peak, afternoon and evening peak periods of traffic in the area. Also high resolution image of the Kaduna Metropolis (Quick Bird 50cm, 2014) was used for proper identification of all roads and junctions in the study area and to extract major landmarks.
The equipment's used for the measurement of road transport emissions gasses in this study are ToxiRAE and MultiRAE gas monitors.

NO2 monitor (ToxiRAE model PGM -1150). This was used for the measurement of Oxides of Nitrogen**.** It is an in *situ* single gas monitor. The monitors have instantaneous direct read out displays which allowed current NO2concentrations to be continuously monitored in ppm (parts per million). The NO2 monitor (Plate 1) is with O- 20ppm detection range with 0.01 ppm resolution. The device has facility for Short Term Exposure Limit (STEL); the Time weighted Average (TWA); and the Peak Reading. For every measurement at selected sites along the road, the "Auto-Zero at Start-up" calibration was carried out as required in the study.

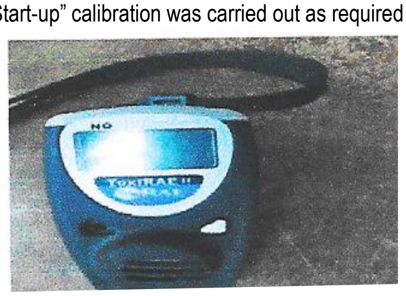

Plate 1: ToxiRAE Monitor for the measurement of Nitrogen dioxide

ToxiRAE Model PGM-1130) was used to measure Sulphur dioxide **(**SO2). ToxiRAE Model RGM- 1110 was used to measure Carbon monoxide **(**CO). ToxiRAE Model PGM-1191 was used to measure Ammonia (NH3). It has detection range of 0-50ppm with 0.1 ppm resolution.

MultiRAE gas monitor (Model PGM50-P) (Plate 2) was used to measure Volatile Organic Compounds **(**VOCs). It is also an in-situ MultiRAE gas monitor; the monitor has an instantaneous direct read out displays through which current VOCs concentration was continuously monitored in parts per million (ppm). It has facility for short term Exposure Limit (STEL), the Time Weighted Average (TWA) and peak Reading are very active. It has a detection range of 0-200ppm with 0.1ppm resolution.

Plate 2: MultiRAE monitor for the measurement of Volatile Organic Compounds

All roads in Kaduna Metropolis served as sample frame from which emission measurement were observed and conducted. Sample sizes of 10% of road junctions in the study area were selected, based on their level of connectivity (i.e. cross junction) for emission measurement.
The equipment's measured and instantly displayed the specific concentration values of various emissions generated by vehicular traffic at the various location (Spatial) and on each day of the week for seven days, at designated times morning, afternoon and evening) otherwise called peaks and off-peak periods of traffic (Temporal) in the study area. The displayed values were recorded in parts per million (ppm). The results were presented in tables. The ambient air quality of emission discharge in the study area as measured by gas analyzer at specific time and specific locations was compared with the Local and International (World Health Organization) standards. Statistical data analysis software called SPSS was used for the analysis of the data obtained on each of the road transport emission at the various locations and at the various time (morning, afternoon and evening) on each day of the selected week.

RESULTS AND DISCUSSION

Spatial and Temporal Variation in Transport Emissions

The Spatial and temporal variations in the ambient concentrations of the following gases CO (Carbon monoxide), NH_3 (Ammonia), VOCs (Volatile Organic Compounds), NO_2 (Nitrogen dioxide) and SO_2 (Sulphur dioxide) are discussed here. The unit of measurement of these gases is in parts per million (ppm).

Spatial Variation in Carbon monoxide (CO) emission at various locations

Mean concentration of CO levels across the five junctions is shown in table 1. The highest measured CO concentration was found at

Ahmadu Bello Way with an arithmetic mean of 30.91ppm, followed by the value obtained at Kawo with an arithmetic mean value of 27.79ppm. Sabo Junction had an arithmetic mean of 27.01ppm and 25.92ppm was recorded at NNPC Junction. The lowest concentration was measured at Yakubu Gowon way with an arithmetic mean of 22.59ppm. This was largely influenced by the characteristics of each junction and the flow of traffic in the area. For instance, the highest concentration was recorded at Ahmadu Bello Way exemplifies the high level of land use mix along the road. Ahmadu Bello Way is one of the Federal roads in the city. The activities around the area account for the high volume of traffic flow on the road such as markets, banks, eateries and retailing shops. The junction with the lowest level of concentration of CO emission at the time of survey was Yakubu Gowon way. Vehicular traffic here was comparatively lower at this location at the time of carrying out this research.

Table 1: Spatial Variation of CO Emission

S/No	Location name	Mean
1.	Kawo	27.79
2.	Ahmadu Bello Way	30.91
3.	Sabo Junction	27.01
4.	Yakubu Gowon	22.59
5.	NNPC Junction	25.92

Source: Authors Fieldwork, 2019

Temporal Variations in Carbon monoxide (CO)

Table 2 shows the mean concentration of CO at designated time (morning, afternoon and evening) measured from each of the sampled junctions. The highest mean concentration of CO at various time/peaks of the day morning, afternoon and evening was found at Ahmadu Bello Way, 34.95ppm, 27.14ppm, 30.65ppm in the morning, afternoon and evening respectively. This was followed by Kawo with mean CO concentration of 31.52ppm and 30.65ppm in the morning and evening, Sabo junction 22.43ppm for afternoon. The lowest mean concentration of CO was at Yakubu Gowon Way with a mean value of 26.98ppm morning, 19.63ppm afternoon and 21.17ppm evening.

The concentration of CO emission was generally higher in the morning and evening peaks than during the afternoon peak. This is attributable to the relatively higher vehicular movement associated with both the morning rush and evening rush hours of the day. Similar patterns in temporal variation of vehicular emissions at off-peak and peak periods of the day were found at Port Harcourt Utang and Peterside (2011). Also, a study of carbon dioxide concentration was noticed to be highest in AYA junction out of the sites tested at both morning and afternoon rush hours Ndoke *et al*., (2003). Specifically, Utang and Peterside (2011) observed that emissions are peak and off-peak dependents; with higher emissions in the morning and evening peak hours and lower emission in the afternoon peaks.

The lower mean CO concentration generally experienced in the afternoon may be attributed to low volume of vehicular movement associated with off-peak periods in all the sampled junctions. This finding is consistence with Lonati (2005) submission that high vehicular flow is associated with high level of emission from vehicles and low traffic is associated with low level of traffic emission.

Table 2: Temporal Variations in CO emission

S/No	Location	Morning	Afternoon	Evening
1.	Kawo	31.52	21.98	29.87
2.	Ahmadu Bello Way	34.95	27.14	30.65
3.	Sabo Junction	30.12	22.43	28.49
4.	Yakubu Gowon Way	26.98	19.63	21.17
5.	NNPC Junction	29.79	21.07	26.91

Source: Authors Fieldwork, 2019

Spatial Variation in Ammonia (NH_3) emission at various locations

Mean concentration of NH_3 across the five locations is shown in Table 3. The highest measured NH3 concentration was found at Ahmadu Bello Way with an arithmetic mean of .889ppm, the next was obtained at Kawo with an arithmetic mean value of .611ppm, NNPC Junction recorded an arithmetic mean of .535ppm and .522ppm was recorded at Sabo junction. The lowest concentration was recorded at Yakubu Gowon way with an arithmetic mean value of .476ppm. The variation in the amount of emission measured could be attributed to the degree of vehicular traffic generated at respective junctions.

Table 3: Spatial Variation of NH_3 Emission

S/No	Location name	Mean
1.	Kawo	.611
2.	Ahmadu Bello Way	.889
3.	Sabo Junction	.522
4.	Yakubu Gowon	.476
5.	NNPC Junction	.535

Source: Authors Fieldwork, 2019

Temporal Variation of Ammonia at Various times

Table 4 shows the arithmetic mean concentration of ammonia NH_3 emission at designated time morning, afternoon and evening across the sampled locations. The highest mean concentration of NH_3 emission at various peaks morning, afternoon and evening were found at Ahmadu Bello way with an arithmetic mean value of .796ppm, .1.174ppm, .653ppm in the morning, afternoon and evening respectively, Kawo recorded .665ppm, .514ppm, .653ppm in the morning, afternoon and evening. The temporal variations of

NH_3 emissions obtained at NNPC Junction shows that .588ppm was obtained in the morning, .501ppm in the afternoon and .515ppm in the evening. Sabo Junction recorded .549ppm in the morning, .493ppm in the afternoon and .523ppm in the evening. The lowest mean concentration was at Yakubu Gowon way with an arithmetic mean value of .541ppm, .476ppm and .411ppm in the morning, afternoon and evening respectively.

The values of emissions measured at the various junctions were influenced by the traffic flow around each of these locations. It is worthy of note that, the highest mean concentration for Ammonia in the entire study area in the morning peak was .796ppm; this was measured at Ahmadu Bello way, 1.174ppm was also measured at Ahmadu Bello way in the afternoon, and the highest mean concentration in the evening peak was .698ppm and was also measured at Ahmadu Bello way. This may be attributed to the relatively higher vehicular movement along these junctions at the time.

Table 2: Temporal Variations in NH_3 emission

S/No	Location	Morning	Afternoon	Evening
1.	Kawo	.665	.514	.653
2.	Ahmadu Bello Way	.796	1.174	.698
3.	Sabo Junction	.549	.493	.523
4.	Yakubu Gowon Way	.541	.476	.411
5.	NNPC Junction	.588	.501	.515

Source: Authors Fieldwork, 2019

Spatial Variation in Sulphur dioxide (SO_2) emission at various locations

Mean concentration of SO_2 levels across the five sampled locations is shown in Table 5. The result revealed that the highest measured SO_2 concentration was recorded at Ahmadu Bello way with an arithmetic mean of .0836ppm, followed by the value obtained at Kawo with .0773ppm, Sabo junction .0606ppm, NNPC Junction .0376ppm. The lowest .0373ppm was recorded at Yakubu Gowon way. The concentration of emission observed at various locations depended largely on the volume of vehicular traffic at each of the junctions.

Table 3: Spatial Variation of SO_2 Emission

S/No	Location name	Mean
1.	Kawo	.0773
2.	Ahmadu Bello Way	.0836
3.	Sabo Junction	.0606
4.	Yakubu Gowon	.0373
5.	NNPC Junction	.0376

Source: Authors Fieldwork, 2019

Temporal Variation in Sulphur dioxide (SO_2)

Table 6 shows the mean concentration of SO_2 emission at various times/peaks morning, afternoon and evening from each of the sampled locations. The highest mean concentration of SO_2 at various peaks morning, afternoon and evening was observed at Ahmadu Bello way .1ppm and .085ppm in the morning and afternoon; Kawo .098ppm in the evening respectively. The lowest mean concentration was observed at Yakubu Gowon with .034ppm and .031ppm in the morning and evening, NNPC .038ppm in the afternoon. The concentration of SO_2 emission was higher in some of the locations in the afternoon peak than it was in both morning and evening peaks; this is attributable to the volume of vehicular traffic in the areas concerned. However, the results generally revealed that, relatively higher emission values were recorded in both the morning and evening peaks, while the afternoon peaks value was comparatively lower, this may be attributed to the relatively lower vehicular movement along these junctions at the time.

Table 4: Temporal Variations in SO_2 emission

S/No	Location	Morning	Afternoon	Evening
1.	Kawo	.052	.082	.098
2.	Ahmadu Bello Way	.1	.085	.066
3.	Sabo Junction	.035	.053	.094
4.	Yakubu Gowon Way	.034	.047	.031
5.	NNPC Junction	.042	.038	.033

Source: Authors Fieldwork, 2019

Spatial Variation in Volatile Organic Compounds (VOCs) emission at various locations

Mean concentration of (VOCs) levels across the five locations is shown in Table 7. The highest measured VOCs concentration was found at Ahmadu Bello way with an arithmetic mean of 1.628ppm, followed by the value obtained at Kawo with an arithmetic mean value of 1.556ppm, then NNPC Junction and Sabo Junction with 1.513ppm and 1.099ppm. The lowest concentration was recorded at Yakubu Gowon with 1.079ppm. Ahmadu Bello way is the main central business district and as such, has high propensity for concentration of VOCs. The situation in Kawo was also similar in terms of traffic volumes because it is the main entrance to Kaduna from the North, hence the high level of concentration. The lowest mean concentration of VOCs was measured at Yakubu Gowon way. This was largely influenced by the flow of traffic at the time of carrying out this survey.

Table 7: Spatial Variation of VOCs Emission

S/No	Location name	Mean
1.	Kawo	1.556
2.	Ahmadu Bello Way	1.628
3.	Sabo Junction	1.099
4.	Yakubu Gowon	1.079
5.	NNPC Junction	1.513

Source: Authors Fieldwork, 2019

Temporal Variation in Volatile Organic Compounds (VOCs)
The mean concentration of VOCs at various time across the sampled locations is shown in Table 8. The highest mean concentration of VOCs emission at various peaks morning, afternoon and evening were found at Ahmadu Bello way in the morning and afternoon 1.062ppm and 1.701ppm, the highest in the evening was recorded at NNPC Junction 3.3ppm respectively. The lowest mean concentrations were recorded at Yakubu Gowon in the morning and evening with .461ppm,1.856ppm and Sabo junction in the afternoon .561ppm.

Table 5: Temporal Variations in VOCs emission

S/No	Location	Morning	Afternoon	Evening
1.	Kawo	.924	1.499	2.246
2.	Ahmadu Bello Way	1.062	1.701	2.122
3.	Sabo Junction	.466	.561	2.271
4.	Yakubu Gowon Way	.461	.922	1.856
5.	NNPC Junction	.531	.709	3.3

Source: Authors Fieldwork, 2019

Spatial Variation in Nitrogen dioxide (NO_2) emission at various locations
Table 9 shows the mean of NO_2 levels across the sampled locations. The highest measured NO_2 concentration was found at Ahmadu Bello Way with an arithmetic mean of .203ppm, followed by the value obtained at Kawo with an arithmetic mean of .191ppm. NNPC Junction and Sabo Junction recorded .175ppm and .155ppm respectively. The lowest concentration was observed at Yakubu Gowon way with an arithmetic mean of .123ppm; this must have been influenced by the flow of vehicular traffic at the various junctions at the time of carrying out this research.

Table 6: Spatial Variation of NO_2 Emission

S/No	Location name	Mean
1.	Kawo	.191
2.	Ahmadu Bello Way	.203
3.	Sabo Junction	.155
4.	Yakubu Gowon	.123
5.	NNPC Junction	.175

Source: Authors Fieldwork, 2019

Temporal Variation in Nitrogen dioxide (NO_2)
Table 10 shows the arithmetic mean concentration of NO_2 emission at various time of the day morning, afternoon and evening. The highest mean concentration of NO_2 emission at various peaks morning, afternoon and evening was at Kawo .228ppm in morning, NNPC Junction .242ppm in the afternoon and Ahmadu Bello way .401ppm in the evening. The lowest mean concentration of was at Ahmadu Bello way .099ppm in the morning, .088ppm in the afternoon at Sabo junction and NNPC Junction with .082ppm in the evening respectively. It is also worthy of note that, emission was higher in the morning and evening. This may be attributed to relatively higher vehicular movement associated with both morning rush and evening rush hours of the day. The relatively lower NO_2 concentration generally experienced in the afternoon may be attributed to low volume of vehicular movement associated with off peak periods in all the sampled junctions. Lonati (2005) observed that high level of emission from vehicles are usually stimulated by high level of vehicular traffic and vice versa.

Table 7: Temporal Variations in NO_2 emission

S/No	Location	Morning	Afternoon	Evening
1.	Kawo	.228	.162	.183
2.	Ahmadu Bello Way	.109	.099	.401
3.	Sabo Junction	.185	.088	.192
4.	Yakubu Gowon Way	.167	.096	.106
5.	NNPC Junction	.201	.242	.082

Source: Authors Fieldwork, 2019

Conclusion
This study has analyzed the spatial and temporal variations of road transport emissions in Kaduna metropolis. It observed that, variations in the concentration of the studied gases at various locations (spatial) and at various times of the day (morning, afternoon and evening) as well as days in the week (temporal).
Although the situation at the moment for most of the gases has not gone beyond the local and international safe limits, it is already sending negative signals; this is particularly true of carbon monoxides emission, where the mean concentration values obtained; though below the 50ppm internationally acceptable safe limits, is found to be above the 20ppm stipulated by FEPA (Federal Environmental Protection Agency) base line. Other gases (NH_3 .889ppm, SO_2 .0836ppm, VOCs 1.628ppm, NO_2 .203ppm) has not gone beyond the local and international safe limits.
Besides, even for other gases which are presently below the acceptable safe limits, it is pertinent to emphasize that, continuous exposure of urban residents to these emissions could have cumulative negative impacts on the health of urban residents. To that extent, a concerted effort has to be put in place to ensure that carbon monoxides and others from various road transport modes are within acceptable safe limit.

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