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Full Length Research Article

ASSESSMENT OF CONCENTRATION AND SPATIAL VARIATION OF AIR POLLUTION IN ZARIA METROPOLIS, NIGERIA

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ABSTRACT
The emission of air pollutants has led to numerous air quality issues in cities and a major factor in this is increasing population and growth in road traffic. This study assessed concentration of carbon monoxide (CO), Nitrogen dioxide (NO_2), and Sulfur dioxide (SO_2) in relation to traffic density on ambient air quality in Zaria metropolis. The Gray Wolf sensing solutions with the model number (203) 402-0477 was used for monitoring the concentration of the three (3) gases at the selected motorways in Zaria metropolis, and a vehicle count was conducted in the morning, afternoon, and evening time. The results indicated that the concentration levels of CO, NO_2, and SO_2 detected varied in space and time. The concentration were generally high and above the National Ambient Air Quality (NAAQ) permissible limits during traffic peak periods, especially during the evening period. The level of pollutants across all the sampling points also increases with traffic volume. The study established strong statistical evidence that traffic volume influences the pollutants concentrations at all sampling points. The study recommended development of road networks and construction of modern roundabouts and bridges in Zaria Metropolis to ease traffic flow and reduce the concentration of air pollutants to acceptable limits.

Key words: Air pollution, air quality, CO, NO_2, SO_2

INTRODUCTION

Air pollution is one of the world's leading causes of death, contributing to seven million deaths annually (Katoto et al., 2021). Urban air quality is presently a key area of concern in environmental health agenda in many countries. Global estimates show that almost one billion people in urban settings are incessantly exposed to health hazards from air pollutants (Amegah & Agyei-Mensah, 2016).

Air pollutants are mobile components that occur in concentrations high enough to cause adverse effects on health, the environment, and indoor/outdoor structures (Manucci & Franchini, 2017). They affect human health in numerous ways and varying the degrees of severity ranging from minor irritation, serious ill-health to premature death (Awe, et al., 2015). Air pollutants can damage human health and cause harm to plants and animals. The emission of air pollutants has led to numerous air quality issues in cities such as photochemical smog, acid rain, and decreased visibility (Parjuli, et al., 2016). A major factor in this is the continued growth in road traffic, as vehicle exhaust contributes up to 50% of urban particulate matter (Cassee, 2013). Keeping the air quality suitable for human use is an essential issue for public health (Cohen, et al., 2017).

Air pollutants from road traffic include Carbon Monoxide (CO), Particulate matter (PM), and Hydrocarbons (HCS), known as the product of incomplete combustion. Nitrogen Oxide (NO_2) is a product of high-temperature combustion processes, and Sulfur Oxide (SO_2) and heavy metals are by-products of combustion due to impurities within the fuel (Guo, et al., 2017). Non-combustion products are the evaporative emissions; and the secondary air pollutants such as photochemical oxidants including ozone (O_3) and peroxyacetyl nitrate (PAN) (Guo, et al., 2017).

Road traffic and industrial pollutions are the dominant if not the foremost vital anthropogenic source of pollution in urban areas worldwide, and the density of traffic congestion in an area account for the temporal variation in the concentration of pollutants released. Thus, transport emission of pollutants into the atmosphere is an increasingly serious health issue that affects nearly everyone (Katoto, et al., 2019).

Much consideration is given to general industrial pollution and pollution in the oil and gas sector, with less attention to pollution caused by vehicular transportation sources in Nigeria (Magbabeola, 2001). Pollution from vehicular transportation sources is on the increase, and so is per capita vehicle ownership, hence causing high congestion on Nigeria urban roads as well as an increase in the concentration of pollutants in the air, consequently increasing health risks on human population (Abam & Unachukwu, 2009).

A number of studies have established that vehicular emissions pose a problem to air quality across Nigerian metropolitan areas. Utang & Peterside (2011) estimated the air pollutants CO, NOx, SOx, and hydrocarbons in Port Harcourt and found that the level of hydrocarbons detected in the atmosphere varied in space and time, and found them to be above the local and international standard limit. Studies recently have also assessed the level of some selected vehicular air pollutants such as PM, CO, NO_2, and SO_2 and found that the pollutants have exceeded the stipulated threshold by Federal Government of Nigeria, and the levels of vehicular-related air pollution from all the studies conducted revealed a rising trend and thus a probable health threat to the public (Onalapo, 2015; Aliyu et al., 2013; Ojo & Awokola, 2012; Hena, 2014).

Several other studies have found that transport-related pollution is significant and may likely cause severe health consequences. For instance, a study by Gazali and Kazeem (2013) revealed high PM10 concentrations at all locations studied in Calabar, and that traffic wardens had a high incidence of health indicators that are possibly related to and are worsened by exposure to vehicle emission. (Okunola et al., 2012)'s study in Kano, Nigeria found that the concentrations of the CO, H_2S, NO_2, and SO_2 measured at some sites were above the AQI stipulated by United State Environmental Protection Agency (USEPA) especially during the dry season, and that transport-related pollution in Kano metropolis is significant with potentially hazardous health consequences.

The high concentration of these pollutants detected by the studies

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can be attributed to increased population growth, increased production of gaseous wastes, and increased vehicular movement. The concentration of those pollutants have increased within the past few decades in Nigeria due to the influx of old and used vehicles into the country following variations in government policy (Abam & Unachukwu, 2009; Baba *et al.,* 2021). Despite many studies conducted in this area, few or no study similar to this was conducted in Zaria metropolis, hence the development of this study.

Study Area

Zaria metropolis is the second-largest city in Kaduna State, Nigeria and comprises Zaria, Sabon-Gari and parts of Giwa LGA. It has a geographical position located between latitudes 11^0 05' – 11^0 10'N of the equator and longitudes 7^0 36'-7^0 42' E Greenwich meridian. It covers an area of about 563 km^2 (Ubogu et al., 2011).

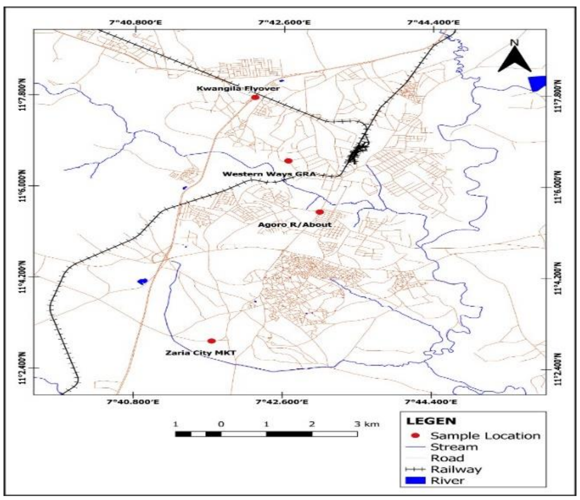

Figure 1: Zaria metropolis showing the four (4) sampling points. Source: Modified from Zaria Topographic Map

MATERIALS AND METHODS

This study examined three (3) important air pollutants, Carbon monoxide (CO), Nitrogen dioxide NO_2, and Sulphur dioxide (SO_2), from automobile emission in Zaria metropolis, compared them to the Nigerian Ambient Air Quality Standard (NAAQS) and determined the spatial variations between the concentration levels. The study also determined to what extent traffic density influenced the levels of CO, NO_2, and SO_2. Direct observation was first carried out to study the environmental ecosystem. The Gray wolf sensing solution with the model number **(**203) 402-0477 which is potable gas detector with embedded software was used for data collection. Google Earth Map was used to create proportional symbol for the four sample points to spatially indicate the extent of variation in gas emission in the sampled points. In doing so, a handheld GPS 76CX model was used to get the accurate coordinates of all the four sample points spatially.

Sampling points

Four (4) sampling points were adopted purposively due to their potential traffic capacity and knowledge about the study area (Glenn, 2017). They were: Zaria city market, Agoro roundabout, and Kwangila flyover, while Western ways was within the less traffic flash point and served as the control point**.**

Data Collection Procedure

Monitoring of CO, NO_2, and SO_2 was done using a Gray Wolf gas meter at strategic points to get the average measurement at three different day-time peak periods. The time frame for the collection from the four sampling points was one (1) week. The periods used for data collection were termed peak because they are the busiest vehicular periods of the day. They are categorized as follows:

7:00am - 10:00am = Morning peak hours.
12:00noon - 3:00pm = Afternoon peak hours.
4:30pm - 7:30pm = Evening Peak Hours.

Measurement and vehicular counting were done within 30 minutes at each sampling point using space-time sampling techniques. Traffic density at each of the experimental sites was determined through traffic count and is expressed in the number of vehicles per hour (v/h).

Table 1: Space Time Sampling Technique

LOCATIONS					
	DAYS	**ZC**	**AR**	**KW**	**WW**
TIMING	**M**	7:00 – 7:30 am 12:00 – 12:30 pm 4:30 – 5:00 pm	7:40 – 8:10 am 12:40 – 1:10 pm 5:10 – 5:40 pm	8:20 – 8:50 am 1:20 – 1:50 pm 5:50 – 6:20 pm	9:00 – 9:30 am 2:00 – 2:30 pm 6:30 – 7:00 pm
	T	9:00 – 9:30 am 2:00 – 2:30 pm 6:30 – 7:00 pm	8:20 – 8:50 am 1:20 – 1:50 pm 5:50 – 6:20 pm	7:40 – 8:10 am 12:40 – 1:10 pm 5:10 – 5:40 pm	7:00 – 7:30 am 12:00 – 12:30 pm 4:30 – 5:00 pm
	W	8:20 – 8:50 am 1:20 – 1:50 pm 5:50 – 6:20 pm	7:00 – 7:30 am 12:00 – 12:30 pm 4:30 – 5:00 pm	9:00 – 9:30 am 2:00 – 2:30 pm 6:30 – 7:00 pm	7:40 – 8:10 am 12:40 – 1:10 pm 5:10 – 5:40 pm
	TH	7:40 – 8:10 am 12:40 – 1:10 pm 5:10 – 5:40 pm	9:00 – 9:30 am 2:00 – 2:30 pm 6:30 – 7:00 pm	7:00 – 7:30 am 12:00 – 12:30 pm 4:30 – 5:00 pm	8:20 – 8:50 am 1:20 – 1:50 pm 5:50 – 6:20 pm
	F	7:00 – 7:30 am 12:00 – 12:30 pm 4:30 – 5:00 pm	7:40 – 8:10 am 12:40 – 1:10 pm 5:10 – 5:40 pm	8:20 – 8:50 am 1:20 – 1:50 pm 5:50 – 6:20 pm	9:00 – 9:30 am 2:00 – 2:30 pm 6:30 – 7:00 pm

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	ST	8:20 – 8:50 am 1:20 – 1:50 pm 5:50 – 6:20 pm	7:00 – 7:30 am 12:00 – 12:30 pm 4:30 – 5:00 pm	9:00 – 9:30 am 2:00 – 2:30 pm 6:30 – 7:00 pm	7:40 – 8:10 am 12:40 – 1:10 pm 5:10 – 5:40 pm
	S	9:00 – 9:30 am 2:00 – 2:30 pm 6:30 – 7:00 pm	8:20 – 8:50 am 1:20 – 1:50 pm 5:50 – 6:20 pm	7:40 – 8:10 am 12:40 – 1:10 pm 5:10 – 5:40 pm	7:00 – 7:30 am 12:00 – 12:30 pm 4:30 – 5:00 pm

ZC= Zaria City Market, **AR**= Agoro Roundabout, **KW**= Kwangila Flyover, **WW**= Western Ways.
Source: Field survey, 2020

RESULTS AND DISCUSSION

The mean and total emission levels of the air quality parameters CO, NO_2, and SO_2 for all the three periods morning, afternoon, and evening were calculated, followed by the statistical analysis of the pollutants using SPSS software (version 23) using descriptive and inferential analysis respectively.

Concentration of Selected Pollutants in Zaria Metropolis

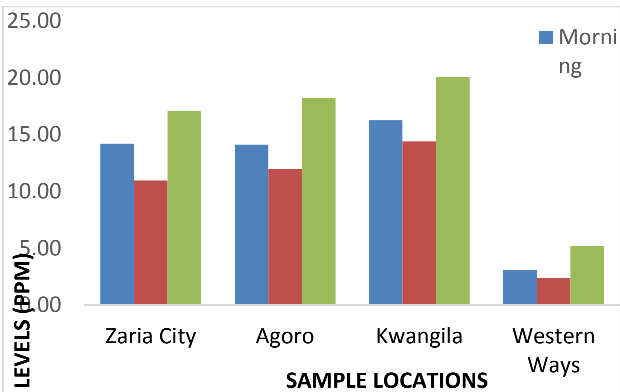

Figure 1: Average weekly concentration level of CO at the sampling points at Zaria metropolis

Figure 1 revealed that the highest concentration level of CO was observed at Kwangila flyover followed by Agoro roundabout and Zaria city market respectively, while Western ways point had the least concentration level of CO. Apart from Western Ways, all the values measured at various sampling points were beyond the stipulated NAAQ standard which is 10ppm (NESREA, 2013).This indicates that the environment around these sampling points is exposed to CO, and this poses a potential health risk. From direct observation, markets, filling stations and motor parks are located around some of the sampling points, the high concentration of these pollutants are as a result of several factors such as high traffic concentration, smaller size and quality of the roads, emissions from generators, burning of refuse and expired vehicles tyres. Some of the sampling points also served as bus-stops for some vehicles and motorcycles.

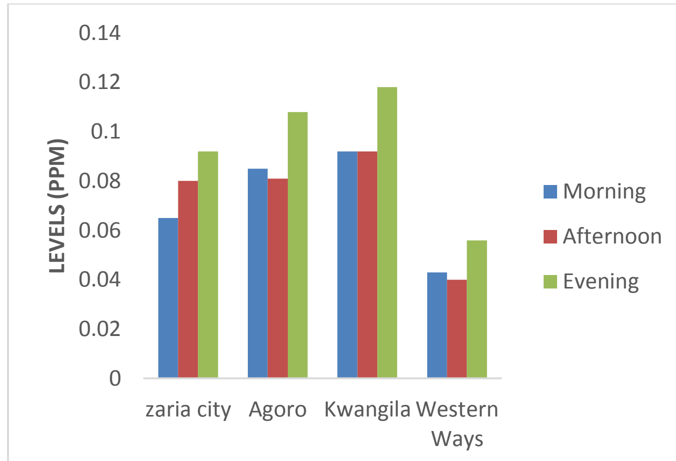

Figure 2: Average weekly concentration level of NO_2 at the sampling points at Zaria metropolis

Figure 2 revealed that NO_2 concentration were high at all the sample points, with the highest observed at Kwangila flyover while Western ways had the least concentration. Comparing the level of NO_2 with the values presented in two separate studies, the periodic mean of NO_2 was found to be similar and high. The study by Onalapo (2015) with values 0.09ppm - 0.39ppm in Minna Niger State and that of Okunola et al., (2012) with values of 0.029ppm - 0.115ppm in Kano metropolis agreed with this finding that NO2 emission was high. Additionally, besides the Western ways point, which are within the specified limit, all the values measured at various sampling points were beyond the stipulated NAAQ standard which is 0.04ppm – 0.06ppm (NESREA, 2013). This means that they are unsafe.

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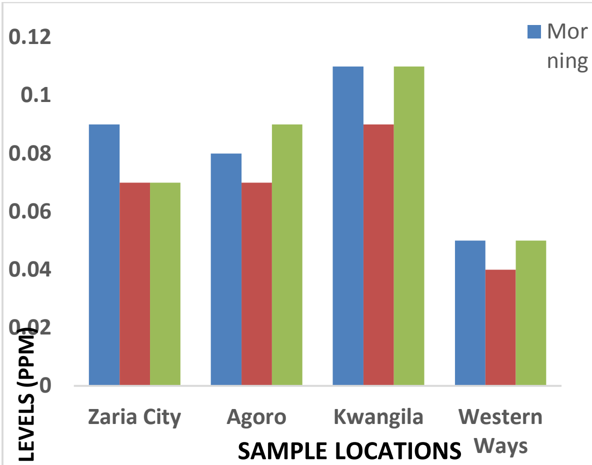

Figure 3: Average weekly concentration level of SO_2 at the sampling points at Zaria metropolis

Figure 3 revealed that the concentration level of SO_2 was high in the Kwangila flyover followed by the Agoro roundabout and Zaria city market while Western ways had the least concentration level of SO_2 within the Zaria metropolis. Though, the concentration of SO_2 is lower than ranges of 16ppm - 64ppm and 7.4ppm – I5.5ppm as reported in similar studies conducted by Ettouney *et al.* (2010) in Port-Harcourt and Greece respectively, but was within the range of 0.052ppm - 0.07ppm, and 0.03ppm - 0.09ppm as reported by Hena (2014) and Okunola *et al.* (2012) in Kaduna and Kano metropolises respectively. All the values measured at various sampling points were within the stipulated NAAQ standard which is 0.01ppm – 0.1ppm, except for the Kwangila flyover which was slightly high both in the morning, afternoon, and evening (NESREA, 2013). This means that the three points were slightly safe.

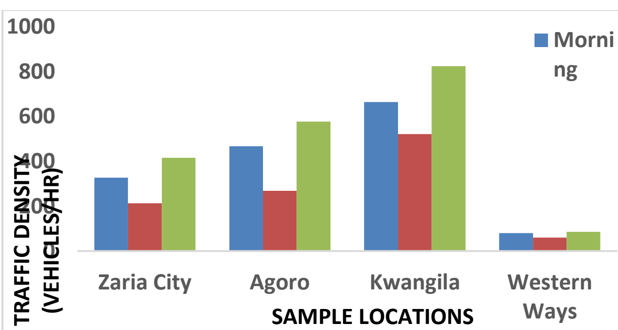

Figure 4: Average weekly concentration level of Traffic flow at the sampling points at Zaria metropolis

Figure 4 revealed that Kwangila flyover had the highest traffic flow followed by Agoro and Zaria city market, while Western Way had the least traffic flow. Kwangila flyover has the highest traffic flow point in Zaria metropolis because it serves as the major link between some northern parts of Nigeria to other parts of Nigeria. The results indicate that the evening peak had the highest traffic flow between all the periods of the day.

Spatial Variations between Concentrations Level of CO, NO_2, and SO_2 in Zaria Metropolis

In this section, the spatial variation of CO, NO_2, and SO_2 was assessed and discussed respectively.

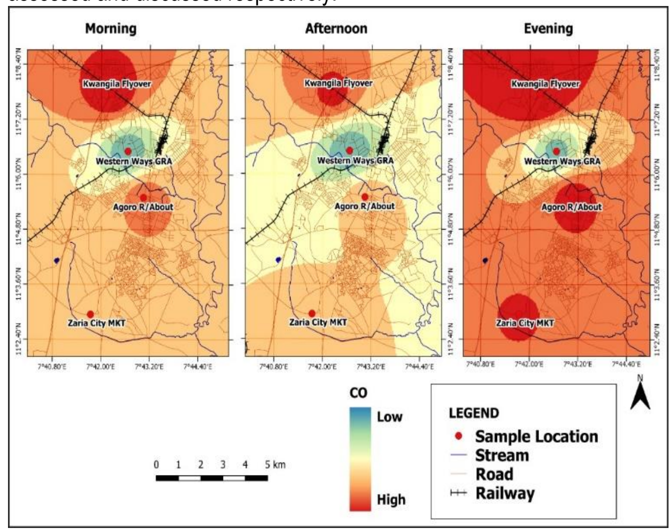

Figure 5: Zaria metropolis showing CO concentration across the sample points

Figure 5 displayed the spatial variation of CO concentration during the three traffic peak periods of the day. The morning peak indicates a low level of concentration around Western ways, while a high level was observed around Kwangila flyover and Agoro roundabout, and a moderately high around Zaria city market. In the afternoon, a high concentration level of CO was observed around Kwangila flyover, while areas around Western ways remain low. The evening peak reveals that a high concentration of CO was observed around Zaria city market, Agoro roundabout, and Kwangila flyover, while a low concentration level was observed around Western ways.

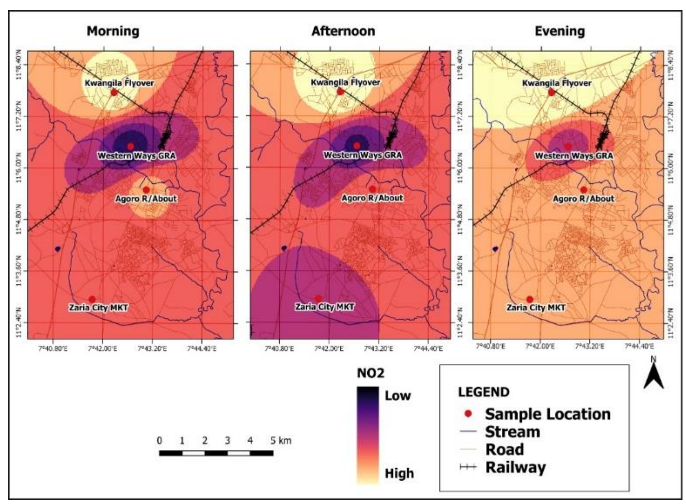

Figure 6: Zaria metropolis showing NO_2 concentration across the sample points

Figure 6 showed the spatial variation of NO_2 concentration at the three traffic peak periods of the day. The morning peak indicates a low level of concentration around Western ways, while a high level was observed around Kwangila flyover and Agoro roundabout, the concentration is moderately high around Zaria city market. In the afternoon, a high concentration level of NO_2 was observed around Kwangila flyover, moderately high around Agoro roundabout, and moderately low around Zaria city market, while areas around Western ways remain low. The evening peak reveals that a moderately high concentration of SO_2 was observed around Zaria city market and Agoro roundabout, low concentration around Western ways, and high concentration around Kwangila flyover.

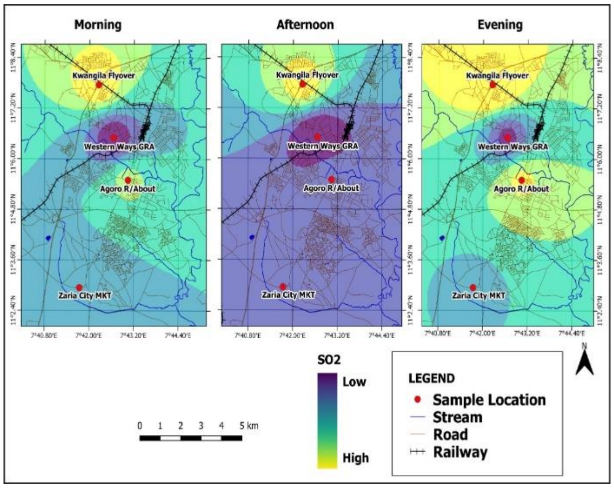

Figure 7: Zaria metropolis showing SO_2 concentration across the sample points

Figure 7 showed the spatial distribution of SO_2 concentration at the three periods of the day.
The morning peak revealed that around Kwangila flyover and Agoro roundabout the concentration was high, while around Zaria city market was averagely low, a low concentration level of SO_2 was recorded and maintained around Western ways. In the afternoon, a high concentration level was recorded around Kwangila flyover for the second time, averagely low around Agoro roundabout and Zaria city market, while a low concentration level of SO_2 was recorded around western ways as usual. The evening peak also revealed that the concentration level of SO_2 was high around the Kwangila flyover and Agoro roundabout, moderately low around the Zaria city market, while it remained low around Western ways.

Figures 5, 6 and 7 showed the spatial spread across the periods of the day which are morning, afternoon, and evening. The colors indicate high and low levels of concentration of the pollutants. It is however observed that the concentration level of the selected pollutants (CO, NO_2, and SO_2) is always high during the evening. This occurs probably because most of the road users have a specific time of going to their places of business in the morning, but during the evening period, about 80% of them use the same time back to their places of residence mostly from 5pm to 7 pm. Kwangila flyover has the highest level of concentration, this could be because it stands as a junction that connects almost all the North West Nigeria and some of the North-East with the Southern and Eastern parts of the country. A bad road network also plays a role. Moreover, this indicates that the concentration level of CO, NO_2, and SO_2 in the Zaria metropolis varies with time and space.

Conclusion/Recommendation

This study recorded varying concentrations of gases detected at all sampling points. Generally, vehicle emissions in the Zaria metropolis are very high, with a likely health effect on humans. Concentration levels of CO measured at the various sampling points except for Western ways were above the NAAQ permissible limit. This indicates that the air quality may be harmful to health. At most of the sampling points, the NO_2 concentration was beyond NAAQ permissible limit, while at some of the sampling points it was in between the lower and upper NAAQ permissible limit, but lower at some points. Likewise, the SO_2 measured were slightly beyond the NAAQ permissible limit, but still not beyond the higher safe limit at some points. Thus, the air quality in such cases is safe except for the Kwangila flyover which was higher than the NAAQ permissible limit.
Finally, this study also suggests that vehicles in Zaria metropolis contribute significantly to air pollution and that the urban environment is characterized by high vehicular volume that might cause a serious health and wellbeing threat to road users and passers-by, especially when vehicles are over-used. The study recommends that air quality can be improved greatly both spatially and temporally by improving the road network to ease the flow of traffic, and by improving quality assurance on the types and ages of vehicles imported into the country and by making air quality management a priority for cities and also by building bridges and roundabouts at some strategic places in the metropolis.

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