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Effect of Vehicular Traffic Emission on Ambient Air Quality in Oredo LGA of Benin City, Nigeria.

*Rawlings, A. and Oriakhi, O.
Department of Civil Engineering, Faculty of Engineering, University of Benin, Benin City, Edo State, Nigeria.
*Corresponding Author's Email: *animetu.seghosime@uniben.edu*

ABSTRACT
The rapid increase in urban population, coupled with economic growth and urbanization, has had a substantial impact on urban air quality. Vehicular emissions play a significant role in elevating levels of urban air pollution, which poses health risks to human populations. Therefore, it is imperative to assess the effects of traffic-originated air pollutants on urban air quality. Consequently, this study aims to evaluate the impact of vehicular traffic emissions on ambient air quality in the Oredo Local Government Area of Benin City. Data for this study were collected by conducting a traffic flow survey and analysing some air quality parameters (CO_2, PM, HCHO, and TVOC) at three different junctions (Winners', PZ, and ADP junctions) within Oredo LGA of Benin City during morning peak, evening peak, and off-peak traffic periods. Winners' and PZ junctions served as traffic hotspots, while ADP, a less-traffic area, served as the control. Results of the average traffic density showed that Winners' and PZ junctions had a higher traffic density compared to ADP junctions. The results of the air quality analysis showed that the average concentrations of all the parameters exceeded the thresholds. The mean concentrations of each of the pollutants were higher at peak traffic periods than at off-peak traffic periods and at Winners', PZ, and ADP junctions than at ADP junctions. The most elevated levels of pollutant in the atmosphere were CO_2, with mean concentrations of 753.00 ppm, 1020.67 ppm, and 673.67 ppm; 759.33 ppm, 1049.67 ppm, and 680.00 ppm; and 740 ppm, 986.00 ppm, and 224.33 ppm during the morning peak, evening peak, and off-peak traffic periods at Winners', PZ, and ADP junctions. Traffic density and pollution levels were highly correlated. Hence, improved road conditions and traffic control measures at these junctions are recommended to reduce peak traffic periods, thereby contributing to better environmental health in Oredo LGA.
Keywords: Air Quality Parameters, Traffic Emissions, Traffic Flow Survey, Air Pollution, Thresholds, Pollutant Levels.

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I.

II. Introduction

The environment is the key to the survival of life on Earth. Without the proper environment, human beings cannot survive. There is currently a massive focus on air quality due to its impact on public health caused by pollutants such as particulate matter, carbon monoxide, ozone, nitrogen dioxide, and sulfur dioxide [1]. Vehicle emissions are among one of the largest greenhouse gas emitters in the world [2] and contribute significantly to air pollution. In most countries, including Nigeria, population and urbanization have been on the rise, resulting in a tremendous increase in automobile ownership. Rapid urbanization and high vehicular traffic are significant contributors to air pollution in many cities around the world [3, 4]. In Nigerian cities, private transport is a popular mode of transportation, with every individual using their own vehicle for different purposes. Although the advent of fuel subsidy removal, which has increased the cost of fuel prices, has resulted in people parking their cars and using public transport, some people (well-placed Nigerians) prefer to drop their big cars for smaller ones to reduce fuel consumption rather than cope with the stress and inconveniences of using public transport. The poor state of these vehicles, coupled with the frequent traffic jams resulting from poor road conditions in the country, increases vehicular emissions and contributes to air pollution [5].

Air pollution is the presence of harmful or poisonous substances in the air that can cause damage to the climate, materials, and the health of humans, animals, and plants [5]. It originates from numerous sources of emissions, both natural and anthropogenic, such as household combustion devices, the burning of fossil fuels, industrial facilities, deforestation, forest fires, mining operations, motor vehicles, etc. Pollutants of major public health concern include particulate matter, carbon monoxide, ozone, nitrogen dioxide, and sulfur dioxide [5]. Most vehicles are gas-powered, which makes use of internal combustion engines, and these engines emit two types of pollutants, namely, primary and secondary. Primary pollutants are emitted from a source directly into the atmosphere, and they include carbon monoxide, carbon dioxide, nitrogen oxides, sulfur oxides, hydrocarbons, heavy metals, and particulate matter [6,1]. These primary pollutants undergo chemical reactions in the atmosphere, possibly involving the natural components of the atmosphere, especially water and oxygen, to form secondary pollutants such as photochemical smog [7, 8], fog, ground-level ozone, and peroxyacetylnitrate (PAN). All these pollutants emitted by vehicles are of major public health concern.

Exposure to air pollutants such as particulate matter ($PM_{2.5}$ and PM_{10}), nitrogen dioxide (NO_2), ozone (O_3), carbon monoxide (CO), and sulfur dioxide (SO_2) can cause respiratory and other diseases, especially in children, and are important sources of morbidity and mortality. Excessive exposure to these pollutants has been closely linked to cardiovascular diseases, respiratory diseases, and lung disease [9]. According to the World Health Organization (WHO), air pollution is responsible for an estimated 7 million premature deaths worldwide annually [10]. About 92% of the world's population lives in places where air quality levels exceed WHO limits [11].

Policies to reduce air pollution can offer a win-win strategy for both climate and health by lowering the burden of disease attributable to air pollution while contributing to the near- and long-term mitigation of climate change. Although international conferences have recently developed different ways to improve and assure air quality employing global strategic perspectives [12], many people are still exposed to hazardously polluted breathing air on a daily basis in Nigeria as vehicles are usually not checked or certified for standard emission levels in the country [13]. Hence, it is important to monitor air quality so as to take measures to reduce air pollution and improve air quality to protect public health.

Several studies have been conducted on vehicular emissions, air quality, and their impact in Nigeria [14, 15, 16, 6, 17]. However, there is a lack of data on vehicular emissions and air quality in Benin City, Edo State, Nigeria. A recent study by Raji et al. [18] assessed vehicular-induced emissions in some selected areas of Benin City, and a study by Ukpebor et al. [19] examined the impact of improved traffic control measures on air quality in Benin City, Nigeria. Although there are traffic control measures in Benin City, the bad roads currently in the city, especially within the Oredo LGA axis (those linking Benin City and the neighboring state), have resulted in frequent traffic jams within the axis. Therefore, this study aims to investigate the influence of traffic density on some air quality parameters such as carbon dioxide (CO_2), particulate matter (PM), formaldehyde (HCHO), and total volatile organic compound (TVOC) within the Oredo Local Government Area (LGA) of Benin City, Edo State, Nigeria.

III. Materials and Methods

2.1 Study Area

Oredo Local Government Area (Figure 1) has its headquarters in Benin City and a land area of about 319 square kilometers [20]. It lies between latitudes 6°00' and 6° 30' north of the equator and longitudes 5° 25' and 5° 35' east of the Greenwich meridian [20]. It is located within the rainforest zone of Nigeria, with mean annual rainfall in the range of 1500 mm to 2500 mm and the mean monthly temperature varying from 25°C to 28°C [21]. The LGA witnesses two distinct seasons, which are the dry and the rainy seasons, with an average humidity level of about 61% [22]. The rainy season typically runs from March to October, with a brief pause in August. The dry season, on the other hand, lasts from November to February, with dry harmattan winds blowing in from the northeast between December and February. However, due to the effects of global warming and climate change, rainfall has been observed to fall irregularly almost every month of the year, with double peak periods in July and September. Oredo is home to many; thus, it has a population of about 374,515 people [23].

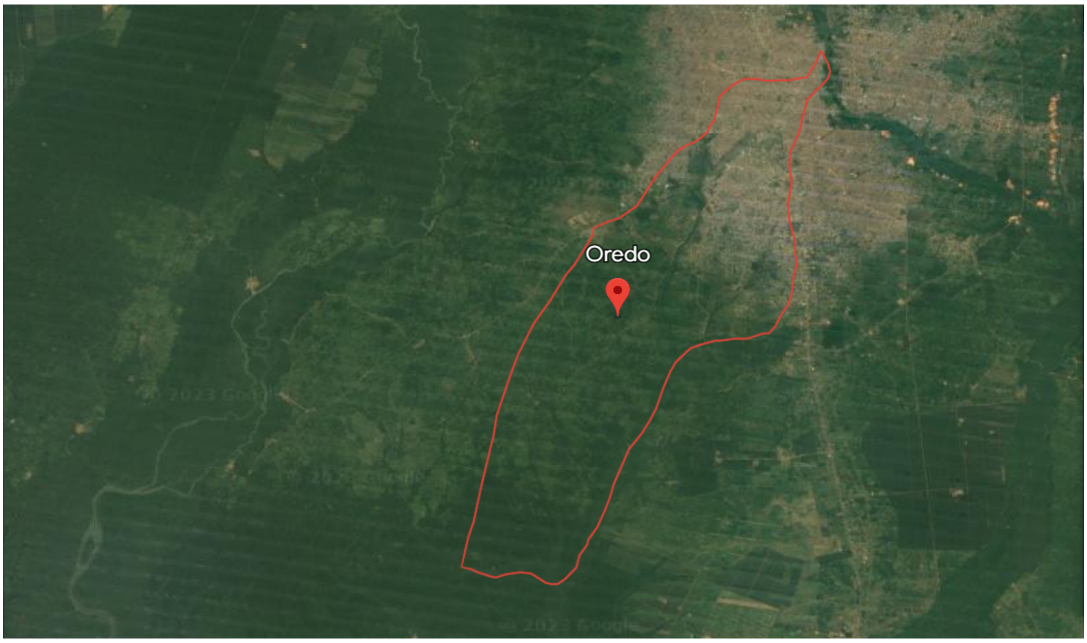

Figure 1: Map Sowing the Location of Oredo LGA, Benin City (Source: [24])

2.2 Data Collection and Analysis

The data collection process involved two surveys: a traffic flow survey and an environmental survey, as described by Ekwumemgbo et al. [6]. The surveys were conducted for a period of three weeks between November and December 2023 at three different locations in Oredo LGA: PZ Junction, Winner's Junction, and Estate Junction. These locations were chosen because of the road condition and the non-traffic control measures at these junctions. The first two locations (PZ and Winner's Junctions) are areas of high traffic volume as a result of their bad road condition, and the third location (ADP Junction) is an area with minimal traffic due to the good road condition and, as such, served as a control location. The sampling points' locations are shown in Table 1 and Figure 2. Data collection was carried out for three working days within the study time frame (November to December, 2023) at 15 minutes averaging time during three time periods: the morning peak period (7.00 am–10.00 am), the off-peak period (10.00 am–1.00 pm), and the evening peak period (4.00 pm–7.00 pm). Air samples were analyzed using an air quality monitor (air knight AK1000) for four parameters, namely: carbon dioxide (CO_2), particulate matter (PM), formaldehyde (HCHO), and total volatile organic compound (TVOC). The traffic flow survey involved observing and collecting traffic flow data from the three traffic junctions using the direct counting method (tally sheet method). The traffic density is expressed in the number of vehicles per minute (v/min), and it was carried out during the same period as the environmental survey. Data were analyzed using descriptive statistics such as mean and standard deviation, as well as inferential statistics such as simple linear regression with the statistical package for the social sciences (SPSS, version 26.0, 2018). The results were presented using descriptive tables.

Table 1: Location and GPS Coordinates of Traffic and Air Samples Location

Location ID	Traffic/ Air Sample Location	GPS Coordinates (Decimal Degree)	
		Longitude (E)	Latitude (N)
PZJ	PZ Junction	5.63358328	6.27945071
WJ	Winners' Junction	5.63511716	6.26486849
ADP J	ADP Junction	5.59017795	6.29523454

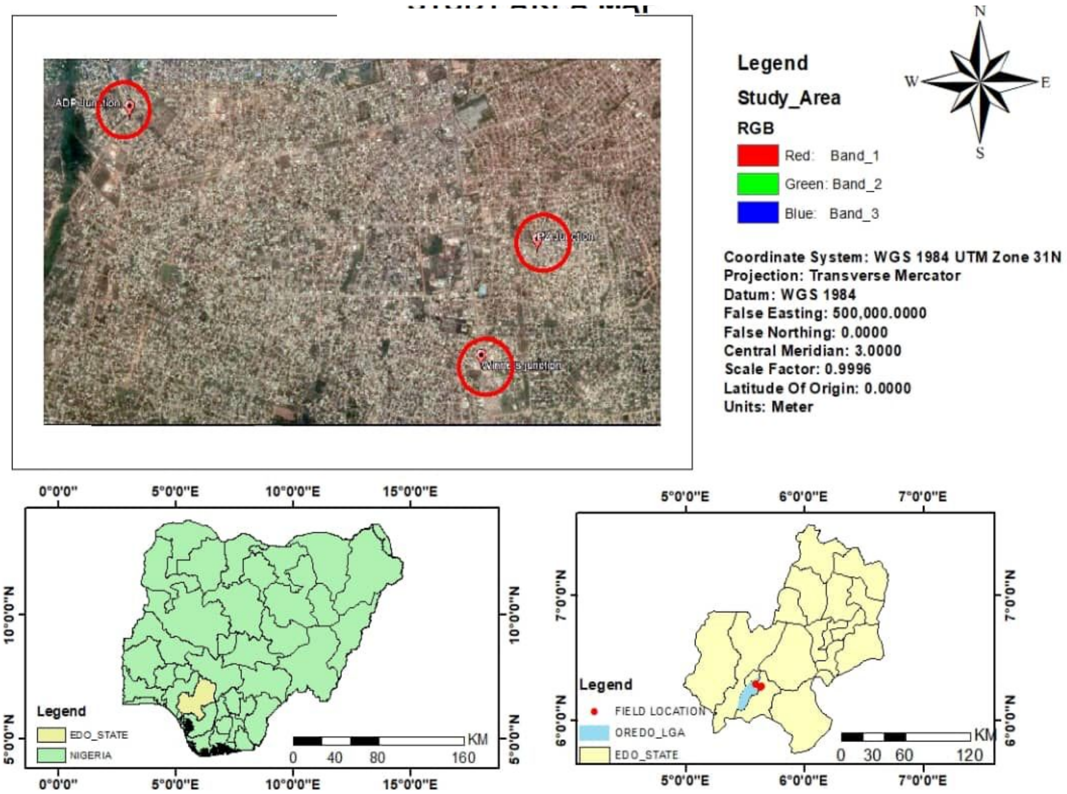

Figure 2: Map of the Study Area Showing Sampling Points

IV. Results and Discussions

The findings of this study are displayed in Tables 1, 2, and 3. Tables 1 and 2 display the traffic density and air quality data at the different locations at 15 minutes averaging time, respectively. Table 3 presents the correlation coefficient between the traffic density and air quality parameters.

Table 1: Traffic Density at the Different Locations (V/min)

Location	Cars	Buses	Mini Buses	Heavy Duty Vehicles	Motor Cycles
Morning Peak					
Winners' Junction	19.00 ± 2.65	5.67 ± 1.53	4.67 ± 4.16	3.00 ± 0.00	1.00 ±1.73
PZ Junction	23.00 ± 4.00	5. 67 ± 2.52	6.67 ± 2.08	3.67 ± 1.53	3.67 ± 1.53
ADP Junction	6.67 ± 1.16	2.33 ± 0.58	1.33 ± 0.58	0.33 ± 0.58	0.00 ± 0.00
Off Peak					
Winners' Junction	7.67 ± 0.577	4.00 ± 1.73	3.67 ± 2.89	2.00 ± 2.00	1.00 ± 1.00
PZ Junction	10.00 ± 3.00	5.67 ± 2.31	2.67 ± 2.52	1.67 ± 1.53	0.67 ± 1.16
ADP Junction	1.00 ± 1.73	1.33 ± 2.31	0.67 ± 1.16	0.33 ± 0.58	0.00 ± 0.00
Evening Peak					

Winners’ Junction	32.00 ± 13.86	7.67 ±0.58	4.33 ±0.58	5.00 ± 1.73	1.33 ± 2.31
PZ Junction	29.67 ± 2.52	8.67 ± 4.16	4.33 ± 1.53	3.67 ± 1.53	1.00 ± 1.73
ADP Junction	5.33 ± 2.31	2.67 ± 0.58	2.00 ± 1.73	1.67 ± 1.53	0.67 ± 0.58

Results from Table 1 indicate that the traffic density varies over a 15-minute period at the three locations in the study area. The number of cars was higher than those of other types of vehicles considered at the three locations during the different time periods, with 19.00 ± 2.65 v/min, 23.00 ± 4.00 v/min, and 6.67 ± 1.16 during the morning peak period; 32.00 ± 13.86 v/min, 29.67 ± 2.52 v/min, and 5.33 ± 2.31 v/min during the evening peak period; 7.67 ± 0.577 v/min, 10.00 ± 3.00 v/min, and 1.00 ± 1.73 v/min during the off-peak period at PZ, Winner’s, and ADP junctions, respectively and motorcycles were the least in number with 1.00 ±1.73 v/min, 3.67 ± 1.53 v/min, and 0.00 ± 0.00 during the morning peak period; 1.33 ± 2.31 v/min, 1.00 ± 1.73 v/min, and 0.67 ± 0.58 during the evening peak period; 1.00 ± 1.00 v/min, 0.67 ± 1.16 v/min, and 0.00 ± 0.00 v/min during the off-peak period at PZ, Winners', and ADP junctions, respectively. This implies that the majority are car owners, and motorcycles are not allowed to ply major roads in Benin City. When the mean traffic density data from each location's morning peak, evening peak, and off-peak periods were compared, it was evident that the morning and evening peak periods had higher traffic density than the off-peak periods. This could be because of a variety of activities that take place during these times, such as workers, businesspeople, and students leaving and returning to their homes; however, it was lessened at the off-peak time due to fewer activities during this time [18]. Kaduna and other areas of Benin City have shown comparable patterns in traffic density data [6, 18]. PZ and Winners’ junctions had a higher traffic density compared to the ADP junction, which served as the control location. The reason for this could be that the junctions are in a highly trafficked area due to their strategic location near numerous commercial establishments, including government buildings and small, medium, and large-scale businesses, and along the road (which is in very bad condition) that connects Benin City directly to its neighboring states [25]. Generally, it was observed that the number of vehicles plying the roads was not as high as it used to be before. This could be a result of the increase in premium motor spirit (PMS) due to subsidy removal in the country at the time this study was conducted.

Table 2: Air Quality Parameters at the Different Locations

Location	CO_2 (ppm)	PM ($\mu g/m^3$)	HCHO (mg/m^3)	TVOC (mg/m^3)	Temp. (°C)

		$PM_{2.5}$	**PM_{10}**			
Morning Peak						
Winners' Junction	753.00 ± 85.72	29.67 ±3.33	36.33 ± 2.02	0.07 ± 0.08	0.10 ± 0.07	27.53 ± 1.94
PZ Junction	1020.67 ± 41.10	23.83 ± 4.04	28.50 ± 4.58	0.08 ± 0.06	0.33 ± 0.16	28.00 ± 0.46
ADP Junction	673.67 ± 12.34	10.87 ± 0.51	13.23 ± 0.83	0.04 ± 0.03	0.19 ± 0.06	28.00 ± 1.18
Off Peak						
Winners' Junction	740 ± 89.59	25.33 ± 3.69	30.33 ± 1.61	0.17 ± 0.25	0.14 ± 0.02	30.43 ± 2.21
PZ Junction	986.00 ± 30.51	20.17 ±3.51	25.17 ± 2.31	0.10 ± 0.03	0.24 ± 0.13	32.03 ± 0.64
ADP Junction	224.33 ± 388.56	3.40 ± 5.89	4.10 ± 7.10	0.01 ± 0.01	0.01 ± 0.01	9.10 ± 15.76
Evening Peak						
Winners' Junction	759.33 ± 86.73	34.33 ± 3.62	41.67 ± 1.04	0.07 ± 0.06	0.15 ± 0.08	28.77 ± 2.05
PZ Junction	1049.67 ± 54.78	29.50 ± 4.44	37.50 ± 9.00	0.13 ± 0.07	0.11 ± 0.06	29.67 ± 0.76
ADP Junction	680.00 ± 7.55	11.40 ± 0.61	13.90 ± 0.72	0.09 ± 0.02	0.19 ± 0.14	29.33 ± 0.96

Table 2 showed that high concentrations of CO_2 were recorded during the morning, evening peak periods, and off-peak at all three locations. The mean concentrations of CO_2 recorded during the morning peak periods were 753.00 ± 85.72 ppm, 1020.67 ± 41.10 ppm, and 673.67 ± 12.34 ppm at Winners', PZ, and ADP junctions, respectively. During the evening peak periods, the concentrations were 759.33 ± 86.73 ppm, 1049.67 ± 54.78 ppm, and 680.00 ± 7.55 ppm at Winners', PZ, and ADP junctions, respectively, while during the off-peak periods, the concentrations were 740 ± 89.59 ppm, 986.00 ± 30.51 ppm, and 224.33 ± 388.56 ppm at Winners', PZ, and ADP junctions, respectively. This indicates that higher levels of CO_2 were found during the morning and evening peak periods than the off-peak period in the three locations, and it implies that increased vehicular emissions in these locations may have contributed to high levels of CO_2 since higher traffic densities were observed at these times in these locations. The highest mean concentrations of CO_2 (1049.67 ± 54.78 ppm) were at PZ junction during the evening period, irrespective of the highest traffic density recorded in Winners' junction at this time. This suggests that, apart from vehicular emissions, other sources such as climatic elements and temperature (Table 1) may also be contributing to higher levels of CO_2 in this location [26, 18]. The concentrations of CO_2 observed in the sampling locations have exceeded the threshold of 416 ppm [27]. This clearly confirms the report by the UN Environmental Programme [27] that atmospheric CO_2 has exceeded the threshold at the end of 2021. Although CO_2 exposure has several benefits to plants and human life, high concentrations in the atmosphere can result in devasting effects on the environment. CO_2 causes climate change (by trapping heat), dizziness, headaches, respiratory diseases, and changes in plant life among others [28, 29].

Regardless of the number of traffic densities, high concentrations of particulate matter (PM) were found throughout all peak periods at the sampling locations. PM_{10} was observed to be higher in the atmosphere than $PM_{2.5}$. The mean concentrations of PM_{10} for the morning traffic peak period were 36.33 ± 2.02 µg/m^3, 28.50 ± 4.58 µg/m^3, and 13.23 ± 0.83 µg/m^3 at Winners', PZ, and ADP junctions, respectively. The mean concentrations for the evening peak traffic period were 30.33 ± 1.61µg/m^3, 25.17 ± 2.31µg/m^3, and 4.10 ± 7.10µg/m^3. During the off-peak, the mean concentrations were 41.67 ± 1.04 µg/m^3, 37.50 ± 9.00 µg/m^3, and 13.90 ± 0.72 µg/m^3 at Winners', PZ, and ADP junctions, respectively. Although there isn't a specific 15-minute threshold for PM (PM2.5 and PM10), according to Stieb et al. [30], high health risks are associated with short-term exposure to 10 µg/m^3 ($PM_{2.5}$) and 20 µg/m^3 (PM_{10}) increased concentrations in the atmosphere. Hence, this implies that the concentrations obtained from this study have exceeded the threshold, and they suggest that pavement deterioration (which is common in the study area) may also be contributing to air pollution in the study area. Daily and short-term exposure to PM has been linked with cardiovascular and respiratory diseases. and lung cancer [31, 32].

Further, Table 2 indicates varying formaldehyde (HCHO) concentrations at the different traffic junctions during the different periods: the mean concentrations of HCHO during the morning peak traffic period were 0.07 ± 0.08 mg/mg^3, 0.08 ± 0.06 mg/mg^3, and 0.04 ± 0.03 mg/mg^3 at Winners', PZ, and ADP junctions, respectively. The mean concentrations for the evening peak traffic period were 0.07 ± 0.06 mg/mg^3, 0.13 ± 0.07 mg/mg^3, and 0.09 ± 0.02 mg/mg^3 at Winners', PZ, and ADP junctions, respectively, while during the off-peak period, the mean concentrations were 0.17 ± 0.25 mg/mg^3, 0.10 ± 0.03 mg/mg^3, and 0.01 ± 0.01 mg/mg^3 at Winners', PZ, and ADP junctions, respectively. These concentrations exceeded the EPA-AEGL [33] threshold of 0.1 ppm (which is equivalent to 0.122 mg/mg). Daily and short-term exposure to concentrations above this level results in notable discomfort like watery eyes, throat irritation, difficulty breathing, or certain asymptomatic and non-sensory effects [33, 34, 35]. TVOC concentrations also varied across different traffic junctions during various periods. Notably, the highest mean concentration of 0.33 ± 0.16 mg/m^3 was observed at the PZ junction during the morning peak period, which coincided with heavy traffic density. This concentration is above the European Community acceptable limit of 0.3 mg/m^3 in the air [36]. When TVOC concentrations exceed 0.3 mg/m^3, there may be noticeable odors, eye and skin irritation, and discomfort [36, 37, 38].

Table 3: Coefficient of Correlation Between the Traffic Density and Air Quality Parameters

Coefficients	**CO_2 (ppm)**	**PM (µg/m^3)**		**HCHO (mg/m^3)**	**TVOC (mg/m^3)**
		$PM_{2.5}$	**PM_{10}**		
Morning Peak					
R	0.27	0.93	0.70	0.67	0.83
R^2	0.07	0.87	0.48	0.45	0.69
F	0.08	6.64	0.93	0.80	2.20
Sig. F	0.83	0.24	0.51	0.54	0.38
Off Peak					
R	0.94	0.94	0.995	0.996	0.65
R^2	0.89	0.88	0.99	0.99	0.42
F	8.10	7.48	100.07	132.30	0.73
Sig. F	0.22	0.22	0.06	0.06	0.55
Evening Peak					
R	0.63	0.73	0.19	0.92	0.60
R^2	0.39	0.54	0.34	0.85	0.36
F	0.64	1.16	0.04	5.79	0.56
Sig. F	0.57	0.48	0.88	0.25	0.59

The air quality parameters (each of the air pollutants) were correlated with the traffic density (regression analysis). Results from Table 3 indicated that CO_2 and PM_{10} showed a low correlation with traffic density at R = 0.27 and 0.19, respectively, during the morning peak traffic period. This result indicates that the air quality parameters CO_2 and PM_{10} exhibited a weak correlation with traffic density, and this could be the result of off-chance circumstances since the significance F is large [6]: for CO_2, it is 0.83 and for PM10, it is 0.51. $PM_{2.5}$, PM_{10}, HCHO, and

TVOC showed a high correlation with traffic density during the morning peak traffic period at R = 0.93, 0.70, 0.67, and 0.83, respectively. During the evening peak period, CO_2, $PM_{2.5}$, HCHO, and TVOC showed a high correlation with traffic density at R = 0.63, 0.73, 0.92, and 0.60, respectively. During the off-peak traffic period, CO_2, $PM_{2.5}$, PM_{10}, HCHO, and TVOC all exhibited a high correlation with traffic density at R = 0.94, 0.94, 0.995, 0.996, and 0.65, respectively. These strong positive correlations of air quality parameters with traffic density suggest that air quality may be influenced by traffic density, implying that an increase in traffic density may increase the concentrations of air pollutants resulting from vehicular emissions [39, 6] in the study area.

V. Conclusion

This study has assessed the effect of vehicular traffic emissions on some air quality parameters (CO_2, PM, HCHO, and TVOC) at three junctions (Winners', PZ, and ADP junctions) located in Oredo LGA of Benin City, Nigeria. Results from the air quality assessment indicated that the average concentrations of all the parameters analyzed were higher during peak traffic periods (morning and evening) than during off-peak traffic periods at all locations, except for PM and HCHO, which were higher throughout all the periods at all locations. Average concentrations of all parameters were generally low throughout all the periods at ADP junction compared to Winners' and PZ junctions, which may probably be because it is a low-traffic area due to the good road condition (thus was used as the control). All the parameters (PM, HCHO, and CO_2) average concentrations in the sampling locations during all the periods exceeded thresholds [30, 33, 27] except for TVOC, which only exceeded thresholds [36] during the morning peak period. The average concentrations of the parameters CO_2, PM, HCHO, and TVOC showed a strong correlation with traffic density, except that CO_2 and PM_{10} showed a weak correlation during the morning peak period only. This suggests that vehicle emissions may increase the level of air pollutants in Oredo LGA of Benin City and may contribute to atmospheric pollution as a result of increasing vehicle traffic and population growth. Hence, improved road conditions and traffic control measures at these junctions can reduce air pollution and improve air quality in Oredo LGA.

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