RESEARCH ARTICLE

OPEN ACCESS

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

Rawlings, A.^{1,*}, Ugbeni, P. O.¹ and Oriakhi, O.¹

¹Department 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 trafficoriginated 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 (CO₂, 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 CO₂, 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.

Date of Submission: 13-03-2024	Date of acceptance: 27-03-2024

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 in automobile ownership. Rapid increase urbanization and high vehicular traffic are significant contributors to air pollution in many cities around the world [3, 4]. In Nigerian cities,

I.

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, groundlevel 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 PM₁₀), nitrogen dioxide (NO₂), ozone (O₃), carbon monoxide (CO), and sulfur dioxide (SO₂) can cause respiratory and other diseases, especially in children, and are important sources of morbidity and mortality. Excessive exposure to these pollutants has been linked to cardiovascular closely 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 longterm 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 (CO₂), 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.

Location ID	Traffic/ Air Sample	GPS Coordinates (Decimal Degree)		
	Location	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	

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



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.

		J		Heavy Duty	Motor	
Location	Cars	Buses	Mini Buses	Vehicles	Cycles	
		Morning Pea	k			
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						

Table 1: Traffic Density at the Different Location	s (V/min)
--	-----------

www.ijera.com

I	I	I	1	1	I
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, $29.67 \pm$ 2.52 v/min, and 5.33 \pm 2.31 v/min during the evening peak period; 7.67 ± 0.577 v/min, $10.00 \pm$ 3.00 v/min, and 1.00 ± 1.73 v/min during the offpeak 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 $0.67 \pm$ 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)	m) PM (μg/m ³) HCHO (mg/m ³) TVOC (mg/m ³)				
www.ijera.cor	n	DOI: 10.9790/9622-140	3140148		148 Page	

*Rawlings et. al., International Journal of Engineering Research and Applications www.ijera.com

	1	-						
		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		

ISSN: 2248-9622, Vol. 14, Issue 3, March, 2024, pp: 140-148

Table 2 showed that high concentrations of CO₂ were recorded during the morning, evening peak periods, and off-peak at all three locations. The mean concentrations of CO₂ 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 \pm 54.78 ppm, and 680.00 \pm 7.55 ppm at Winners', PZ, and ADP junctions, respectively, while during the off-peak periods, the concentrations were 740 \pm 89.59 ppm, 986.00 \pm 30.51 ppm, and 224.33 \pm 388.56 ppm at Winners', PZ, and ADP junctions, respectively. This indicates that higher levels of CO₂ 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 CO₂ 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 CO₂ in this location [26, 18]. The concentrations of CO₂ 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 CO₂ exposure has several benefits to plants and human life, high concentrations in the atmosphere can result in devasting effects on the environment. CO₂ 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. PM₁₀ was observed to be higher in the atmosphere than $PM_{2.5}$. The mean concentrations of PM₁₀ for the morning traffic peak period were $36.33 \pm 2.02 \,\mu g/m^3$, $28.50 \pm$ $4.58 \ \mu g/m^3$, and $13.23 \pm 0.83 \ \mu g/m^3$ at Winners', PZ, and ADP junctions, respectively. The mean concentrations for the evening peak traffic period were $30.33 \pm 1.61 \mu g/m^3$, $25.17 \pm 2.31 \mu g/m^3$, and $4.10 \pm 7.10 \mu g/m^3$. During the off-peak, the mean concentrations were $41.67 \pm 1.04 \,\mu\text{g/m}^3$, $37.50 \pm$ $9.00 \ \mu g/m^3$, and $13.90 \pm 0.72 \ \mu g/m^3$ 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 μ g/m³ (PM₂₅) and 20 μ g/m³ (PM₁₀) 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 \pm 0.06 mg/mg^3 , and 0.04 \pm 0.03 mg/mg3 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/mg³ at Winners', PZ, and ADP junctions, respectively, while during the off-peak period, the mean concentrations were 0.17 ± 0.25 mg/mg³, $0.10 \pm 0.03 \text{ mg/mg}^3$, and $0.01 \pm 0.01 \text{ mg/mg}^3$ 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/m³ 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/m³ in the air [36]. When TVOC concentrations exceed 0.3 mg/m³, there may be noticeable odors, eye and skin irritation, and discomfort [36, 37, 38].

		PM (μg/m ³)			туос			
Coefficients	CO ₂ (ppm)	PM 2.5	PM ₁₀	HCHO (mg/m ³)	(mg/m ³)			
	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 P	eak					
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			

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

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}, PM₁₀, 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, CO₂, 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, CO₂, PM_{2.5}, PM₁₀, 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 (CO₂, 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 CO₂) 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 CO₂, PM, HCHO, and TVOC showed a strong correlation with traffic density, except that CO₂ and PM₁₀ 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.

References

[1]. Kumar, P. G., Lekhana, P., Tejaswi, M. and Chandrakala, S. (2021). Effects of Vehicular Emissions on the Urban Environment- A State of the Art. Materials Today: Proceedings 45: 6314–6320.

- [2]. Avellar, J. (2020). Car Emissions are a Major Source of Pollution. Environmental, Natural Resources and Energy Law, Lewis and Clark Law School. Available online from: https://law.lclark.edu/live/blogs/156car-emissions-are-a-major-source-ofpollution-
- [3]. Amuthadevi, C., Sathya-Priya, J. and Madhusudhanan, B. (2019). Validation of Multicast Routing in Cyber Physical Systems Monitoring Air Quality. Cluster Computing 22 (Suppl 2): 3917–3923.
- [4]. National Geographic, (2023). Urban Threats. Available online from: https://www.nationalgeographic.com/enviro nment/article/urban-threats
- [5]. WHO, (2023). Air Pollution. Available online from: https://www.who.int/healthtopics/air-pollution#tab=tab_1 [Accessed 1st October, 2023]
- [6]. Ekwumemgbo, P. A., Omoniyi, I. K., Godwin, O. F. and Edem, O.I. (2016). Inspection of the Impact of Vehicular Emissions on some Air Quality Parameters in Zaria Metropolis, Kaduna, Nigeria. The Pacific Journal of Science and Technology, 17 (1): 364- 373.
- [7]. Reyes, F., M. Grutter, A. Jazcilevich, and R. Gonzalez-Oropeza. (2006). Technical Note: Analysis of Non-regulated Vehicular Emissions by Extractive FTIR Spectrometry: Tests on a Hybrid Car in Mexico City. Atmospheric Chemistry and Physics, 6:5339–5346.
- [8]. Khitoliya, R.K. (2007). Environmental Pollution: Management and Control for Sustainable Development (2nd ed.), S. Chand Publishing, New Delhi, India.
- [9]. WHO, (2022a). Guidance on Air Pollution and Health. Avaliable online from: https://www.who.int/tools/compendium-onhealth-and-environment/air-pollution-andhealth#:~:text=The%20combined%20effects %20from%20ambient%20%28outdoor%29 %20air%20pollution,IHD%2C%20COPD% 2C%20lung%20cancer%20and%20acute%2 0respiratory%20infections
- [10]. WHO, (2022b). Ambient (Outdoor) Air Pollution. Available online from: https://www.who.int/news-room/factsheets/detail/ambient-%28outdoor%29-airquality-and-health [Accessed 1st October, 2023]

- [11]. WHO, (2016). WHO Releases Country Estimates on Air Pollution Exposure and Health Impact. Available online from: https://www.who.int/news/item/27-09-2016who-releases-country-estimates-on-airpollution-exposure-and-healthimpact#:~:text=In%20May%202016%2C%2 0WHO%20approved%20a%20new%20"roa d,role%20in%20national%20policies%20tha t%20affect%20air%20pollution [Accessed 01 October, 2023]
- [12]. Curtis, L., Rea, W., Smith-Willis, P., Fenyves, E. And Pan, Y. (2006). Adverse Health Effects of Outdoor Air Pollutants. Environment International, 32(6):815-830.
- [13]. Abam, F.I. and Unachukwu, G.O. (2009). Vehicular Emissions and Air Quality standards in Nigeria. European Journal of Scientific Research, 34(4):550-560.
- [14]. Akpan, P. E., Usip, E. E. and U. O. Jeremiah (2014). Impact of Traffic Volumes on Air Quality in Uyo Urban, Akwa Ibom state, Nigeria. Journal of Environment and Earth Science, 49(2):189 – 201.
- [15]. Prince, C. M. and Ubokobong, E. (2014). Spatio-temporal Variations in Urban Vehicular Emissions in Uyo City, Akwa Ibom State Nigeria. Journal of Sustainable Development, 7(4):272-281.
- [16]. Ekwumemgbo, P. A., K. I. Omoniyi, and Okon, I. E. (2015). An Assessment of the Impact of Vehicular Emission on the Proximate Composition of Roadside Amaranthus hybridus in Zaria Metropolis, Kaduna State, Nigeria. Ethiopian Journal of Environmental Studies & Management, 8(Suppl. 1): 835 – 845.
- [17]. Sunday, H. K., Joseph, O. S. and Laraba, R. S. (2020). Air Quality Assessment along the Transport Corridors of Kaduna Metropolis, Kaduna-Nigeria. Confluence Journal of Environmental Studies,13 (2): 1-14.
- [18]. Raji, W. A., Jimoda, L. A., Odobor, J. K., and Popoola, A. O. (2021). Assessment of Vehicular-Induced Emissions in some Selected Areas in Benin City, Edo State, Nigeria. Journal of Applied Science and Environmental Management, 25(8): 1535-1539.
- [19]. Ukpebor, J. E., Omagamre, E. W., Abayode, B. U., Charles, A., Dibie, E. N. and Ukpebor, E. E. (2021). Impacts of Improved Traffic Control Measures on Air Quality and Noise Level in Benin City, Nigeria. Malawi Journal of Science and Technology, 13(2): 51-83.

- [20]. Ojiako, J. C., Igbokwe, E. C. and Oliha, A. (2018). Creation of Geospatial Database for Educational Facilities in Oredo Local Government Area of Edo State, Nigeria. Journal of Research & Method in Education, 8(2) Ver. IV (Mar. – Apr.):72-84.
- [21]. Rawlings, A. and Ikediashi, A. I. (2020). Impact of Urbanizing Ovia-North East on the Quality of Groundwater using Water Quality Index. Nigerian Journal of Environmental Sciences and Technology (NIJEST), 4 (1): 87 – 96.
- [22]. Manpower, (2023). Oredo Local Government Area. Available online from: https://www.manpower.com.ng/places/lga/2 73/oredo [Accessed 4th March, 2023]
- [23]. National Population Commission (NPC), (2006). Nigeria National Census.
- [24]. Google Earth, (2023). Explore Google Earth. Available online from: https://earth.google.com, [Accessed 09/03/2023]
- [25]. Nwankwo, Wilson, Akinola S. Olayinka, Kingsley E. Ukhurebor (2019). The Urban Traffic Congestion Problem in Benin City and The Search for An ICT Improved Solution. International Journal of Scientific and Technology Research, 8 (12):65-72.
- [26]. Nkwocha A.C., Ekeke I.C., Kamalu C.I.O., Kamen F.L., Uzondu F.N., Dadet W.P., Olele P.C. (2017). Environmental Assessment of Vehicular Emission in Port-Harcourt City, Nigeria. International Journal of Environment, Agriculture and Biotechnology (IJEAB), 2 (2): 905-911.
- [27]. UN Environmental Programme, (2021). Atmospheric CO₂ Concentration. Available online from: https://data.unep.org/climate/essentialclimate-variables-eco/atmosphere-co2concentration [Accessed 15th February, 2024]
- [28]. Brooks, E. (2021). Carbon Dioxide Effects on Humans and the Environment. Available online from: https://ecojungle.net/post/carbon-dioxideeffects-on-humas-and-the-environment/.
- [29]. Nuruz, C. (2022). Carbon Dioxide Levels are at a Record High; Here is What you Need to Know. National Geographic, 1145 17th Street NW, Washington, DC 20036. Available online from: https://education.nationalgeographic.org/res ource/carbon-dioxide-levels-are-recordhigh-here-what-you-need-know/
- [30]. Stieb, D. M., Judek, S., Burnett, R. T. (2002). Meta-Analysis of Time-series

Studies of Air Pollution and Mortality: Effects of Gases and Particles and the Influence of Cause of Death, Age, and Season. Journal of the Air and Waste Management Association, 52: 470–484.

- [31]. Shang, Y., Sun, Z., Cao, J., Wang, X., Zhong, L., Bi, X., Li, H., Liu, W., Zhu, T., and Huang, W. (2013). Systematic Review of Chinese Studies of Short-term Exposure to Air Pollution and Daily Mortality. Environment International 2013, 54: 100–111.
- [32]. Jiang, X. Q., Mei, X. D.; Feng, D. (2016). Air pollution and chronic airway diseases: What should people know and do? Journal of Thoracic Disease, 8: E31–E40.
- [33]. United State Environmental Protection Agency Acute Exposure Guideline Levels (EPA-AEGL) for Hazardous Substance, (2008). Interim Acute Exposure Guideline Levels (AEGLS) for Formaldehvde (CAS 50-00-0), Reg. No. United State Environmental Protection Agency, Washington, DC, USA. Available online from. https://www.epa.gov/sites/default/files/2014-07/documents/formaldehyde tsd interim 07 2008.v1 0.pdf
- [34]. National Institute for Occupational Safety and Health (NIOSH), 2019. Formaldehyde. Available online from: https://www.cdc.gov/niosh/npg/npgd0293.ht ml
- [35]. United State Environmental Protection Agency, USEPA (2023a). What Should I Know about Formaldehyde and Indoor Air Quality. Available online from: https://www.epa.gov/indoor-air-qualityiaq/what-should-i-know-aboutformaldehyde-and-indoor-air-quality
- [36]. Health Canada, (1995). Indoor Air Quality in Office Buildings: A Technical Guide. A Report of the Federal-Provincial Advisory Committee on Environmental and Occupational Health.
- [37]. Minnesota Department of Health, 2022. Volatile Organic Compounds in Your Home. Available online from: https://www.health.state.mn.us/communities /environment/air/toxics/voc.htm [Accessed 16th Februrary, 2024]
- [38]. United State Environmental Protection Agency, USEPA (2023). Volatile Organic Compounds' Impact on Indoor Air Quality. Available online from: https://www.epa.gov/indoor-air-qualityiaq/volatile-organic-compounds-impact-

indoor-air-quality [Accessed 16th February, 2024]

[39]. Wallington, T. J., Sullivan, J. L. and Hurly, M. D. (2008). Emission of CO_2 , CO, NO_x , HC, PM, HFC-134a, N₂O and CH_4 from the Global Light Duty Vehicle Fleet. Meteorologische Zeitschrist, 17(2):109-116(8).

DOI: 10.9790/9622-1403140148