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Roadside Environmental Quality Estimations for Particulate Matter 10 (PM_{10}) in Akure-South LGA, Ondo State, Nigeria

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Abstract: Transportation serves as a vibrant sector for current civilization without which commerce, industrialization, and societal development will be slowed or impossible, however, movement in space is not without its negative outcome, part of which is the generations of particulate. The objective of this research is to analyze Particulate Matter 10 (PM_{10}) on the roadside in Akure-south LGA of Ondo State, Nigeria. Traffic movement was collected along these corridors with the aid of counting and then disaggregating them into various categories such as passenger cars, heavy trucks, motorcycles, and buses, while, CLJ-D Particulate counter (100-1million (PCS) Brand) was used in collecting PM_{10} particles generated along the traffic corridor. Findings show that the highest PM_{10} generated along the corridor is 1019 μg/m^3 and the least generated PM_{10} is 312 μg/m^3, while the corridor with the highest traffic is 3973 pcu/hr, and the least has 1299 pcu/hr traffic volume. The research concluded that although the traffic volume is not exclusively the only contributor to PM_{10}, in the selected corridor, there could also be some other contributors as the areas generating the highest traffic movement do not mean the highest PM_{10}.
Keywords: Environmental Quality; particulate matter 10; traffic volume; air pollution.

1. Introduction

Environmental quality refers to the condition of a surrounding area that is subject to the predominant activities occurring within the geographical spectrum. According to global trends, fossil-fuelled road vehicles contaminate the air surrounding them, which has the potential to harm those who live along these corridors and contribute to poor environmental quality. Road transportation has been linked by numerous studies to the deterioration of the environment, which causes a rift between people and their local surroundings. [1-7]. With the internal burning of Hydrocarbon fuels, the road transportation system is one of the worst polluters of the environment, making it the main producer of many important pollutants and greenhouse gases in the United Kingdom [8].

World over, activities of fossil-fuelled automobiles lead to reasonable ambient air contamination with Particulate Matter (PM). Studies in the past have proved with releasable evidence that over-exposure to these pollutants can have epidemiological effects on people who subsist in such an area [6, 9-12]. According to the World Health Organisation, estimated of 91% total world's total population stays in areas with ambient air surpasses the recommended boundaries for habitation [13]. The level at which these pollutants are formed varies from location to location, hence, it has been discovered that roadway traffic is a major generator of this pollutant in city centres [1, 14]. The main factor behind the worsening air quality in metropolitan areas are automobile generated particulate [15-17]. Automobile air contaminators is an admixture of gaseous substances and particles that might directly emerge through the tailpipe of vehicles, they can be described as particles with Aerodynamic diameter and are designated as fine particles less than 2.5μm and coarse particles of less than 10μm for $PM_{2.5}$ and PM_{10} respectively [18]. Emissions from traffic-related sources are produced at lower heights and hence contribute to surface pollution, concerns about these emissions are greater [19]. These pollutants are released into the surrounding environment with other gaseous compounds like Carbon monoxide, Sulphur dioxide [6], etc, other things from an automobile that can generate PM are brake wear and tire ware, dust from roadside re-suspension in the air and the complete and incomplete combustion process of engine fuels, and other aerosols in the secondary state [20].

These particulate matter (PM) can be released directly or indirectly from sources that are connected to cars through non-exhaust particles. According to Pant and Harrison (2013), automobiles are the primary source of high levels of PM emissions in metropolitan areas. According to [21] the fuel type, oil intake, method in which fuel is introduced, the process of engine combustion, size of the engine, the gradient of roadside, age of the vehicle, the environment of driving, and distance which the cars have covered all have an impact on the PM released from automobiles (Tailpipe emission). The rising vehicular flow in urban centres has also brought about traffic congestion, and accident, and increased air pollution [22, 23]. According to [24] 90% of non-exhaust generated PM are PM_{10} and about 85% are $PM_{2.5}$ which are released to urban centres. In addition to tile pipe contributions to PM, surface degradation of road, rust, and road dust particle re-suspension are further sources of non-exhaust particulate matter [25, 26]. PM has been extensively studied and frequently divided into $PM_{2.5}$ and PM_{10} to calculate possible health implications [27, 28]. Particle exposure from pedestrians is the worst among all forms of transportation, according to recent research conducted in Singapore [29]. According to a study conducted in Delhi, India, the recorded on-road of the concentration of $PM_{2.5}$ is on average, 40% greater in number than $PM_{2.5}$ values [30]. Additionally, these particles have a reasonable level of effect on both the immediate area and the entire planet [31, 32]. Environmental Protection Agency (EPA) and World Health Organization (WHO) standards show that the Air Quality Index (AQI), is posing a serious environmental issue that endangers many lives.

According to [33] using a portable emission monitor, they selected 15 sites to monitor PM concentration in Addis Abeba City, from the traffic passages chosen for the study, results show that the Air quality index (AQI) exceeds (54% to 65%) of standardized AQI and (8% - 395%) of World Health Organisation (WHO) standard. They also observed that most of the PM_{10} emission contraction from transportation-related sources is classified as non-exhaust parts, while a small amount of the emission includes $PM_{2.5}$, depending on the source, non-exhaust PM_{10} emission generation and concentration levels vary, they frequently come from weighty metallic elements such as lead, iron, zinc, and copper [34]. For instance, [35] also observed that nighttime hours are less hazardous for pedestrians than morning and afternoon hours in terms of PM exposure. In addition, it has been noted that meteorological factors like the directions of the wind and its speed, have an impact on levels of PM exposure. According to [36] Modern motor vehicles come with a variety of air pollution management devices. Despite improvements to control vehicular release of emissions with improved systems in diesel engines and petrol engines, automobile emissions remain a key major issue for generating pollutants mostly in metropolitan areas.

Research on air pollution is still in its infancy in Africa. According to [37], it is commonly believed that Ethiopia has minimal levels pollutants. However, some levels of research carried out across that nation have shown increasing health issues as results of both indoor and outdoor concentration of emission of ambient air is increasing. A recently conducted needs assessment study revealed a tenuous correlation between health and the environment. The report, however, has identified pollutants from the air as a crucial issue within Ethiopia and needs urgent policy concern [38]. In Nigeria, not much study has been done on PM except for few works by [6, 39]. This study focuses on PM_{10} in a developing city, in Southwest Nigeria.

This work focuses on the analyses of particulate matter 10 (PM_{10}) generated along roadside corridors in Akure-South Local Government Area (LGA), Ondo State located in Nigeria. The selected city is the capital city of Ondo State, Nigeria, and has the largest road transport activities in the state, and the selected corridors are the main collectors of motorized traffic volume to the Central Business District (CBD) of the city [40]. The organization of this work is as follows: Introduction; which contains a background to the studies done on PM_{10}, likewise, the section examines relevant past literature. The material and method section contains the study area which comprises maps and relevant information on the study locations. The next section is the results and discussion section, it presents the analysis of various results obtained for traffic flow and PM_{10} in the study location, and finally, the conclusion and recommendation section.

2. Material and Methods

2.1. Research Locations

The research area is Akure-South LGA, it is located southwest Nigeria. It is the state capital of Ondo, which is bordered in the north by the states of Ekiti and Kogi, in the east by the states of Edo and Delta, and in the west by the states of Osun and Ogun. In the southern region, it shares a border with the Atlantic Ocean. Akure Land is made up of two (2) LGA's: Akure South and Akure North. This study, however, will concentrate on Akure South. On the north of the equator, it is located on Latitude 7° 4' and 70° 25', while on the south it is on longitude 5° 5' 5° 30' east of the Greenwich meridian are the locations of the study area. According to its incredible pace of population increase, Akure south is a metropolis that can be liken as a medium-sized city in Nigeria. With a wide range of urban challenges, including badly maintained roads, housing problems, environmental hygiene concerns, financial issues for education, and most recently, issues linked to abduction and herdsmen farm destructions. Figure 1 displays a map of Nigeria with Ondo State highlighted while Figure 2 displays a map of Akure South LGA.

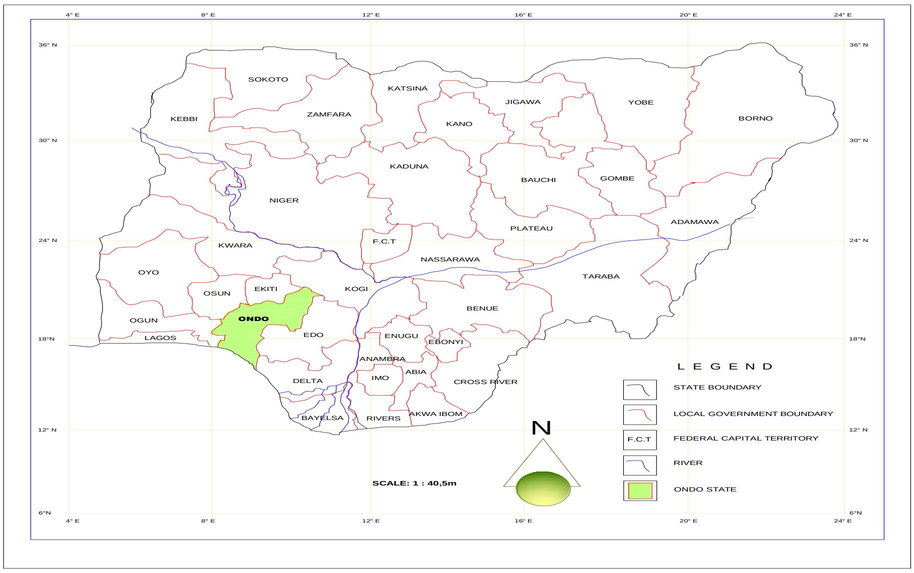

Figure 1. Nigeria's map featuring Ondo State,

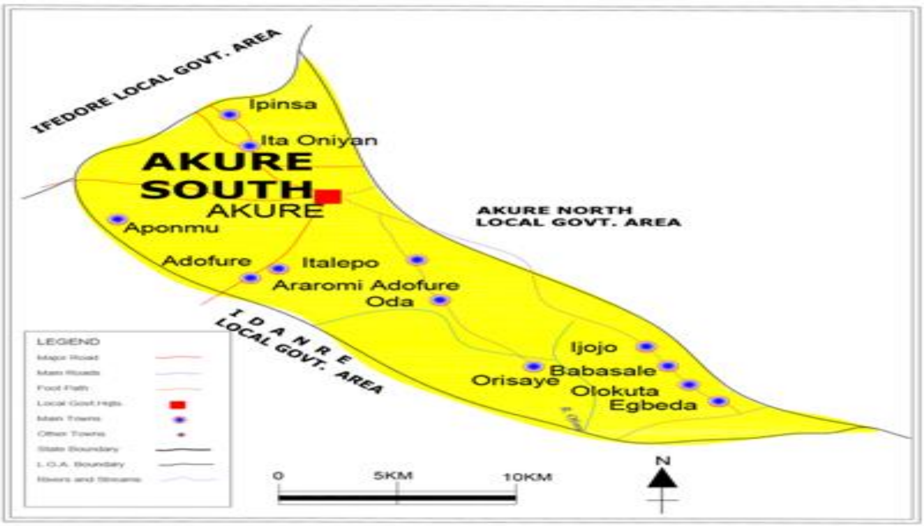

Figure 2. Shows the map of Akure

2.1.1. Network of Road system in Akure South LGA.

The arterial roads in Akure are typically made of asphaltic concrete, but there are also some areas with earth roads, surface dress roads that typically connect to sub-arterial roads, and streets that joins-up with villages, towns, and another metropolis in the state and, consequently, help to connect states and urban centres in Nigeria. Several vehicles ply on Akure's 230.1 km of bituminous roads and 233.9 km of unpaved roads as of 2011 [40, 41]. Ondo State Road Maintenance Agency (OSARMACO) oversees and maintains the majority of the roads. This organization is tasked with managing and maintaining the state's road system, particularly in the state's major cities and villages. The network of roadways in Akure South city is depicted in Figure 3 with the selected road corridor, area of land use, and auto mechanic location emphasized for this study.

2.1.2. Sampled Corridor and Spot

Six (6) corridors and Eighteen (18) spots (both ends of the corridors and midpoints) were considered to examine the level of PM, along the corridors in Akure South LGA for three (3) months starting from March 2019 to May 2019. The corridors are: Road block to Cathedral; Idanre Road (from Arakale/Idanre Road Junction to Oba Afunbiowo Estate, Oke-Aro); Adekunle Ajasin Road/Parliament Road/Igbatoro Road (NEPA Junction to SCAAB Filling Station at Igbatoro Road); Arakale Road (from NEPA Roundabout to Isinkan Roundabout); Oba Adesida Road (from Nigeria Police Force "A" Division, Akure to Mobil Filing Station, Fiwasaye junction); Oke-Ijebu Road (from Ijomu junction to Oke-Ijebu-Ijapo Roundabout). These corridors were chosen because they span the width of Akure Metropolis and are amongst major traffic arteries in the State capital. These corridors span out from the Central Business District (CBD) of the town. The code for each of the spot is captured in Table 1.

Table 1. Selected spot and codes

S/N	Corridor	Code
1	Cathedral point	CP
2	Ilesha gerage	IG
3	Road block	RB
4	1st bank	IB
5	A-division	A-D
6	Fiwasaye	FW
7	Ijopu gate	IJG
8	Ijomu junction	Ij
9	Oke-Ijebu roundabout	O-I-R
10	Health centre	HC
11	Isinkan roundabout	IR
12	Arakale/NEPA 1st bus stop	A/N
13	NEPA	NP
14	SCAB filling station	SFS
15	Shoprite	SP
16	Cashold	CH
17	Commercial	CM
18	Afunbiowo estate	AE

2.2. Instruments and Data Collections Technique

The instruments used for gathering data are highlighted in this section. Vehicle flow and PM_{10} data were collected and analyzed.

2.3. Traffic Volume Collections

Similar study in which traffic count was conducted had been carried out by Oguntoke & Yussuf, (2008); Okunola, *et al.*, (2012). Similarly, the collected data is transformed for easy analyses into passenger car unit (PCU) Okoko (2006). To collect peak volume flows of automobiles at the selected road corridor, the following procedure was used.

2.4. Procedure for traffic count

Based on hourly traffic data collection with the aid of video cameras, the volume of traffic was tracked along each of the chosen corridors. Traffic flow from 7am to 9 am for the morning session was collected, afternoon flow from 12 pm to 2 pm, and evening peak flow from 5 pm to 7 pm are all included in the data collection. GPS was used to determine the corridor's positions. A stopwatch was used to record the time. A playback video device was used to extract the traffic movement recorded along the corridor and spot after which each recording was played back and the data gathered.

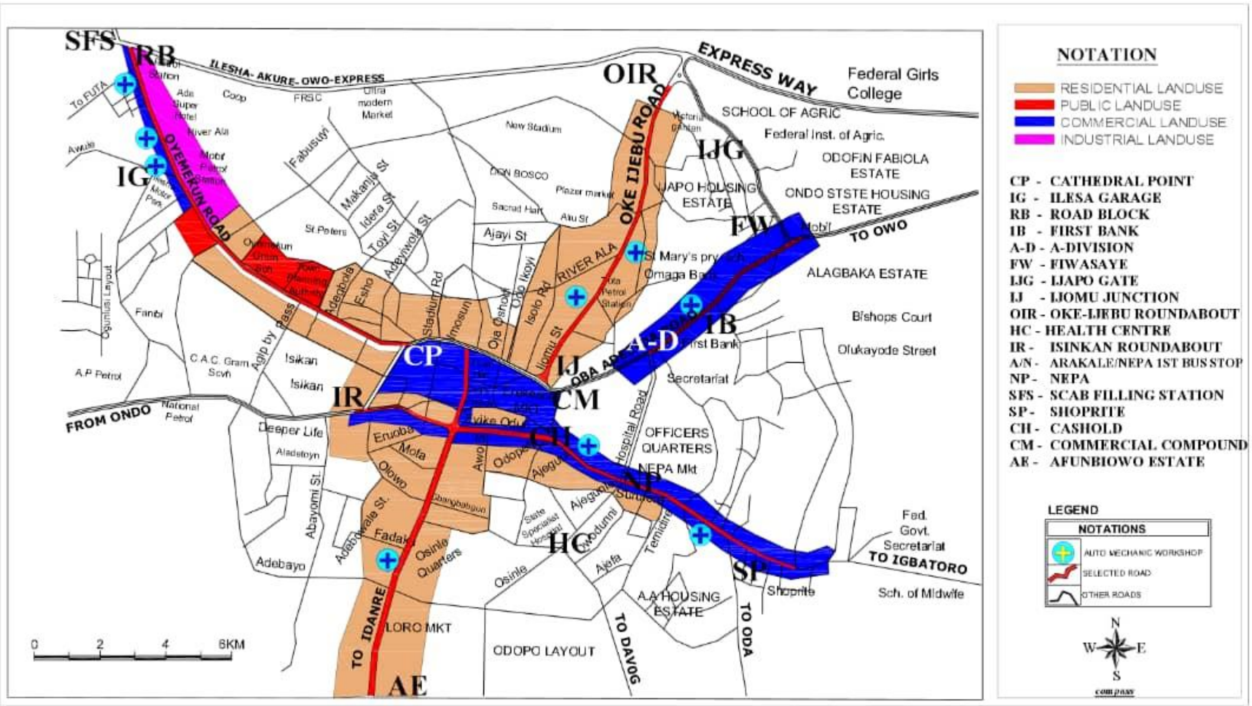

Figure 3. Akure-South network of road showing network of selected road corridor

2.5. Procedure for Collecting Particulate Matters (PM_{10})

The devices use to collect PM_{10} are as follows a GPS, a timer, and a CLJ-D Particulate Counter (100-1,000,000 (PCS) Brand) The CLJ-D Particulate counter was used to quantify PM10 levels. A 1.2 liter per minute internal volume-controlled pump sucked outside air into the monitor. After going through the measuring cell, laser diode detector, and measuring cell, the sample was collected onto a filter. To avoid contaminating the laser-optic assembly, clean sheath air is pumped into the particulate counter, which is sieved and given back into the optical chamber via a sheath air regulating chamber. All dust particles are removed from the sample air by passing it through a thin, tiny dust filter at 1.2 L/min. A valve is used as a safety safeguard to allow a membrane pump to pull in clean air.

The flow of the sample was managed by a flow controller that monitored the pressure decrease across the aperture. Some of the cleansed air was used to irrigate the measurement chamber, keeping it clean, as well as the optic and measurement chambers. During the functional self-test, the system was calibrated for zero particles using this pure air. The CLJ-D Particulate counter is displayed in Figure 4 and was used to collect field data.

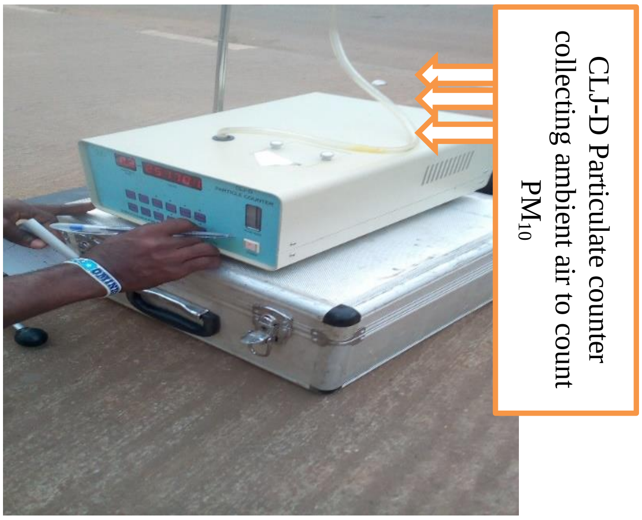

Figure 4. A CLJ-D Particulate counter in use on the field

3. Results and Discussion

3.1 Results

The converted average traffic flow in passenger car units (PCU) [42] for motorcycles, cars, buses, and heavy trucks along each corridor of study as collected during the research for three months starting from March 2019 to May 2019 in Akure-South LGA.

3.1.1. Average Traffic Flow in Selected Spots and Corridors

The average results for the three months is analysed and presented. From the analysis of the traffic flow obtained for the first corridor of study, it shows that CP generated a traffic flow of 2093 pcu/hr, while IG generated 2280 pcu/hr and RB produced 2121 pcu/hr. For the second corridor of study, 1B produced 2328 pcu/hr, while A-D produced 2208 pcu/hr, and FW generated 3318 pcu/hr the highest on this corridor. The reason for this is that this spot links the Northern part of the town to the southern part of the town. Hence, more traffic is generated along this spot as more commuters migrate from the northern part to the southern part where most government offices are located. For the third corridor, IG produces 2565 pcu/hr, while O-I R generated 1733 and IJ spawns 3621 pcu/hr, which is the highest generated traffic flow data in this corridor, this is because this spot is right in the centre of the CBD of the state capital. The fourth corridor has HC generating 3973 pcu/hr, the highest generated traffic flow in either study, while IR produced 2507 pcu/hr and A/N generated 3810 pcu/hr of traffic, the second highest traffic flow in the study. For the fifth corridor of study, the CH produced the highest traffic flow of 3361 pcu/hr while, the CM produced 3257 pcu/hr of automobile traffic movement, and the fifth corridor has NP generating the highest traffic flow of 2719 pcu/hr and SFS generating the lest traffic flow for the fact that this spot is located on the Government Reserved Area (GRA). The sixth and last corridor has traffic-generated data for CH, CM, and AE as 3361 pcu/hr, 3257 pcu/hr, and 1553 pcu/hr respectively. This result is presented in Figure 5.

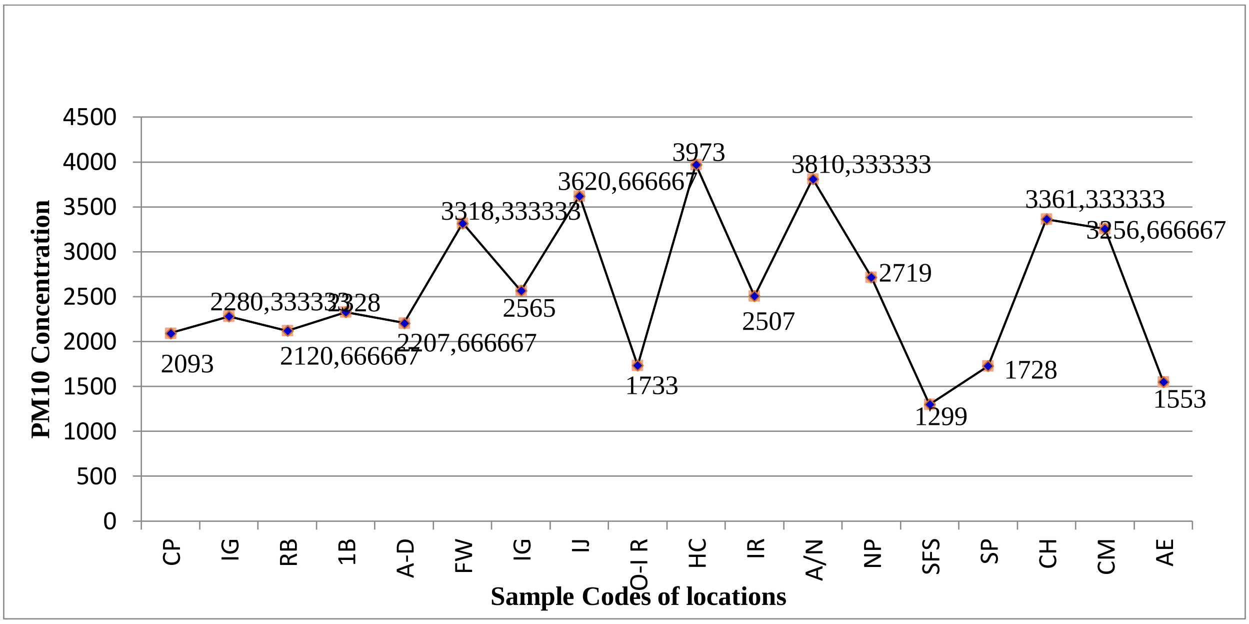

Figure 5. Average traffic flow generated from March, 2019 to May, 2019

3.1.2. Level of Particulate Matter PM_{10} in Selected Corridor

The average PM Pollutant along each corridor of study as acquired for a period of three (3) months starting from March 2019 to May 2019 in Akure-South LGA is available in Figure 5. Investigations carried out in Akure-South LGA for the first corridor, demonstrate that IG junction has the highest level of PM_{10} 418.47µg/m^3 was recorded. A search on the second corridor shows that the A-D junction has the highest level of PM_{10} of 494.08 µg/m^3, this could be due to road dualization constructions going on in that area as of the moment when the research is on. For the third, corridor considered, it was observed that IJ junction has the highest contribution to PM_{10} in the entire Akure-south LGA with 1019.28 µg/m^3, this could be a result of the traditional marketing activities that are related to that area. The fourth corridor of the study shows that the A/N junction has the peak PM_{10} with 556.94 µg/m^3. This result is so because of the road construction activities going on in that corridor during the collection of data. The fifth corridor has NP junction having the highest PM_{10} contribution of 467.47 µg/m^3 the last corridor of study has CM having the highest PM_{10} of 819.29 µg/m^3 this could also be because of the many traditional market activities taking place in that area. This result is presented in Figure 6.

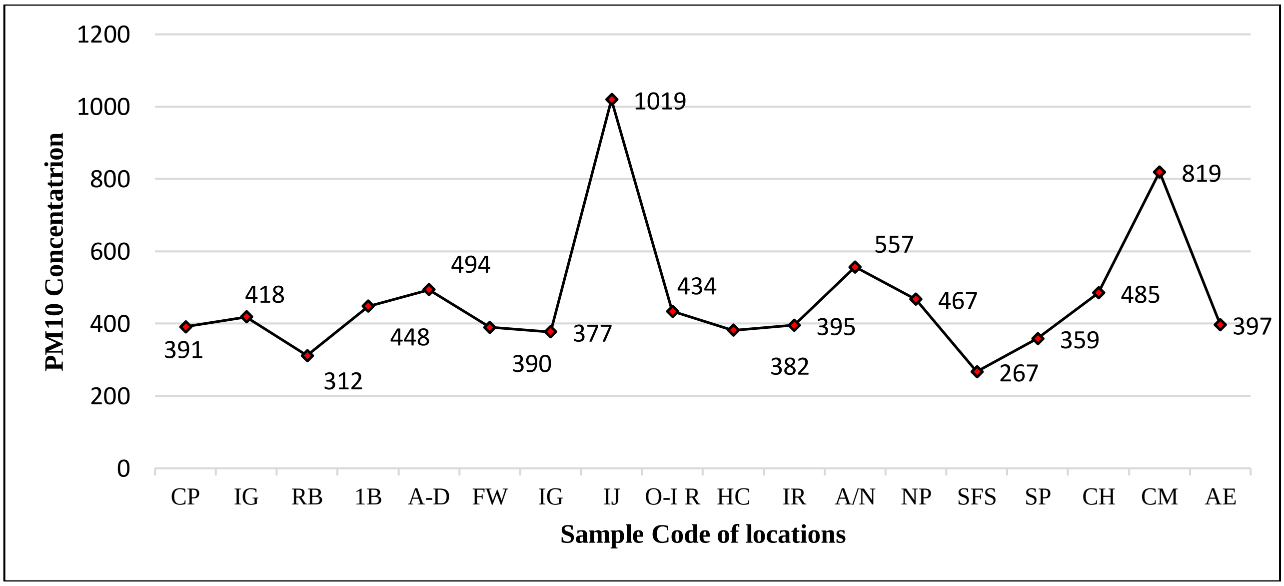

Figure 6. Average traffic flow for 3 months at selected spot in Akure-South LGA.

3.1.3. Relationship between PM and automobile traffic flow

The study also seeks to know if there is a relationship between traffic flow in (pcu/hr) and Particulate Matter (PM_{10}) produce along the traffic corridors selected for this work. Using Pearson's Product Correlations at a 0.05 significant level, it shows that a positive relationship of 0.628 exists between traffic flow and PM_{10} generated. Although, PM_{10} is influence by other conditions such as weather, temperature, climatic condition etc. This is true because at ground level when the same experiment is carried out in an exclusive area (control site) away from automotive inference, values were recorded for PM_{10} but the values recorded were infinitesimal compared to what is obtainable near the road. Table 2 presents the correlation between traffic movement and PM_{10}. Result obtained has 95% confidence level.

Table 2. Correlation between traffic flow in (pcu/hr) and PM_{10} in Akure South LGA

Akure_Pcu/Hr	Akure_Pcu/Hr	Akure_PM_{10}
	1	.628**
		0.005
Akure_PM_{10}	18	18
	.628**	1
Akure_Pcu/Hr	0.003	
	18	18

*Correlation is significant at the 0.05 level (2-tailed).

Based on the Nigeria National Ambient Air Quality Standard (NAAQS) [43] unlike Ethiopia without an air quality standard [33], the NAAQS describes that particulates' daily averages of daily values should not exceed a limit of 250 µg/m^3 and 600 µg/m^3 in one hour, from the result obtained during the study, the hourly daily average of the entire corridors studied have some spots that excess the daily limit. CP has a daily hourly average of 391µg/m^3 which is less than the 600 µg/m^3 recommended hourly limit. Other spot which generated data with ambient particulate matter diameter of 10 micros less than the average hourly limit of 600 µg/m^3 is IG which has 418 µg/m^3, RB with 312 µg/m^3, 1B has 448 µg/m^3, A-D has 494 µg/m^3, FW has 390 µg/m^3, IG with 377 µg/m^3, O-I has 434 µg/m^3, HC with 382 µg/m^3, IR has 395 µg/m^3, NP generated 467 µg/m^3, SFS generated the lest PM10 in the cause of this study, it generated 267 µg/m^3 while SP produced 359 µg/m^3, CH and AE generated 485 µg/m^3, and 397 µg/m^3 correspondingly.

However, spot with the highest PM10 are A/N which result is very close to the daily limit. It generated an average hourly average of 557 µg/m^3 about 7.17% away from the avoidable daily limit, CM has the second largest PM_{10} of 819 µg/m^3 and this spot also generated a high traffic of 3257 pcu/hr. The high result obtained at this spot could be as a result of a densely packed cluster of buildings in with little regard for proper planning hinders fresh air from coming into the space to reduce the PM_{10} in the spot which is in support of work done by [44, 45]. [9] Believes that tube-like structures built around the roadside can help reduce the influence of PM. However, in this case, many of the buildings around the spot on the road are tightly dense making the spot serve like a canal. IJ has the highest PM_{10} of 1019 and 3621 pcu/hr of automobile traffic flow. Buildings here are also close and densely packed and the spot is right in an environment where traditional market activity takes place.

4. Conclusions

For particulate matter with a diameter of 10 micros (PM_{10}), the level at which it is generated on the side is significantly high and is above the recommended minimum daily average of daily value based on the Nigeria National Ambient Air Quality Standard (NAAQS) values. This study has been able to show that Particulate Matter 10 (PM_{10}) increases gradually with traffic flow and that automobile traffic movement contributes positively to the production of PM_{10}. However, Due to high levels of potential health hazard associated to automobile generated pollutant on humans subsisting along traffic corridors as observed from the study, the use of open spaces beside roads for shops and residential purposes in developing countries needs to be discouraged to minimize exposure of human to automobile generated pollutant like PM_{10}. The use of noise mask, regular, and compulsory medical check-ups for workers working several hours near motorways should be encouraged. This will also enable data to be gathered on the health effect of near road pollution.

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