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POLLUTION OF VEHICULAR EMISSION ANALYSIS AT FEDERAL UNIVERSITY OF TECHNOLOGY AKURE NORTH GATE

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ABSTRACT

The paper dwells on the atmospheric pollution resulting from the vehicular exhaust discharge at the north gate of the Federal University of Technology, Akure (FUTA), Nigeria. The vehicular traffic census took place at gate on the Ilesh-Akure high way passing in front of the gate for six days. The census was conducted using a digital tally and a stop watch for nine hours at thirty minute interval daily. The tally was pressed to count each time a vehicle passed both to and from either direction along the road at a chosen point in front of the University north gate. A daily vehicular count was obtained from the ratio of total vehicles to the total time interval of nine hours. Thereafter the average vehicular exhaust discharge, pollution source strength and pollution concentration were determined. At the same time, a data logger was used to measure the meteorological elements of the temperature, the wind speed and the relative humidity of the weather daily. The relationship between the pollution source strength and concentration with the meteorological parameters obtained with data logger, speed and distance covered by vehicles were also determined. The average daily vehicle populations within the time interval being considered were respectively 8280, 8306, 7315, 7210, 8766 and 8491 for the six days in succession. The meteorological data analysis showed that the air relative humidity and wind speed increased with decrease in temperature especially when it rained. The source strength and concentration of pollution decreased with increase in the speed of vehicles and the distance moved indicating that pollutants dispersed faster into the air in the process.

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1.0 INTRODUCTION

Atmospheric pollution results from natural causes as well as from man's activities and as result increase of this pollution is due partly to the anthropogenic activities of man. The urban air pollution originated from mainly from anthropogenic emission sources comprising automobiles, industries and domestic combustion (Bhaskar and Mehta, 2010). All economic and societal activities cause emission of atmospheric pollutants (Hooftman, *et al.,* 2015). Gases especially carbon dioxide produced as a result of combustion of fuels of hydrocarbon origin principally in internal combustion engines with the accompanying particulate matter are the established culprits. The production of these pollutants is traceable to three major sources; point, multiple or area, and line sources. The point sources discharge the

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pollutants from a stationary point to the atmosphere as in the industries such as steel mill while the multiple or area source is from residential areas. The line source on the other hand is not fixed but mobile as is the case with vehicular combustion exhaust discharge along high ways (Rao, 2008). The figure of motor vehicles continues to grow due to development of automobile industry and so is the air pollution (Chen, *et al*., 2019). They also reported that exhaust emission from motor vehicles have become important source of urban air pollution. The dispersion of the pollutants from both sources depends on the atmospheric meteorological conditions like the temperature, the wind speed and the relative humidity among others. The pollutants as they accumulate upset the natural atmospheric conditions and these have adverse effects on global temperature, climate, vegetation and mankind.

Dong, *et al*., (2017) investigated by mathematical model of CO_2 concentration from vehicular discharge in a tunnel 120 m long with a radius 5 m. The conditions considered were the vehicle speed was at 0 km/h (idling), 10 km/h (slow speed) and 40 km/h (medium speed). They reported that the CO_2 concentration attained a dangerous level of 6000 ppm down stream towards the exit of the tunnel especially when the vehicles were idling. However the piston effect of vehicles at 10 km/h and 40 km/h reduced the CO_2 concentration further as the speed increased. The installation of fans at the upper sides of the tunnel reduced the CO_2 concentration especially at the idling stage.

Greenstone, *et al.,* (2017) reported that 660 million Indians reside in areas that surpass the National Ambient Air Quality Standards (NAAQS) for particulate pollution in India. They reported also that surrounding environmental particulate matter is the cause for about 6% of global death from which more than 10% of premature deaths are due to lower respiratory diseases. This is more than the deaths caused by tuberculosis and malaria combined. The NAAQS for particulate pollution is put at 80 μg/m^3 (Goverdhan, *et al*., 2015).

One anthropogenic air pollutant from the human activities is particulate matter. They are inform of either primary direct particles emissions or secondary particle precursors such as oxides of nitrogen (NO_X) and volatile organic compounds (VOCs) linked to combustion sources including motor vehicles and stationary applications (Sher, 1998). Particulate matters have diameters of 10 μm or less and they are synthesized with a flame and both diesel and gasoline engines have average emission of 80 μg per kilometre (Jones, 2008). The particulate matter is a blend of liquid and solid particles of different sizes and chemicals that varies in composition both spatially and temporally (Xue *et al*., 2013). The motor vehicles discharge between 25% and 30% particulate matter with diameter 2.5 μm ($PM_{2.5}$) and this adversely affects the respiratory health human of beings especially living within 10 m from streets with vehicular traffic (Buckeridge, *et al.* 2002). Particulate matter causes serious problem to the environment and health (Amoral, *et al.* 2015).

According to Hirota (2010), two stroke motorcycles are the dominant sources of carbon monoxide emissions and the most effective to reduce the emissions are proper maintenance and use of catalytic converters.

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Table 1: Compounds of vehicle discharge and exposure limit with time

Compound	Limit	Exposure
CO	1000 mg/m^3 or 90 ppm	15 minutes
Pb	0.5-1 μg/m^3	Annual
NO_2	200 μg/m^3 or 11 ppm	1 hour
O_3	120 μg/m^3 or 6 ppm	8 hour
Particulate matter	50 μg/m^3 or 25 ppm	Annual
SO_2	500 μg/m^3	10 minutes

Source: Chishakwe (2017)

Motor vehicles play a critical function in the social-economic development of modern societies. As a result, the vehicular group worldwide has been on the increase. Resulting from this, they form a main cause of pollution especially in the urbanized areas and then contribute to the greenhouse gas (GHG) emission (Chisakwe, 2017). Xue, *et al.,* (2013) reported that 80% air pollution in cities globally is due to vehicular emission while it is in the range of 45 – 70% in India (Subramani, 2012).

Major vehicle emission standards with the exposure limits are as given in Table 1

Therefore this paper has the objective to determine the rate of spread of the vehicular discharge with respect to speed of the vehicles in the prevailing weather conditions.

2.0 MATERIALS AND METHODS

The research took place at the Federal University of Technology, Akure's (FUTA's) Northgate section of the highly busy Ilesha/Akure express way, Akure, Ondo State, South West Nigeria where the intensity of the movement of vehicles is high thereby leading to heavy vehicular emissions. Akure is situated in the humid part of the western region of Nigeria on latitude 7° 16' N and longitude 5° 13' E. The area investigated is populated because of the University and other commercial centers. A glaring characteristic of the area is the occurrence of intense flow of transportation actions where the fossil fuel combustion from the internal combustion engines exists.

In the study area, the pollutants concentration of the carbon monoxide, the sulphur oxide, the nitrogen oxides, the organic acids, and the hydrocarbons (recorded typically from exhaust gases) in the environment is likely to be high. However, vehicular discharge may be responsible for nearly all of the whole pollutants emitted with respect to other sources.

In this investigation, the data collection was carried out for six consecutive days (Monday through Saturday) on a nine hour basis. Vehicular census and the meteorological data collection were carried out at the area at 30 minutes intervals.

The vehicular census was done using a counter, a digital tally shown in Figure 1. The researcher stationed at a location five metres from the road at the FUTA north gate. The researcher pressed the counter each time a

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vehicle passed the station point in front of the researcher either to the right hand side or left and then record the figure of vehicles after thirty minutes throughout the time the exercise took place. At the end, the researcher divided the overall number of vehicles with the number hours covered within the period of the research. The time measurement of thirty minutes was done using a stop watch shown in Figure 2. It is a handy device with knob that was used to start, stop, and then zero the display, used for taking periodic timings as the vehicles were counted.

Similarly, the researcher used the data logger to measure the weather parameters using the same logic as was done for the vehicular census within the same time interval. The data logger being a versatile instrument is equipped with model LM-8000 4in1 that incorporates anemometer, hygrometer, thermometer and light meter. The anemometer measured the wind speed with an accuracy of ±3% m/s while the hygrometer measured the relative humidity of the atmosphere with maximum capacity of 80% at ±1.2 RH accuracy. Thermometer measured the temperature of the environment at accuracy of $\pm 1^{o}C$ The light meter measured the intensity of light and brightness of the day at accuracy of ±1 ft-cd. The meteorological weather elements measured were pressure, temperature, the speed and direction of the wind, and the relative humidity.

The measurement of cylinder dimensions of stroke and bore of scraps of different vehicle types were earlier done in Akure city with a vernier caliper. Five automotive workshops used for repairing motor vehicles were randomly selected for this purpose. The amount of exhaust out of the internal combustion engine depends on the configuration of the cylinder, thus the cylinder parameters such as stroke to bore ratio were also determined. The mean values of these vehicular parameters were then used to estimate the exhaust discharge of the vehicles enumerated. The traffic concentration of the sampled location was used to estimate the quantity of exhaust discharge.

Figure 1: The digital tallies counter

Figure 2: The data logger

Figure 3: A stop watch with an accuracy of 0.1sec.

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2.1 Design calculations

Before the design calculations, the discharge estimation was considered ideal and based on the following assumptions, that:

(i) The vehicles considered were four stroke four cylinder engines;

(ii) The mean obtained from the vehicular discharge represents of the average discharge of total vehicles;

(iii) The hydrocarbon was used and it underwent complete combustion to produce water and carbon dioxide;

(iv) The entire content of the combustion chamber was swept out at the exhaust stroke with no residue left in the chamber;

(v) The major pollutant for estimation was carbon dioxide, and

(vi) 1% by volume of a gas is equal to 10^4 ppm

Chemical reaction of fuel combustion

$$\underset{Carbon}{C} + \underset{oxygen}{O_2} \rightarrow \underset{carbondioxide}{CO_2} \quad (1)$$

$$\underset{Hydrogen}{H_2} + \underset{oxygen}{\frac{1}{2}O_2} \rightarrow \underset{water}{H_2O} \quad (2)$$

$$m_T = mCO_2 + mH_2O \quad (3)$$

$$Per_{CO_2} = \frac{m_{CO_2}}{m_T}\% \quad (4)$$

$$y(\mu g/m^3) = \frac{1000 * x * M}{24.04} \quad \text{(Rao, 2006)} \quad (5)$$

where, m_T is total mass of combustion products, m_{CO2} is mass of carbon dioxide in the products, m_{H2O} is mass of water vapour in the combustion products, M is molecular mass of the gas, x is concentration of the gas in parts per million (ppm), and y is the concentration of the gas in microgram per cubic metre.

The concentration of the vehicular pollutant was determined using equation (6) (Rao, 2006)

$$\rho(x, y, 0, 0) = \frac{2Q_L}{(2\pi)^{0.5}\sigma_z U} \quad (6)$$

$$Q_L = \frac{\alpha_v \varepsilon_R}{v} \quad (7)$$

$$\sigma_z = Bx^p \quad (8)$$

where, α_v is the vehicle density per hour, ρ is the pollutant concentration; σz is the spreading coefficient; Q_L is the traffic density per hour with average emission rate; U is the average wind speed; εR is the vehicular emission rate; ν is the vehicle speed; B is stability of the atmosphere at moderate level; and p is a constant.

For neutral conditions D, the values recommended for B and p are shown in Table 1

3.0 RESULTS AND DISCUSSION

The daily vehicular traffic census against the time is shown in Figure 4. It is seen that the traffic was high in the first two days because they were days beginning the week. People in

Table 1: Fitted values for the spreading coefficient (σ_z)

		x less than x1	
Class	Distance, x1 (metres)	B	p
D	100, 250, 500, 1000	0.105	0.827

Source: Rao, 2006

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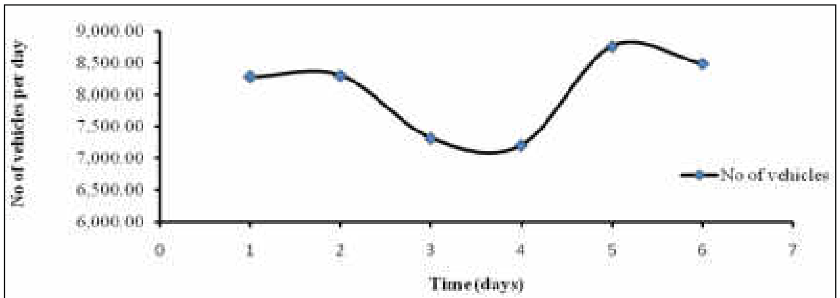

Figure 4: Daily vehicular traffic versus time (days)

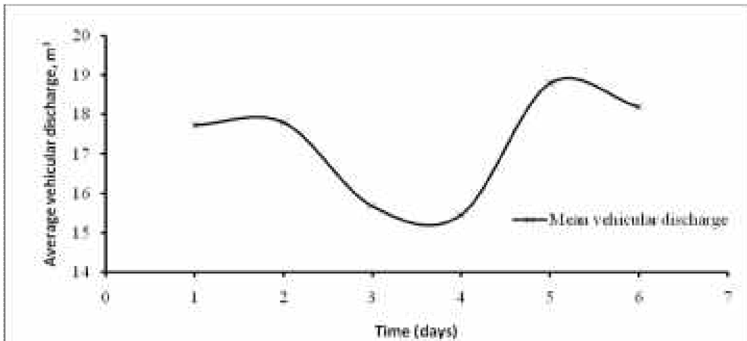

Figure 5: Mean vehicular discharge versus time in days

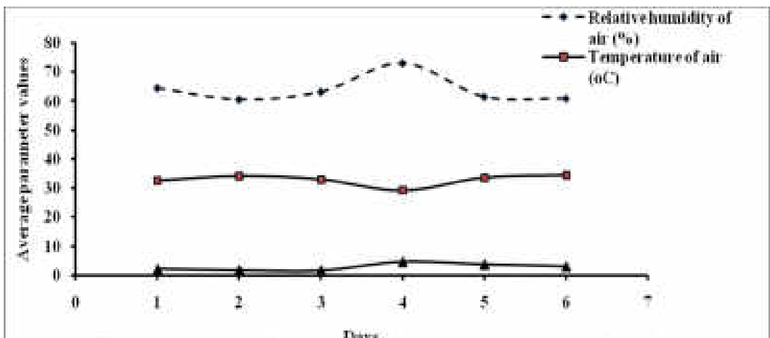

Figure 6: Average values of relative humidity, temperature and wind speed versus number of days

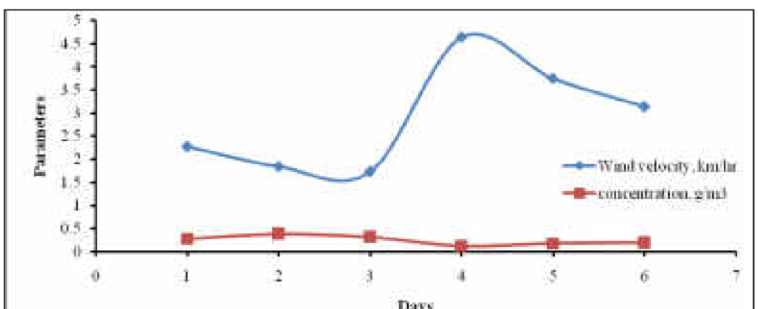

Figure 7: Plot of wind speed and pollution concentration against time (days)

the public and private sectors travelled back within these days to their places of work after they had relaxed in the previous weekend. During the week, everybody was fully engaged in his or her place of work and unless it was necessary to travel, hence the relatively

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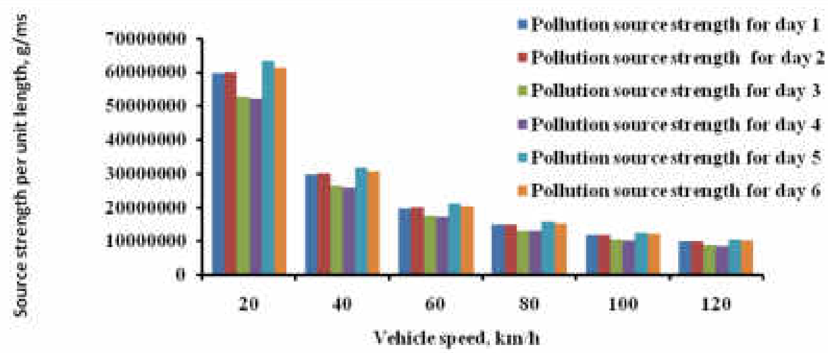

Figure 8: Souce strength of Pollutant versus speed of vehicle

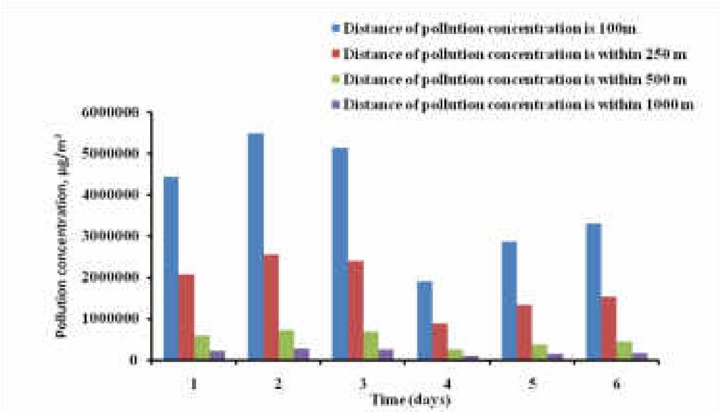

Figure 9: Pollution concentration versus time for chosen distances

lower number of vehicles travelling. As the week was drawing to an end again the people travelled to relax in places of their choice after the hectic activities and therefore the vehicular traffic increased.

The plot of the average vehicular discharge versus time is revealed in Figure 5. In the figure, it shows that the average vehicular exhaust discharge increase with the number of vehicles. These average vehicular discharges were found to vary and of course directly proportional to the average daily vehicular population. The quantities of instantaneous gases produced will be high, and the injection of the volume into the atmospheric air will increase the temperature of the environment since the gases are hot, thereby making the immediate surroundings hotter than it would have been in the natural state. Also these discharges will combine with atmospheric moisture and precipitate in form of acid rains. The increase in the quantity of CO_2 and other gases has been reported to increase the acidity of rain water.

The graphs of the mean of each parameter (relative humidity, temperature and wind speed) versus time is presented in Figure 6. The Figure shows that at relatively high temperatures there was a decrease in the wind speed. The wind speed on the average was high on day 4 when it rained compared to other days. This showed that rainfall increased the speed of wind as the air was lighter its moisture content was reduced through precipitation as rain. In addition the rain dissolved the pollutants especially the CO_2 by

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scrubbing thus reducing the amount of atmospheric pollutants (Jayamurugan, *et al.*, 2013). It was also observed that the hotter the environment the lower the moisture content (relative humidity) in the air. It indicated that relative humidity of air is in inverse relationship with the temperature.

The graphs of wind speed and pollution concentration versus time are shown in Figure 7. The graphs depicted that the pollution concentration at a particular point decreased as the wind velocity increased and vice versa.

The source strength of pollutants versus the vehicle speed is presented in Figure 8. The source strength in this Figure decreased as the speeds of the vehicles increased and with the daily vehicular number. This was due to the fact that the combustion products from vehicle exhaust were discharged at high velocities which are diluted and dispersed at any wind velocity. This dispersion increased with vehicular speed and consequently the strength will be lower at any point than when the vehicles are at lower speeds.

Similarly with decrease in the source strength the pollutant concentration decreased with the increase in speeds of the vehicles and distance covered by spread through dispersion as it is the case in Figure 9. This agrees with the work of Xue *et al.*, (2013) that the emission of pollutants like carbon monoxide and hydrocarbons decreases with increase in vehicular speed.

The pollutant concentration at a time is affected with the distance it is measured. Since the pollutant and the speed are inversely related, the concentration that was recorded within 250 metres was more than that recorded at 500 metres and this was also greater than the pollutant concentration at 1000 metres.

4.0 CONCLUSION

At the finish of the vehicular traffic census which was conducted at the FUTA north gate, the totality of the vehicles soared for the first two days as people moved or even travelled to their various places of work. It was relatively lower on the third and fourth days as people were now settled at work and movement of people for long distances were reduced. On the days five and six people had to travel as for relaxation as it was a weekend after a hectic week activities. The source strength and concentration of pollutants decreased with the vehicular speed and the distance travelled as pollutants dispersed into the atmosphere faster than at low speed. The meteorological data indicated that the air relative humidity and wind velocity were increased with decrease in temperature especially when it rained. The pollution concentration decreased with increase in wind velocity and vice versa.

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