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Abstract - In this study, we proposed an approach for investigating whether vehicular emissions vary with Ambient Temperature and Humidity of the day. The proposal includes mathematical models that can be used to predict the amount of pollutants dispersed into the atmosphere at a particular time of the day. The pollutants include; NO_x, CO, C_xH_y. These pollutants were measured and analyzed during the morning and afternoon periods, using the Exhaust Gas Analyzer and the Digital Thermometer/Hygrometer. The measured and estimated values of these pollutants compared favorably using MATLAB simulations.

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I. INTRODUCTION

Research work had been carried out in the past to investigate the influence of ambient temperature on exhaust emissions [1 – 14]. It was reported that exhaust emissions could be increased tremendously at cold ambient conditions. For instance, the hydrocarbon emissions could increased by 650% at -20°C and carbon monoxide emissions could increased by 800% at -20°C, compared to standard certification values at +25°C [8, 9]. However, the influence of cold temperatures on NO_x was much lower and more complex as cold temperatures increase engine heat losses and cool the flame, thus reducing NO_x emissions from the engine. This partially offset the slower catalyst light off.

The low ambient temperature can reduce lubricating oil pumpability and increase viscosity of lubricating oil and thus results in higher mechanical losses for engine's cold start. The performance of the battery would be affected by low ambient temperature. The air and fuel mixture can be affected due to poor volatility of fuel at low ambient temperature and therefore cause deterioration of combustion quality. The lower the ambient temperature, the richer the air fuel mixture required for a start up. Incomplete combustion with excess fuel results in increased carbon monoxide and hydrocarbon emissions. The low ambient temperature can also delay the light-off of the catalyst, which is one of the most important reasons accounting for high emissions at cold start.

The literature above reveals the influence of ambient temperature on vehicular emissions at 'cold start' period only. However not much work has been done to investigate the variation of vehicular emissions with ambient temperature and humidity at both the morning and afternoon periods, which entails the cold start and warm-up period of the engine.

With a unique approach, this study investigates the variation of vehicular emissions with ambient temperature and humidity in the tropics by considering both the morning and afternoon period for exhaust emission measurements and analysis.

II. METHOD OF INVESTIGATION

Certain exhaust samples were collected from a number of vehicle engines (that use Motor Premium Spirit) and analyzed using the Exhaust Gas Analyzer with Model number "Testo 350 XL". These samples were collected during the morning (low temperature and high humidity) and afternoon (high temperature and low humidity) periods. A temperature and humidity sensing device (Digital Thermometer/Hygrometer with Model number IT 202) was used to measure both temperature and humidity during those periods. The investigation was carried out in some parts of Edo State of Nigeria and thereafter mathematical models and graphical representation of the investigations were obtained using MATLAB. (See table 1)

Table 1 : Showing measured values of temperature and humidity

Temperature (°C)	Humidity (%)
26.9	70
28.5	64
29.2	61
31.8	54
33.4	49

III. RESULTS AND DISCUSSION

Using linear and quadratic fitting of the MATLAB code, the following mathematical and graphical models for CO, C_xH_y, and NO_x emissions were obtained;

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$$CO = \begin{cases} 14000 - 440T & 25 \leq T \leq 27.5 \\ 3300 - 48T & 27.5 < T \leq 30 \\ 9800 - 260T & 30 < T \leq 32.5 \\ 4200 - 90T & 32.5 < T \leq 35 \end{cases} \quad (1)$$

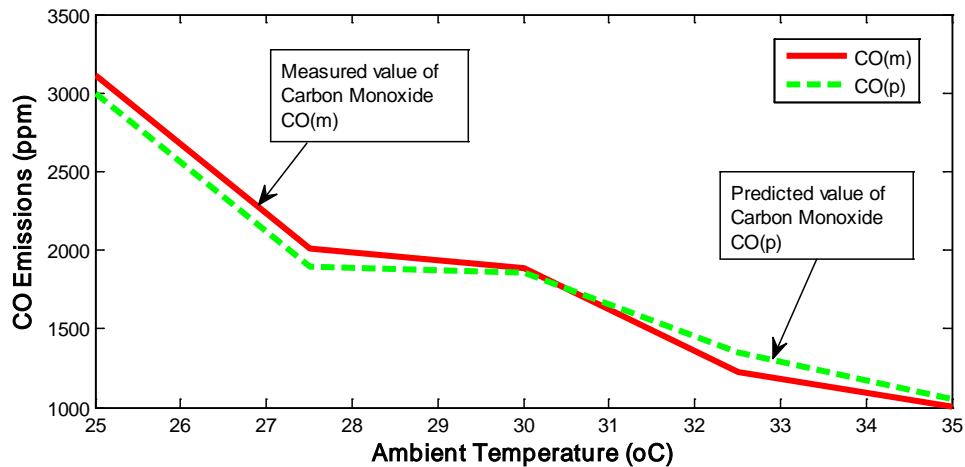


Fig 1 : Graph of Predicted and Measured Values of Carbon Monoxide against Temperature.

$$CxHy = \begin{cases} -1500T + 46000 & 25 \leq T \leq 27.5 \\ 0.84T^2 - 500T + 17000 & 27.5 < T \leq 35 \end{cases} \quad (2)$$

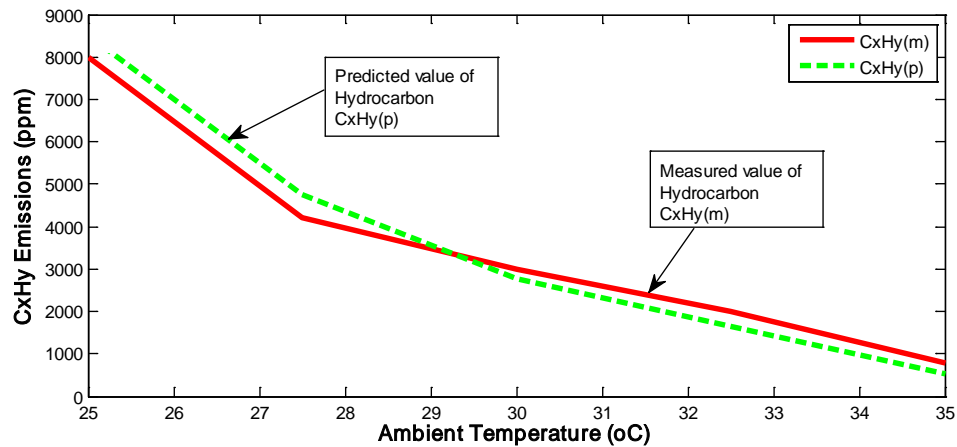


Fig 2 : Graph of Predicted and Measured Values of Hydrocarbon against Temperature.

a) CO and CxHy Emissions

Figure 1 & 2 above show the Carbon monoxide (CO) and Hydrocarbon (CxHy) emissions as function of the Ambient Temperature. The result above shows a high concentration of CO and CxHy emissions at 3114ppm (25°C) and 7987ppm (25°C) during the morning period when the ambient temperature was very low and the vehicle engine and catalyst are just warming

up. As the temperature increases to 35°C during the afternoon period, the concentration of CO and CxHy decreased to 1001ppm and 800ppm, respectively. The reason for the decrease of the pollutants at 35°C is that the humidity level in the atmosphere at this point is very low and again the vehicle engine and catalyst is fully warmed-up; as the engine completely burns off the fuel present in the combustion chamber.

$$NOx = \begin{cases} -0.28T^2 + 25T - 400 & 25 \leq T \leq 32.5 \\ 26T - 740 & 32.5 < T \leq 35 \end{cases} \quad (3)$$

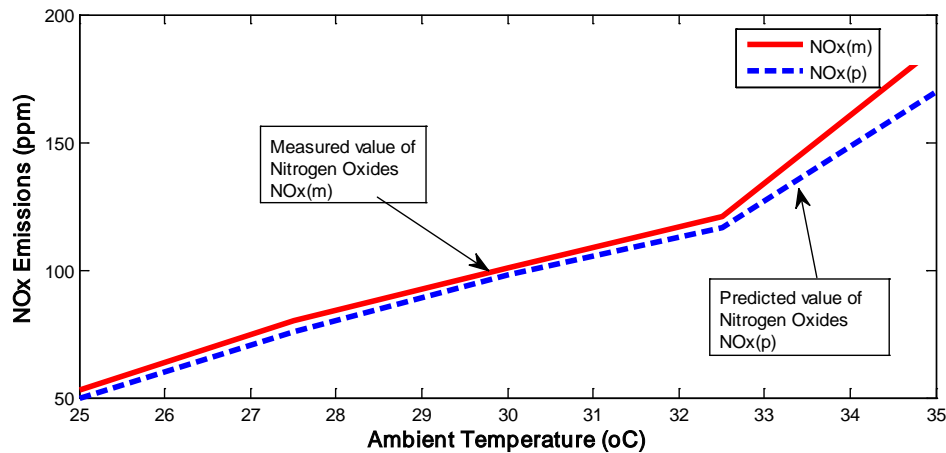


Fig 3 : Graph of Predicted and Measured Value of Nitrogen Oxides against Temperature.

b) NO_x Emissions

Figure 3 above shows the Nitrogen Oxides emissions as a function of the temperature. The result of figure 3 above shows that the “engine out NO_x emissions” are reduced in the morning period when the ambient temperature is very low, but increased during the afternoon period when the ambient temperature was high. This implies that the increase of NO_x emission is directly proportional to the ambient temperature. The reason for this is that NO_x is a temperature dependent pollutant as it is formed in the combustion chamber when the combustion temperature increases to 2000°C [3]. This means that, as the temperatures decreases,

the engine heat loss increases thereby cooling the flame temperature and therefore reducing the amount of NO_x released from the engine exhaust.

The mathematical model and graphical representations of the pollutants against the humidity (H) are shown below;

$$CO = \begin{cases} 38H - 690 & 45 \leq H \leq 51 \\ 110H - 4400 & 51 < H \leq 57 \\ 20H + 740 & 57 < H \leq 63 \\ 180H - 9600 & 63 < H \leq 69 \end{cases} \quad (4)$$

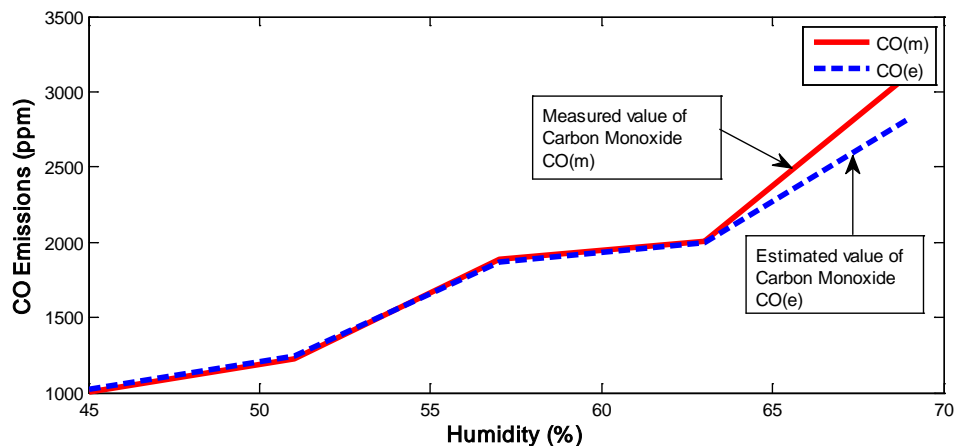


Fig 4 : Plots of Estimated and Measured Values of Carbon Monoxides against Humidity.

$$C_xH_y = \begin{cases} 190H - 7600 & 45 \leq H \leq 63 \\ 630H - 35000 & 63 < H \leq 69 \end{cases} \quad (5)$$

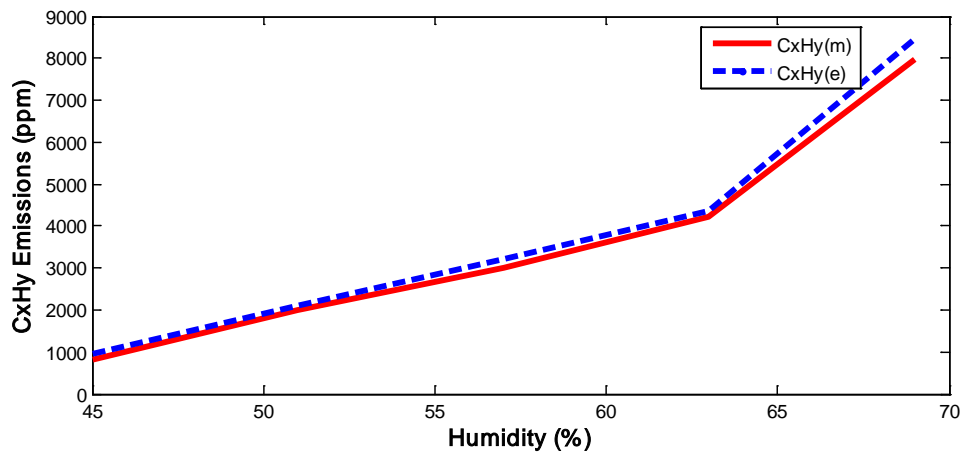


Fig 5 : Plots of Estimated and Measured Values of Hydrocarbon against Humidity.

$$NO_x = \begin{cases} -11H + 680 & 45 \leq H \leq 51 \\ -0.049H^2 + 2.1H + 140 & 51 < H \leq 69 \end{cases} \quad (6)$$

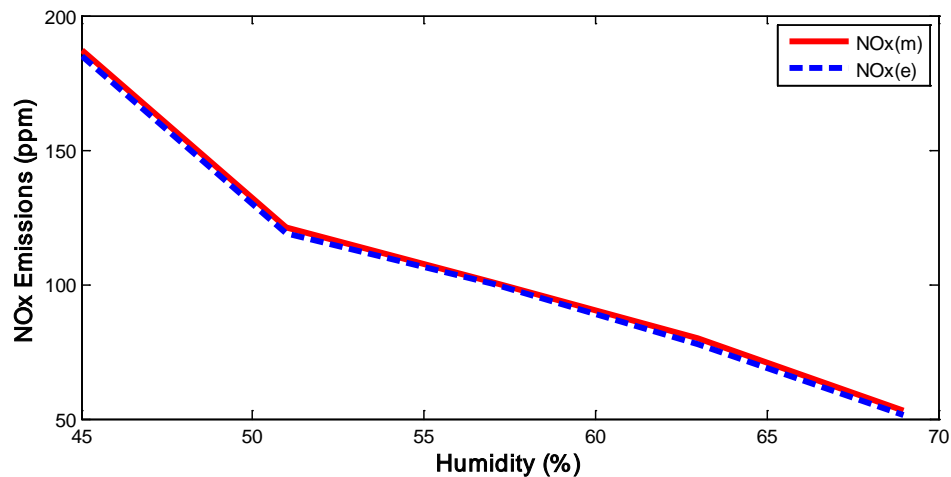


Fig 6 : Plots of Estimated and Measured Values of Nitrogen Oxide against Humidity.

Figures of 4 & 5 show Carbon Monoxide and Hydrocarbon emissions as functions of humidity. It is observed that when the humidity is very high, the concentration of the pollutants (CO & CxHy) will also be high and when the amount of humidity present in the atmosphere is very low, the concentration will automatically be low. The reason for this is that high amount of humidity in the atmosphere can cause poor mixing of fuel and air in the combustion chamber,

thereby resulting in incomplete combustion which will in turn results in excessive release of CO and CxHy pollutants [5].

The case is the reverse for NO_x emissions of figure 6 above as high humidity will result in the reduction of NO_x pollutants released from the engine exhaust. The reason for these has been explain in the previous paragraph of this study.

The estimated value of these pollutants can be obtained by substituting the different range of values of temperature 'T' and humidity 'H' into the modeled equations 1, 2, 3, 4, 5 and 6. The plots of the estimated values of these pollutants are shown in Figures 1, 2, 3, 4, 5 & 6. Both the Measured and the Estimated values of these pollutants are closely related which shows that the mathematical models have been validated.

IV. CONCLUSION

Investigations carried out in this study tend to show that vehicular emissions vary with ambient temperature and humidity at different times of the day. There seem to be much increase in emission rates when the ambient temperature falls below the standard temperature of 75 °F, this might be due to "cold start problem of the vehicle engine". It could also be that it takes a long time for the emission control system (catalytic converter) to warm up, indicating that more fuel is required in the combustion chamber for smooth combustion (rich fuel/air mixture).

The findings from this study have shown high concentration of CO and CxHy pollutants during the early morning periods when the engine is just warming up, and high concentration of NOx emissions during the afternoon period when the engine is fully warmed up. These pollutants are capable of causing harm to the environment by contributing to the formation of smog, ground level ozone and global warming.

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