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Carbon Monoxide Emission and Engine Noise Analyses of Compressed Natural Gas (CNG) and Petrol-Fueled Automobiles

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Abstract: *The problems of global warming and noise pollution require solutions aimed at reducing greenhouse gas emission carbon II oxide (CO) and automobile engine noise. To do this focus must be on measures that enhance the reduction of CO emission and engine noise in vehicle. One of such measures is the use of a gaseous fuel Compressed Natural Gas (CNG) for vehicular transportation. In this work, exhaust emission and engine noise of a vehicle fueled with CNG is compared with exhaust emission and engine noise of the same vehicle fueled with petrol. The exhaust emissions were measured using a portable CO meter and noise level was measured with a sound level meter. The test results show that compared to petrol, CNG allows for a significant decrease in CO emission and engine noise of an automobile vehicle engine.*

Keywords: automobile, noise, carbon II oxide, compressed natural gas, petrol.

INTRODUCTION

Pollution is a major concern all over the world as its effects both on human and the environment is enormous especially in the cities and urban areas [1]. Air pollutants have been identified as matter conveyed in air whose impact on human and the environment is adverse, derogatory and inimical to wellbeing. Furthermore, automobiles are major culprits in respect to air pollution [2]. Population explosion is a major factor in air pollution as the teeming multitudes of people need to move from one place to another. Some of the factors encouraging pollution of the air by automobiles include: use of old vehicles, traffic congestion, urbanization, bad roads, population explosion and poor or non-existent legislation on air quality. Two types of air pollutants have been

identified, namely: gaseous pollutants and particulate matter (PM) [3]. Also, the following vehicular pollutants: Oxides Of Nitrogen(NO_X), Unburnt Hydrocarbon(HC), Lead (Pb), Carbon Monoxide(CO), Petrochemical Oxidants, Benzene(C_6H_6), Particulate Matter(PM),Oxides of Sulphur(SO_X), air toxics, Aldehydes, 1,3 Butadiene(C_4H_6) and Polycyclic Aromatic Hydrocarbons(PAHs) have been identified [1]. Greenhouse gases (GHGs) are gases released into the atmosphere through a number of sources including power plants and automobiles. These gases contribute to global (earth) warming as they trap infrared radiation released from the surface of the earth. Some of the products of combustion of fossil fuels in automobiles that contribute to greenhouse effects include: methane CH_4, Chlorofluorocarbons (CFCS), Oxides of Nitrogen N_xOx, Carbon IV Oxide (CO_2) and water vapour. Mahasneh (2021) identified some effects of global warming to include among others: wildfires, drought, and depletion of the ozone layer protecting the earth from dangerous radiation from the sun; increase in sea level, disappearance of species, floods and other problems associated with the environment [4].

Ogur and Kariuki (2014) identified the health challenges associated with air pollution through automobile emissions to include: asthma, suffocations, lung cancer, heart disease, eye irritation and premature death [5]. Other health challenges include high blood pressure, impaired mental health and damage to internal organs. Also fetal health is not spared from the effect of automobile emissions. The impact of emissions on developing fetus and babies is much more profound than on adults it includes: preterm and or low birth weight, cardiovascular disease, cognitive and behavioral disorders, mental-health challenges and cancer [6] [7]. When sound is non-rhythmic, incoherent and unpleasant to the ear, it is said to constitute noise. Noise pollution is when noise is propagated in such a way that its impact on the environment and humans is harmful both physiologically and psychologically. Road side parties, advertisement on public address systems, religious gatherings and services, traffic, sporting events, political rallies, construction and commercial activities are some of the sources that generate noise pollution [8]. Noise pollution results in auditory impairment or loss of hearing, insomnia and psychological disturbances. It affects the health of pregnant women resulting in cardiovascular challenges and hinders fetal growth and development. When children are born, noise pollution affects their cognitive ability and communication capabilities. Furthermore diabetes and peptic ulcer diseases have been identified with noise pollution [9].

Sawyer, 2010 has identified numerous methods used over the years to reduce automobile emission, namely: introduction of emission regulations, improved and computer-based fuel-air controlled mixture system, improved engine combustion, catalytic improvement and introduction of electric vehicles [10]. Apart from automobiles emissions, other areas of emission reduction would include devices and locomotives powered by fossil fuels, such as aircrafts, trains, ships and diesel engines. Another way of reducing automobile emission is by the introduction of alternative fuels among which are biofuels, hydrogen, dimethyl ether (DME), liquefied petroleum gas (LPG), natural gas (NG), compressed natural gas (CNG), bio-gas and many others. [11], [12]. The purpose of this research work is to investigate Carbon II Oxide (CO) and noise emissions from gaseous fuel Compressed Natural Gas (CNG) and compare with such from gasoline, using one vehicle engine.

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METHODOLOGY

The tests and investigations for this work were carried out at a gas retail company in Ibafo, Lagos-Ibadan Expressway, Ogun State, Nigeria. The emission analyser and sound level meter were placed at distances of 3m, 5m and 9m respectively. The engine speed was gradually increased from start to 4000 rpm. At each of these distances the corresponding values of CO emission and noise levels were measured after the transient response time of two minutes for each of the speed values. The car used as test engine is a Toyota Highlander 2010 (Figure 1) with the parameters shown in Table 1.

Figure 1: The trunk of the Toyota Highlander 2010 showing the CNG cylinder.

Table 1: Parameters of the Hybrid Toyota Highlander 2010 (Test) engine.

Parameter	Data
Engine Type	Petrol/CNG
Drive type	All wheel drive
Transmission	5 speed shift able automatic
Combined MPG	19
Cylinders	V6
Base Engine Size	3.51
Base Engine type	Petrol
Cylinders	V6
Cam type	Double overhead cam (dohc)
Torque	248lb -ft at 4700rpm
Horsepower	270hp at 6200rpm
Valve	24
Valve timing	Variable
Turning cycle	38.7 ft

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The Carbon II Oxide (CO) analyser used in this work is the portable Smart Sensor analyzer, shown in Figure 2, with ± 5% or ± 10 ppm accuracy. Its parameters are shown in Table 2.

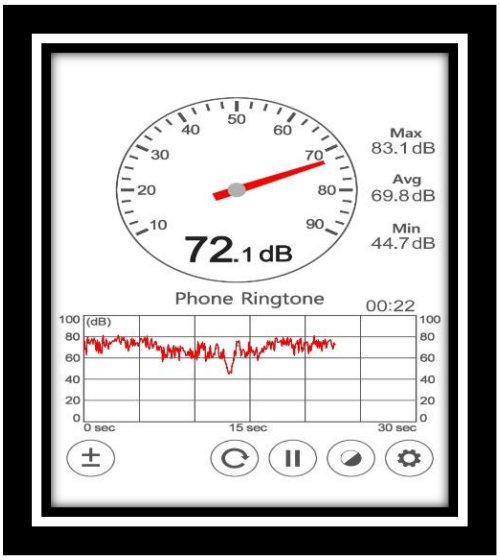

Figure 2: The Portable Smart CO Analyzer. Figure 3: Interface of noise level meter.

Table 2: Parameters of the Portable Smart Carbon II Oxide (CO) Analyzer

Parameter	Data
Brand name	Smart Sensor
Color	Black
Material	Plastic
Sensor type	Stabilized Electrochemical Gas Specific (CO)
Detection gas	Carbon Mono-oxide
Temperature measurement	Ambient Temperature
Display Unit: CO Temperature	 ppm ^{0}C/^{0}F
Measurement Range: CO: Temperature:	 0~1000PPM 0~50^{0}C / 32~122^{0}F
Resolution: CO: Temperature:	 1 ppm 0.1°C / 0.1°F

Accuracy: CO Temperature	 :± 5% or ± 10 ppm : ± 1.5℃

A sound-level meter app, shown in Figure 3, was used to determine the noise levels. It is used for measuring the intensity of noise, music and other sounds in decibel (dB).

The Compressed Natural Gas (CNG) utilized in this work is from a gas retail station at Ibafo, Lagos-Ibadan Expressway. Also, the petrol utilized was sourced from the open market. The characteristics of CNG and petrol are given in Table 3 below.

Table 3: Composition of compressed natural gas (CNG) and petrol.

Properties	CNG	Petrol
Molecular weight (g/mol)	16.04	100 – 105
Density at 15° C and 1atm (kg/m³)	0.75	719 – 779
Lower Calorific Value (MJ/kg)	47.1	42.9
Octane Number	>127	90 – 100
Cetane Number	N/A	5 – 20
Minimum ignition energy in air (MJ)	0.285	0.243
Storage pressure (MPa)	20.6	0.1
Boiling point at Atmos. pressure (°C)	-162	– 200

RESULTS AND DISCUSSIONS

The CO emission values obtained during the test for the same automobile engine fueled with petrol and CNG are presented in Table 4 and Figure 5 showing the relative CO emissions for the tested fuels. It was observed that the CO emission of CNG is lower than that of petrol. Comparing the value of CO emission at different speed and varying distances, it can be seen that the highest CO emission was 139 ppm measured when the test car was running on petrol at a speed of 4000 rpm at 3 meters to the car exhaust (emission source) due to closeness to the emission source. When the test car is powered by CNG the highest CO emission was 109 ppm measured when the test car was running on petrol at a speed of 4000 rpm at 3 meters to the car exhaust. There is a 21 % reduction for the highest value when using CNG compared to petrol.

Table 4: Carbon II oxide (CO) emission for petrol and CNG.

Carbon II Oxide Emission, ppm						
Distance, m	3		6		9	
Speed, rpm	Petrol	CNG	Petrol	CNG	Petrol	CNG
1000	116	92	95	78	24	13
2000	123	96	112	81	32	17
3000	131	101	115	85	35	19
4000	139	109	119	92	38	23

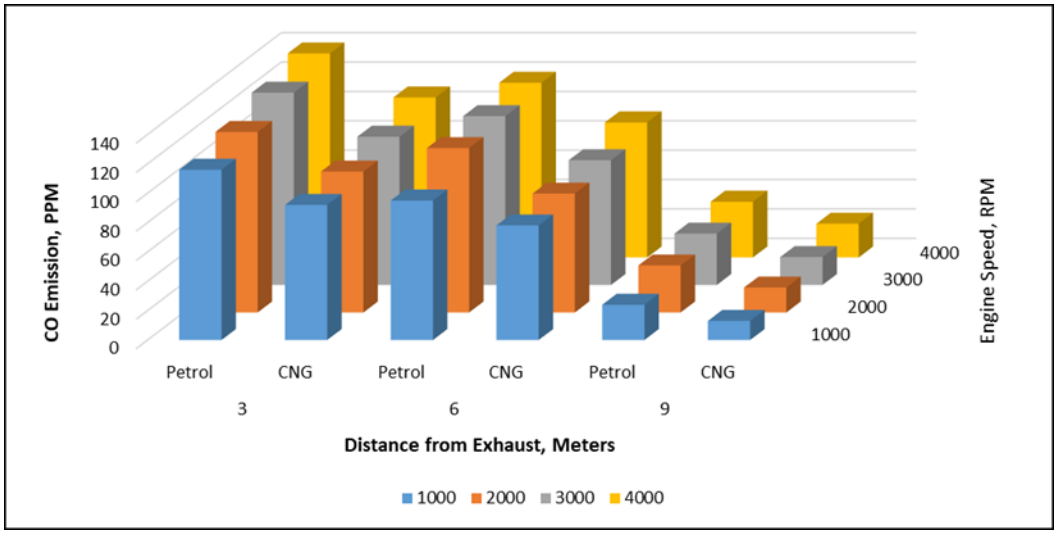

Figure 5: CO emission chart for petrol and CNG.

The engine noise levels obtained during the test for the same automobile engine fueled with petrol and CNG are presented in Table 5 and Figure 6 showing the relative engine noise levels for the tested fuels. The highest noise level was 94 dB at 4000 rpm at 3 m from the test vehicle engine running on petrol, while it was 81.7 dB with CNG. At the maximum engine speed, there is 13.1 % reduction of the highest noise levels when using CNG instead of petrol.

Table 5: Noise levels from the vehicle engine with petrol and CNG.

Noise Level, dB						
Distance, m	3		6		9	
Speed, rpm	Petrol	CNG	Petrol	CNG	Petrol	CNG
1000	83	75.6	69.3	64	55	56.3
2000	88	77.4	74	66.4	60.3	58.8
3000	91.3	79	77.1	68.2	62.2	59.7
4000	94	81.7	79	69	65	60.2

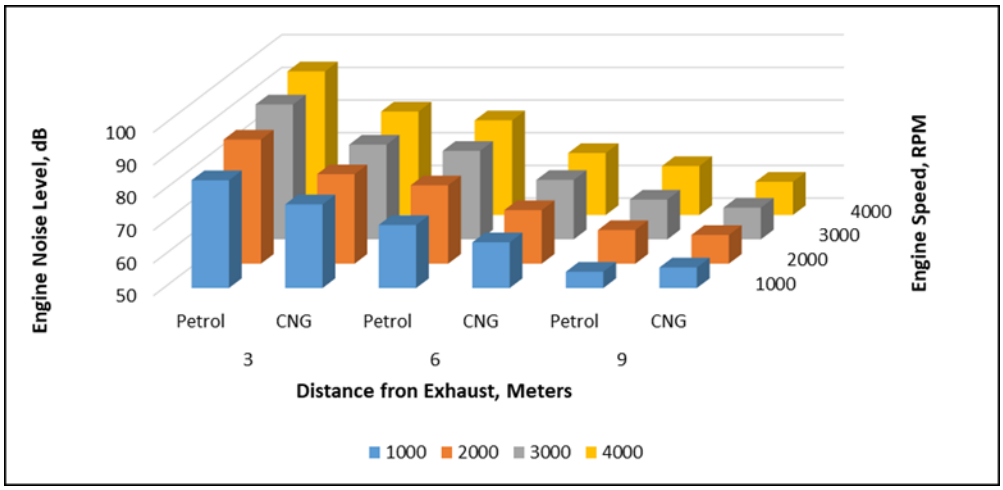

Figure 6: A chart of noise levels from the vehicle engine with petrol and CNG.

CONCLUSION

Based on the research the following conclusions can be drawn. There is 21 % reduction for the highest value reduction in carbon II oxide (CO) emission when using CNG instead of Petrol. Also, there is a 13.1 % reduction of noise when using CNG instead of petrol. Both the CO emission and noise level reduce with distance away from the vehicle exhaust due to diffusion. In general, the average CO emission obtained in the tests are higher when the vehicle was fueled with petrol than with CNG. The data collected during the research can be used to prepare a model of CO emissions for passenger vehicles in the future, but there is still a need to collect more real-time traffic emission data towards meeting exhaust emission standards. This is particularly important for countries where the number of CNG-fueled vehicles is increasing.

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