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### An Assessment of Tail-Pipe Emissions from Petrol and LPG Fuelled Vehicles in Ghana

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#### Abstract

Vehicular exhaust gas emissions are becoming a challenge in urban areas due to rapid increase in vehicle usage. Therefore, the focus of this paper is to evaluate the actual level of emissions for both gasoline and LPG fuelled vehicles. Exhaust gases (i.e. CO, CO<sub>2</sub>, NO<sub>x</sub> and HC) were randomly measured from 200 vehicles using the exhaust gas analyzer. Significant differences were observed in the concentrations of pollutants measured based on the vehicle engine capacity for both gasoline and LPG fuelled vehicles. In addition, the differences in emission pollutants concentrations between gasoline and LPG are also significant. The study concludes that emission levels from LPG vehicles are lower than gasoline ones and could be used as alternative fuel in Ghana.

**Keywords:** Exhaust gas emission; Vehicles; Gasoline; LPG; Ghana.

#### Introduction

The exhaust gases emitted by vehicles contain some levels of pollutant concentration which affects the health of humans, plants and animals. The pollutants exist in the form of nitrogen oxides (NO<sub>x</sub>) ozone (O<sub>3</sub>), unburnt hydrocarbons (HC), carbon monoxide (CO) and particulate matter (PM). These pollutants are formed as a result of burning hydrocarbon fuels as their energy source and contribute significantly to atmospheric pollution in both developed and developing countries (Bell, 2011; He et al., 2002; Mayer, 1999). Among these various pollutants, NO<sub>x</sub> and PM were of much significant because of their implication on human health and the environment. Different studies showed that PM had effect on human health likewise the environment (Chapman, 2007; Colville et al., 2001). Epidemiological studies showed that there is a relationship between PM exposure and acute respiratory diseases, cardiovascular and lung infections (de Haan, and., Keller, 2000).

Because of these health risks, various emission reducing strategies have been proposed in developed countries. These included new technologies, where fuel consumption has been minimized using dynamic optimization (Saerens et al., 2009), applying new legislative standards for newer cars (Arteconi et al., 2010) and using alternative fuel systems, such as using liquefied natural gas (LNG), liquefied petroleum gas (LPG) or biofuels in heavy-duty vehicles instead of the conventional gasoline or petrol (Lopez, 2009). The

use of alternative fuels is becoming widespread in developing countries.

In Ghana, LPG usage as an alternative fuel for commercial vehicles especially taxis is on the increase. However, a study conducted by Biscoff et al. (2012) shows that LPG usage as an alternative vehicle fuel is illegal. This is because governmental policy concerning LPG was centered on domestic or residential consumption. According to the Deputy Minister of Energy “the shift from the use of petrol and diesel to the use of LPG by Taxis and other vehicles constitutes a very serious offence of tax evasion. The drivers using LPG are committing an offence by not paying taxes incorporated in buying conventional gasoline (Biscoff et al., 2013).

In developed and some developing countries, the change from gasoline as vehicular fuel to LPG is because of its environmental benefits. A study by Gamas et al., (1999) indicated that recent moves towards the use of liquefied petroleum gas (LPG) than gasoline is the perception that LPG is a cleaner fuel. It has been widely used as an alternative vehicle fuel in the United States of America, Canada, the Netherlands, Japan and several other countries (Ristovski et al., 2005). In Hong Kong, the government has completed the LPG taxis pilot scheme and started the importation of LPG taxis since 1998. To encourage a quick switch of about 18,000 diesel taxis to LPG taxis, the government of HKSAR provided a one-off grant of HK \$40,000 (approximately US \$5140) for each replacement of

diesel taxis with one that operates on LPG taxis in a subsidy programme starting in August 2000. The incentive programme was completed at the end of 2003 while nearly all diesel taxis (close to 99.8% of the taxis population in Hong Kong) had been switched to the LPG taxis (HKEPD, 2006). In Ghana, commercial drivers convert their cars for LPG usage because it improves fuel economy relative to gasoline. This implies that while other countries are shifting to LPG usage as alternative vehicle fuel to safeguard their environment or reduce emission pollutants levels; drivers in Ghana are converting their vehicles to use LPG because of more profit and better fuel economy.

Vehicle emission rate is influenced by some factors. It largely depends on vehicle type, characteristics of traffic and type of road intersections. Vehicle characteristics such as type, size, age of a vehicle, and condition of its engine, type and condition of emission control equipment, engine characteristics, vehicle maintenance, and weight, all correlate to the emissions. In addition, the engine size also affects the functioning of emission control equipment (Beydoun, 2004). Furthermore, poor maintenance and age of vehicles also contribute significantly to the emission of all classes of vehicles. A study by Perry and Gee (1995) also shows that fuel quality has a direct effect on vehicular exhaust emission. According Zhang (2011) emissions may increase as vehicles spend more time in traffic congestion, idling or crawling, and undergoing numerous acceleration and deceleration events. This is due to vehicular traffic and road intersections. In Ghana, there is little or no documentation concerning vehicle emissions, especially for environmental protection and health safety. Therefore, the focus of this study is to assess the emission levels from different classes of vehicles using gasoline and LPG.

### **Pollutant formation mechanisms in internal combustion engines**

Most of the pollutants are mainly from exhaust gases of the motor vehicle internal combustion engines. The primary exhaust emissions focused on in this study were CO, CO<sub>2</sub>, NO<sub>x</sub> and unburnt hydrocarbons (HC).

#### ***Carbon Monoxide (CO)***

CO is a colourless, odourless, relatively inert gas formed as an intermediate combustion product. It appears in the exhaust when the reaction of CO to CO<sub>2</sub> cannot proceed to completion. This situation occurs from lack of available oxygen in some fuel molecules during combustion, low gas temperature or short residence time in the cylinder (NPI, 2002).

Improvement in air / fuel ratio can reduce CO concentration from exhaust of vehicles.

#### ***Carbon dioxide (CO<sub>2</sub>) and Nitrogen oxides (NO<sub>x</sub>)***

CO<sub>2</sub> is formed as an ideal complete combustion of a HC fuel with stoichiometric air-fuel mixture. Oxygen is needed for complete combustion of fuel in the engine to release the energy needed to propel the vehicle. Mostly, there is free O<sub>2</sub> in the exhaust gases when the engine is burning an air/fuel mixture which is on the weak side of stoichiometry. Nitrogen oxides are formed through three basic different reactions and emitted through the exhaust system into the environment. The three mechanisms are: (i) thermal NO – Zeldovich mechanism oxidation of molecular nitrogen in post-flame zone (Miller and Bowman, 1989). In this case, the main source in the combustion engines is thermal NO<sub>x</sub> from the thermal dissociation and subsequent reaction of nitrogen (N<sub>2</sub>) and oxygen (O<sub>2</sub>) molecules from the combustion air (NPI, 2002). A thermal NO<sub>x</sub> is formed in high-temperature regions in the cylinder or combustor where combustion air has mixed sufficiently with the fuel to produce the peak temperature at the fuel/air interface (NPI, 2002). (ii) Fuel-bound NO oxidation of nitrogen-containing compounds in fuel. Fuel NO<sub>x</sub> occurs from the evolution and reaction with oxygen of fuel-bound nitrogen compounds (NPI, 2002; Miller and Bowman, 1989). When fuel NO<sub>x</sub> is combusted under high temperature, it releases NO<sub>x</sub>. (iii) Prompt NO – Fenimore mechanism formation of NO in flame zone (Miller and Bowman, 1989). Combustion in conventional design combustion engines is by diffusion flames. It is characterized by stoichiometric fuel/air mixtures where temperatures are high and most NO<sub>x</sub> is formed (NPI, 2002).

#### ***Hydrocarbons (HC)***

HCs are made up of pollutants from organic compounds that are emitted into the environment from the exhaust system. It mainly occurs when fuel is unburned or partially burned during combustion. Partially burned hydrocarbons can occur because of poor air and fuel mixing before or during combustion and incorrect air/fuel ratios in the cylinder during combustion due to poor adjustment of the engine fuel system (NPI, 2002).

### **Vehicular Emissions Policy in Ghana**

Ghana has witnessed a tremendous increase in used vehicle importation which could lead to increase in exhaust emission levels. This is because of the high demand for on-road transportation in both rural and urban centers. Since Ghana is not a vehicle manufacturing economy, all vehicles are imported

with most of them being second-hand vehicles. There was Government of Ghana ban on importation of old cars as an alternative way to curb air pollution levels in order to create a healthier environment. According to the Customs, Excise and Preventive Service (Management) Act 1993 (PNDCL 330) section 90-prohibition of importation of over-age vehicles; 'A motorcar or commercial vehicle of more than ten years old shall not be imported into the country.' However, surprisingly after only 4 years of implementation, the ban was subsequently lifted and replaced with an amendment attempting to keep older cars (second-hand cars) through higher penalties as car ages increase. This shows a lot of the vehicles imported into the country might be polluting the environment.

In Ghana, there is no clear cut policy regarding exhaust emission levels. The Environmental Protection Agency (EPA) in Ghana embarked on vehicle exhaust emissions testing programme to collect baseline data for the development of vehicle emissions control standards and regulations. Currently, all assessment of vehicle emissions in Ghana is measured against the European standards.

## Methodology

### Description of study area

The study was carried out in four major cities in the Volta Region of Ghana. The cities have a lot of vehicular movement with traffics in the rush hours of the day along the major routes. Government formal sector works and private businesses are the main occupations of the people in the cities sampled. All kinds of vehicles are being used in the cities; with varying ages and maintenance levels or records.

### Population, sampling and sampling techniques

There are over 1000 vehicles in the cities where the study was conducted. The vehicles were classified into three classes' namely small cars, medium cars and large cars. The criterion for classification was engine capacity. Vehicles with engine capacity of 0.8 – 1.4 litres were classified as small cars. They were mainly Korean and German-made vehicles. Examples included Hyundai Atos, Hyundai I10, Hyundai EON, Kia Picanto, Kia Pride, Maruti, Daewoo Matiz, Daihatsu, Fiat Polio, Opel Astra, Opel Agila and Opel Kadett. Vehicle characteristics that make up the second classification were vehicles with engine capacity 1.5 – 2.0 litres. They were mainly Japan vehicles (i.e. Toyota, Nissan, and Suzuki), Korean vehicles (i.e., Daewoo, Kia, and Hyundai) and German vehicles (i.e. Opel,

Benz). Furthermore, vehicles with engine capacity above 2.1 litres were considered large vehicles. They were mainly 4X4 vehicles and included Japan vehicles (Toyota land cruiser, Highlander, Tundra, Rav4, Tacoma, Mazda Tribute, Mitsubishi Montero Sport, Nissan Pathfinder, Honda Pilot) American Vehicles (Ford Escape, Ford Explorer), German vehicles (Benz, Volvo).

### Determination of exhaust gases concentrations

In all, 200 vehicles were randomly sampled from the cities where the study was conducted. The same vehicle make using LPG were also studied for comparison between the gasoline ones. The other vehicle characteristics which might influence emission such as vehicle age, periodic maintenance culture, type of fuel supply system etc. were not considered due to unwillingness of vehicle owners to participate in the study. This could had some level of influence on the emission levels.

### Procedure

The exhaust gas analyzer type AGA 5000, which was designed to be used for petrol, diesel, LPG and CNG powered engines was used to measure the concentrations of emitted gases from the vehicles sampled. The emission test procedure is as follows:

- The exhaust gas analyzer was calibrated to ensure that every parameter to be determined was reading well.
- The vehicle was parked with the engine warming up to operating temperature for emission test and accurate reading.
- It was ensured that the exhaust gas analyzer battery was fully charged.
- The analyzer was switched-on for the leak check, and it was observed that there was no leakage of exhaust gas.
- Parameters including fuel type being used by the vehicle were selected.
- The probe flexible hose was connected to the analyzer and the probe was inserted into the exhaust pipe.
- Readings were taken at idling and the test was repeated twice.

### Data Analysis

The data was coded and entered into Statistical Package for Social Scientist (SPSS) version 16. Means and standard errors were calculated for each parameter for the various classes of vehicles and engine capacity. The same analysis was performed for vehicles using LPG. One –way analysis of variance (anova) was used to determine

the significant differences between the vehicle classifications.

## Results and discussion

### Exhaust gases emitted from gasoline vehicles

Table 1 shows the mean concentration of emitted exhaust gases from gasoline fueled vehicles. Generally, it was observed that vehicles with engine capacity from 2.0 and above emit low concentrations of CO, CO<sub>2</sub>, O<sub>2</sub> and HC. However, analysis of variance (ANOVA) shows that CO levels were not significant ( $p < 0.05$ ). Least Significant Difference (LSD) analysis indicated that CO<sub>2</sub> levels from vehicles with 2.0 and above engine capacity differs significantly from the others ( $p < 0.05$ ). In addition, O<sub>2</sub>, NO<sub>x</sub> and HC levels showed significant differences ( $p < 0.05$ ). This result agreed with the survey from the drivers that vehicle emission depends on engine capacity. From the survey, drivers also

perceived that vehicles with higher engine capacity should emit higher levels of exhaust gases into the environment. However, this was contrary to the measurements of various emission levels obtained in this study (Table 1). From these, it is deduced that engine capacities of vehicles plays essential role in exhaust gas pollutants into the environment. Technically, the emission of gases from the automobile sector occurs in combustion at low ( $< 950^{\circ}\text{C}$ ) temperatures and they are affected by fuel type, operating conditions and excess air level, oxygen in fuel and catalytic activity (Gajendra and Subramanian, 2013). Exhaust emission from various vehicles depends on other factors or parameters. These include engine maintenance, age of the vehicle, engine load characteristics, type of fuel etc. Vehicles older than 10 years are responsible for 25-40% of all exhaust emissions from off-road machines (Lindgren, 2007).

*Table 1: Mean exhaust emission concentrations from gasoline vehicles*

Engine capacity (L)	Mean concentrations (% vol.)			
	CO	CO <sub>2</sub>	NO <sub>x</sub>	HC / ppm
1.4 and below	1.15 (±0.43)	9.07 (±0.51)	49.96 (±12.64)	302.68 (±86.23)
1.6	1.49 (±0.57)	9.04 (±0.68)	138.14 (±32.18)	435.43 (±124.06)
1.8	1.42 (±0.84)	10.10 (±0.61)	54.14 (±12.66)	392.86 (±185.83)
2.0 and above	0.62 (±0.50)	7.57 (±1.68)	90.57 (±75.87)	61.68 (±28.19)

Figures in bracket are standard errors (n = 200)

### Exhaust gases emitted from LPG vehicles

LPG is one of the alternative fuels used in the automobile industry. This study shows that generally, very low CO and CO<sub>2</sub> were emitted by LPG vehicles. The NO<sub>x</sub> and HC levels were slightly high. The NO<sub>x</sub> levels generally decrease with increasing vehicle engine capacity while no peculiar trend was obtained for HC (Table 2). The differences in the levels of all the gases measured based on their engine capacities were statistically significant

( $p < 0.05$ ). The survey results showed that LPG is mostly used as fuel for vehicles with 2.0 and above engine capacity. Drivers were of the view that it was more economical than gasoline, therefore its usage as alternative fuel is as a result of economic gain rather than the environmentally friendly nature of LPG. LPG is believed to be a cleaner fuel and vehicles running on cleaner fuels produce fewer harmful emissions, and can offer some savings on fuel costs, compared with petrol or diesel (Pundkar et al., 2012).

Table 2: Mean exhaust emission concentrations from LPG vehicles

Engine capacity (L)	Mean concentrations (% vol.)			
	CO	CO <sub>2</sub>	NO <sub>x</sub>	HC / ppm
1.4 and below	0.88 (±0.50)	8.02 (±1.52)	66.00 (±40.75)	1076.60 (±710.57)
1.6	0.89 (±0.38)	7.13 (±0.98)	20.0 (±10.5)	1376.90 (±327.5)
1.8	0.36 (±0.22)	5.18 (±1.04)	24.22 (±14.87)	1413.33 (±425.55)
2.0 and above	0.11 (±0.06)	5.20 (±1.38)	8.25 (±3.01)	495.25 (±184.29)

Figures in bracket are standard errors (n = 200)

### Comparison of exhaust gases emitted from both gasoline and LPG vehicles

The results from the study showed in Figure 1 indicated that pollutant concentration in exhaust gases emitted from LPG fueled vehicles were lower than gasoline ones with the differences been statistically significant ( $p < 0.05$ ). Results from similar studies also indicated that LPG fueled vehicles emit lower exhaust pollutants than gasoline ones. According to Lanje and Deshmukh (2012), emissions from LPG vehicles are significantly lower than conventionally fuelled vehicles. LPG operated vehicle reported hydrocarbon (HC) emissions as 40% lower, carbon monoxide (CO) as 60% lower and carbon dioxide (CO<sub>2</sub>) as substantially reduced. In addition, since LPG has lower carbon content than gasoline, it virtually produces zero emissions of particulate matter and lower amount of NO<sub>x</sub> emission as well. It contains 35% oxygen that helps in complete combustion of fuel and thus reduces harmful tailpipe emissions (Lanje and Deshmukh, 2012).

Exhaust CO emissions are lower with LPG than gasoline. CO<sub>2</sub> emissions typically are also somewhat lower than those for gasoline due to the lower carbon-energy ratio and the higher octane quality of LPG. NO<sub>x</sub> emissions are similar to those from gasoline vehicles, and can be effectively controlled using three-way catalysts. Overall, LPG provides less air quality benefits than CNG mainly because the hydrocarbon emissions are photochemically more reactive and emissions of CO are higher (Pundkar et al., 2012). Another study carried out in Malaysia indicated that LPG as vehicle fuel showed an average reduction of exhaust gas emission was about 36% for CO<sub>2</sub>, 38% for CO and 79% for NO<sub>x</sub> in comparison to the original gasoline fuel (Yusuf et. al., 2005).

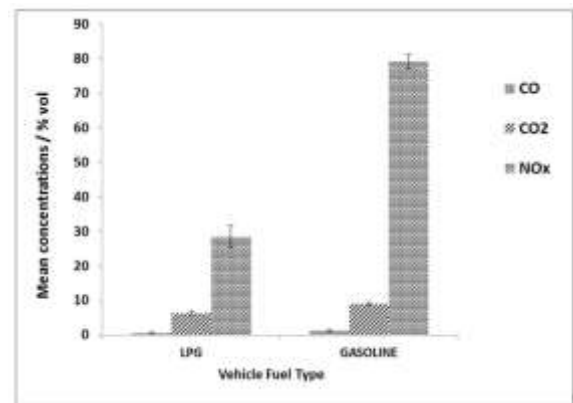


Figure 1: Comparison between emission levels from LPG and gasoline fuelled vehicles

A key finding in this study was that the HC level from LPG fueled vehicles was higher than the level obtained from conventional gasoline vehicles (Figure 2). The difference is statistically significant ( $p < 0.05$ ). LPG is a mixture of gases and primarily composed of propane and butane. It has higher octane number (105) than petrol (91-97). Emitted HC comes from partially burned hydrocarbons that occur because of poor air and fuel mixing before or during combustion and incorrect air/fuel ratios in the cylinder during combustion due to poor adjustment of the engine fuel system (NPI, 2002). Higher emitted HC could be attributed to this factor because most of the LPG vehicles used in the study had their engines modified or converted from the conventional gasoline engines to LPG engines by local mechanics or artisans without using the standard conversion kits. It therefore implies that without a reprogramming of the Electronic Control Unit (ECU), it may not deliver the right quantum of fuel to the engine, hence the higher HC emission. According to Biscoff et al. (2012) installation of LPG in vehicles in Ghana was done using “second hand” non-standard conversion kits.

Most often, the devices are bought in pieces from different automotive dealers and assembled to form the kit. Furthermore, there were no Axle dynamometer test benches to check other performance parameters and emission standards. This, however, adversely affects the performance of the engine fuel system. Air/fuel ratio is very important in exhaust emission. A study conducted by Mustafa and Gitano-Briggs (2008) indicated that level of carbon dioxide (CO<sub>2</sub>) peaked at around relative air-fuel ratio of 1.0 and carbon monoxide (CO) exhibits a sharp decrease as the relative air-fuel ratio increases. Unburned hydrocarbons (UHC) also shows marked reduction as the relative air-fuel ratio exceeds stoichiometric and nitrogen oxides (NO<sub>x</sub>) exhibits an increasing trend as the relative air-fuel ratio increases. This implies LPG installation into conventional gasoline engines need to be carried out appropriately to reduced exhaust emission levels. A report indicated that that conversion of engines using LPG as fuel showed an average reduction of CO and HC as exhaust gas emissions in comparison to the original fuel (Yousufuddin, and Mehdi, 2008; Bayraktar and Durgun, 2005).

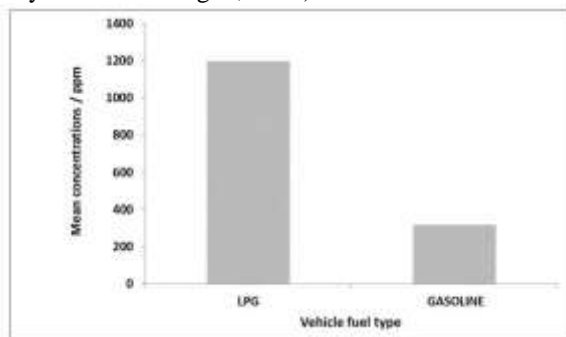


Figure 2: Comparison of hydrocarbon levels between LPG and gasoline fueled vehicles

## Conclusions

Fuels are a very important source of energy in the automobile industry. However, their use in internal combustion engines is associated with emission of pollutants through the exhaust system. The study concludes that vehicle drivers had adequate knowledge regarding the fact that vehicles emit some level of waste gases into the environment but a relatively fewer number of them knew the composition of the exhaust gases. In addition, most LPG vehicle drivers were of the view that emissions from their vehicles do not pollute the environment. However, quantitative measurements of concentration of exhaust gases indicated that emission from LPG vehicle is lower than that of gasoline except in the case of HC emissions.

Therefore LPG represents a good fuel alternative to gasoline and therefore steps could be taken by the relevant governmental agencies to ensure standard conversion methods and kits are used by LPG mechanics if the full environmental benefits are to be derived from the use of LPG.

## Limitations

Vehicular emission control is a key research carried out worldwide because of the negative impact the pollutants are having on the environment. This results in the use of alternative cleaner fuels such as LPG relative to the conventional gasoline. In this study, LPG fueled vehicles have a reduced pollutant concentrations. However, the study had some limitations which could influence the levels of exhaust gases determined and need to be discussed. Vehicle emission level is influenced by the age of a vehicle, condition of its engine, type, engine characteristics, vehicle maintenance and weight which were not considered in the study since many of the vehicles examined were without vital information and maintenance reports. These parameters were assumed to be the same for both LPG and gasoline vehicles assessed. In addition, emission level is also influenced by traffic characteristics and type of road intersections for vehicle is motion but this study was carried out when the vehicles were stationary with the engines running at idle speeds. Although vehicle types were considered in this study, vehicles were classified according to engine capacity and not necessarily the type and make. The researchers believed these factors could have some level of influence on their results but their study was worthy to have a baseline data on exhaust gases emission concentrations from both gasoline and LPG vehicles.

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