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Assessment of Running Losses from Gasoline Powered Vehicles within Benin, Nigeria

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Abstract: This study was undertaken to quantity the amount of evaporative running loss emissions released by gasoline powered motor vehicles subjected to variety of conditions typical of Nigerian urban roads. The vehicle tested was desired to be representative of gasoline powered motor vehicles on Nigerian roads. The results indicate that the amount of unburned hydrocarbon emitted during the average life span of a Nigerian gasoline powered motor vehicle without evaporation emission control systems and driven under conditions typical of Nigerian urban roads, is about 482.5 L. This revealed that every year about 88.1 million of gasoline is lost through evaporation from gasoline powered motor vehicles.

Key words: Running losses, gasoline powered vehicles, nigerian urban roads

INTRODUCTION

Photochemical oxidant, commonly known as photochemical smog is a challenging urban air pollution issue. This has resulted in an increased interest in research aimed at addressing issues that influence air pollution in urban cities (Igbafe and Ogbe, 2005; Ojiegbe, 2005; Marr *et al*., 2000).

Air pollution from motor vehicles continues to rise in Nigerian cities. This is a fall-out of sleep rise in car ownership and usage. Car ownership growth rate has been tremendous since 1998, with relatively order vehicles dominating the fleet, most of which have no catalytic converter or any other form of emission control devices in them (Faluyi *et al*., 2006). Also, fuel specifications internationally have intended to lower vapour pressure fuels to reduce the evaporation potential of the fuel (Batterman *et al*., 2005; Guo *et al*., 2006). The fuel specifications in Nigeria have not followed this trend (NNPC, 2006). This factor implies that the level of HC emission from vehicles plying Nigerian roads is very high.

Emissions from motor vehicles are divided into 2 categories: Exhaust (tailpipe) emissions (31%) (Guo *et al*., 2006). HCs from tailpipe emissions have been tightly controlled to 1 or 2% of their pre-controlled levels (Kylander *et al*., 2003). Evaporative emissions contribution to ambient HC has become significant as the tailpipe emissions have been reduced. One of the possible ways for substantial reduction in HC inventories is reduction in excess evaporative emissions from vehicles, including vapour that is emitted when vehicles are driven (running loss) (Godwin and Ross, 1996). In most modern vehicles, non-exhaust emissions are effectively controlled by returning the blowby gases from the crankcase to the engine intake system and by venting the fuel tank and carburetor float bowl through a vapour-absorbing carbon canister which is purged by some of the engine intake air during normal engine operation (Rubin *et al*., 2006). The US Environmental Protection Agency (USEPA) data indicate that control of these emissions can reduce ambient HC by 25% on a warm sunny day (Touaty and Bonsang, 2000).

Evaporative emissions from vehicle system are generally grouped into three categories namely: Running losses, diurnal emissions and hot-soak emissions.

This study focuses on running losses. Running loses are evaporative emissions that occur while a vehicle operates, this is caused by the generation of vapours from the fuel tank as the fuel is heated during driving. The objective of this study was to quantify the amount of running loss evaporative emissions released by gasoline powered vehicle subjected to a variety of conditions typical of Nigerian urban cities.

MATERIALS AND METHODS

The specifications of the vehicle used for the tests are as shown in Table 1. Prior to the tests, the vehicle was tuned as close to manufacturer's specifications as possible given its age and engine wear, replacing parts as necessary. The tests were of two parts: Road test and laboratory test.

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Table 1: Engine specifications

Make and model	2.0 SLX, Nissan Gasoline
Year of Manufacture	1988
Types	4-Stroke Cycle, in-line
Number of cylinder	4
Bore	88mm
Stroke	82mm
Displacement	1994mm^3
Compression ratio	8.2:1
Air Induction	Naturally aspirated, water cooled
Valves per cylinder	4
Number of plugs	4
Maximum power	60kW at 4600 rpm
Maximum torque	144Nm at 3000 rpm
Maximum speed	5000 rpm

Table 2: Fuel specifications

Characteristics	Unit	Limit
Specific Gravity at 15/4	°C	0.779
Distillation		
a) 10% evaporated	°C	70 (max.)
b) 50% evaporated	°C	125 (max.)
c) 90% evaporated	°C	180 (max.)
d) Final Boiling Point (FBP)	°C	205 (max.)
Colour	-	Red
Odour	-	Marketable
Copper corrosion for 3 months at 50°C	-	No.1 strip (max.)
Total sulphur	% wt	0.20 (max.)
Residue	% Vol.	2 (max.)
Vapour pressure	Bar	0.62(max.)
Ratio T36	°C	68(max.)
Existent gum	mg 100mL^{-1}	4(max.)
Oxidation stability	minute	360(min.)
Lead alkyl	g/pb/litre	0.7
Knock rating	-	90(min.)

Road test: Road test was performed on a Nissan 2.0 SLX blue bird car. A J-type thermocouple was inserted 50 mm into the fuel tank via modified drain plug to monitor the temperature. Another thermocouple, shielded from any radiant heat source, was installed close to the fuel tank to monitor the ambient temperature surrounding the fuel tank. The objective of this test was to expose the vehicle to temperature variations, which reflect typical fuel heating when driving in a crowded urban road. The tests were carried out during the dry season (on hot sunny days with ambient temperature of about 30°C).

During the test, 2 different routes were used, in which fuel level, ambient temperature and fuel temperature inside the tank were monitored and recorded. The first test involved recording temperatures at start-up and shut-off of the vehicle (start-stop).The second was minute-by-minute test, in which the data were recorded every 10 min. These trips were as follows:

- Start-stop: University of Benin gate, Ekehuan campus to cattle market at Aduwawa in Benin (±50 km).
- Minute-by-minute: University of Benin gate, Ugbowo campus to cattle market at Aduwawa in Benin (±70 km).

Laboratory test: The tests were conducted in an air-tight aluminium housing 6×6×3 m^3. This enclosure was our improvise Sealed Housing for Evaporative Determination (SHED). An air conditioning system was installed to control the ambient temperature inside the SHED. A ceiling fan was also installed to ensure thorough mixing of fuel vapour with ambient air within the SHED. To achieve the required fuel temperature for the different tests, the fuel tank was equipped with electric heating units and a variable temperature controller to control the fuel temperature. Different thermocouples were installed to measure both the SHED ambient and fuel temperatures.

Vehicle used for these tests was not equipped with evaporative emission control systems and are therefore representative of the majority of vehicles on Nigerian roads (Faluyi *et al*., 2006). All testing were performed with commercial Premium Motor Spirit (PMS) purchased from a major oil marketer (Texaco Filling Station, Akpakpava road, Benin). Specifications of the fuel are shown in Table 2.

The SHED was thoroughly purged before the start of the test. This was achieved by leaving the SHED door open while the fan was on. After the standard diurnal test (Van der Westhuisea *et al*., 2004), the fuel temperature was stabilized at 35°C within 1 h. The fuel was then heated to 40°C and stabilized for 30 min. This was followed by further heating the fuel to a temperature of 45°C. The fuel temperature was kept at 45°C for 1 h to ensure easy measurement of the magnitude of the fuel evaporation. Flame Ionization Detector (FID) gas analyzer was used to record HC concentration in the enclosure.

The emissions due to the elevated fuel temperatures, coupled with the non-emissions controlled vehicles would lead to saturation of the HC analyzer and a possible safety risk (Touaty and Bonsang, 2000). For this reason, the enclosure was periodically purged and the increase in hydrocarbon concentration thereafter was mathematically added to the concentration achieved prior to the purge.

RESULTS AND DISCUSSION

Figure 1 shows bar chart of fuel temperature distribution obtained from different sections of the trip from University of Benin gate, Ekehuan campus to cattle market at Aduwawa in Benin during start-stop tests. These tests were carried out in the rush hour periods (8.00-9.00 am and 4.00-5.00 pm). This trip was mostly an urban stop-start driving in a congested traffic with average driving speed of 60 km h^{-1} and each Test refers to readings taken periodically along the route with stops of varying length in-between. Ambient temperature surrounding the fuel tank varied from 37-47°C and the

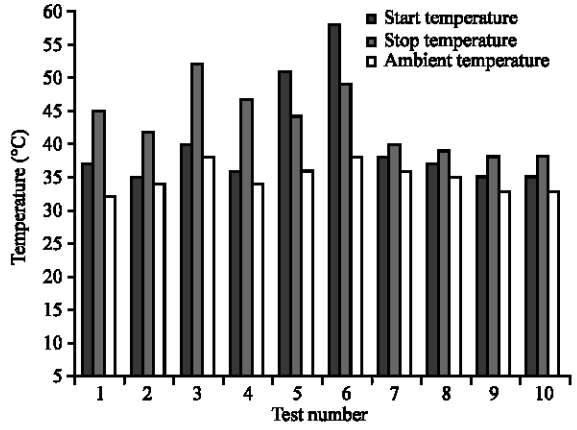

Fig. 1: Comparison of temperatures at different operating conditions

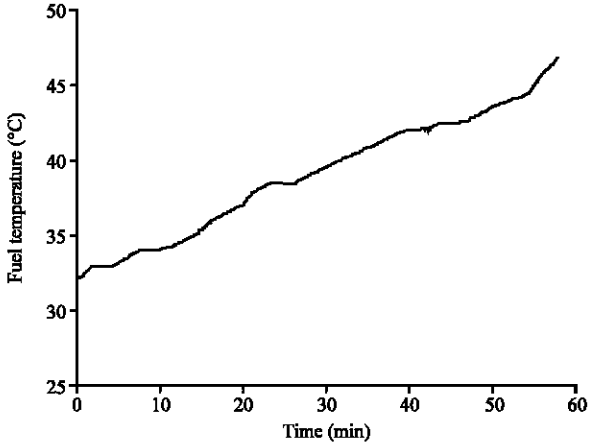

Fig. 2: Variation of fuel temperature with time

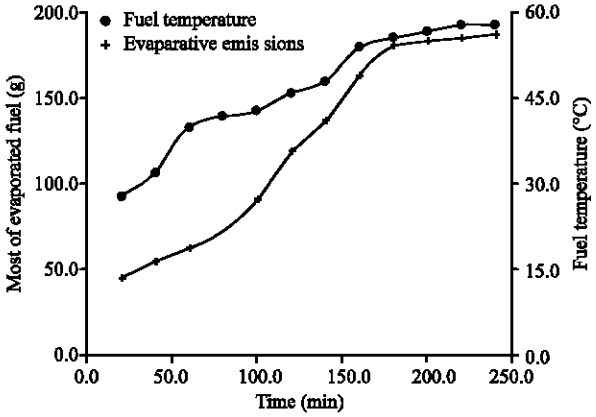

Fig. 3: Vatiation of mass of evaporated fuel and fuel temperature with time

maximum fuel temperature obtained was 58°C. This test shows that the fuel temperature can rise above 50°C on hot days. The rise in fuel temperature is attributable to the high rates of fuel recirculation to the engine where the fuel picks up heat due to the high under-bonnet temperatures as well as the fuel tank proximity to the exhaust system (Rubin *et al*., 2006). Running loss evaporative emissions increase with increasing temperature, because of an exponential rise in gasoline vapour pressure and greater vapour flow out of the fuel tank (Rubin *et al*., 2006). The strong relationship between evaporative emissions and temperature suggests that an overall increase in motor vehicle emissions will be observed on hot days (Rubin *et al*., 2006).

It is glaring from Fig.1 that the start temperatures for Test 5 and 6 are higher than the end temperatures and that the start temperature for Test 6 is higher than the end temperature from the previous sections of the trip. This may be due to heat soak of the fuel in the tank from the hot exhaust system combined with the absence of any cooling due to the relative air movement while the vehicle was stationary (Rubin *et al*., 2006). Once the vehicle starts moving, the tank is cooled by the passage of air over its surface.

Figure 2 depicts the temperature profiles obtained on a crowded urban road driving. The test was carried out between 8.30 and 10.00 am in an urban driving conditions during heavy traffic. There were many rod junctions, hence the driving was slow. The fuel tank contains 25 L of gasoline and weather condition was very bright. The fuel temperature increases linearly with time (Fig. 2). The highest temperature recorded was 47°C. The rate of temperature increase was 14°C h^{-1}.

The running loss test simulated in the SHED at temperature up to 55°C was informed by the road test results, which represents long period of driving on hot days (Haskew *et al*., 1999; Guenther *et al*., 1998) in a typical Nigerian urban area. All tests were performed using the temperature profile obtained from road test results.

The results of the running test are as shown in Fig. 3. During the test, the fuel temperature remain within a tolerance limit of ±3°C (Van der *et al*., 2004) of the temperature profile and the SHED ambient temperature between 30 and 40°C. The results indicate that the mass of evaporated peaked at 188 g during the test.

The running loss test is a reliable simulation of the running losses from gasoline powered motor vehicles in a typical Nigerian urban road. This is true because of the realistic fuel temperature used.

Using Vander Westhuisen *et al*. (2004) approach, percentage of fuel evaporated was evaluated to be 0.965%.

Let's assume that vehicles used in Nigeria have average lifespan of 500×10^3 km with average fuel

consumption of 10 km L^{-1}. The total amount of fuel consumed by a vehicle was calculated to be 50×10^3 L and the total volume of fuel lost due to evaporation was 482.5 L.

With the current price of N70 L^{-1} of fuel in Nigeria, the cost of fuel lost is 482.5×70 = N33,775.00. This means that a vehicle owner would lose N33,775.00 worth of gasoline due to evaporation emission. By the 2006 National Petroleum Corporation (NNPC) annual report, a total of 9.13 billion L of gasoline was consumed in Nigeria in the year 2006. Hence, total volume of fuel lost due to evaporation in the year 2006, was evaluated to be 88.1 million litres. Therefore, the fuel lost due to evaporation in the year 2006 worth N6.17 billion (US $45.3 million).

Road tests under actual driving conditions typical of Nigerian urban areas were performed to find out the relationship between fuel temperature and ambient temperature. The data from road tests were used to simulate fuel loss in an average Nigerian gasoline powered motor vehicle plying Nigerian urban routes. The results indicate the amount of unburned HC emitted during the average life span of a Nigerian gasoline powered motor vehicle without evaporative emission control systems and driven under conditions typical of Nigerian urban roads, is about 482.5 L. This indicates that every year about 88.1 million L of gasoline are lost though evaporation from gasoline powered motor vehicles and this costs the economy about N6.17 billion (US $45.3 million) per year.

These deductions were based on 2006 fuel consumption as reported by the 2006 NNPC annual report and the current fuel prices and exchange rates. Consequence of poor fuel quality, poor vehicle maintenance culture and high proportion of old vehicles in Nigeria, the aforementioned values are likely to be higher.

To reduce fuel consumption and improve air quality pollution control and other relevant agencies in Nigeria should ensure that gasoline powered motor vehicles plying Nigerian roads are equipped with evaporative control equipment.

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