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Evaluation of Diurnal Emissions from Gasoline Powered Vehicles Within Benin, Nigeria

O. Obodeh, S.O. Igbudu, B.E. Omagbeme and O. Osakwe
Department of Mechanical Engineering, Ambrose Alli University,
P.M.B. 14, Ekpoma, Edo State, Nigeria

Abstract: A compressed time, one-hour test procedure was used to measure daily diurnal emissions from gasoline powered vehicles driven in a typical Nigerian urban city. The test showed that carburettor equipped vehicles on Nigerian roads emit about 19 times more fuel than that amount allowed by international standards during the standard diurnal test. They emit about 1.8 times more than that emitted by their counterparts in South Africa. The fuel injected vehicles emit 10.2 times more than that required by international standards and about 45 times more that that emitted by their counterparts equipped with pollution control devices. When compared with their counterparts in South Africa, they emit about 1.3 times more. Comparison of carburettor equipped vehicle and fuel injected one, showed that the former emits about 1.9 times more than the latter. The test also revealed that injected vehicles equipped with evaporative control equipment reduce fuel consumption and improve air quality.

Key words: Diurnal emissions, gasoline powered vehicles, Nigerian urban cities

INTRODUCTION

Vehicles emit approximately 21% of air toxics, including Volatile Organic Compounds (VOCs) (Rubin *et al*., 2006; Touaty and Bonsang, 2000; Guo *et al*., 2006). VOCs along with oxides of nitrogen are the major precursors of Ozone (O_3). Since O_3 in many areas is VOC -limited (Marr *et al*., 2000; Batterman *et al*., 2005), additional VOC controls have been imposed to help attain O_3 standard (Godwin and Ross, 1996).

VOC emissions from vehicles include refuelling losses, starting emissions, evaporative losses and tailpipe emissions. All new vehicles must meet certification standard for these emissions. However, in Nigeria, older vehicles dominate the fleet, most of which have no catalytic converter or any other form of emission control devices (Falayi *et al*., 2006; Igbafe and Ogbe, 2005). Evaporative emissions are further classified into running losses, occurring when the vehicle is driven due to fuel system losses and fuel vapour break-through of the onboard carbon canister; hot soak emissions, which occur immediately after a warmed-up vehicle is parked and turned off due to high under-hood temperatures and diurnal emissions, resulting from parked vehicles experiencing daily temperature changes that expand vapour in the fuel tank. Evaporative emissions result from canister breakthrough, permeation through hoses, joints and plastic fuel tanks, engine breathing losses fuel cap leakage and fuel system leaks (Batterman *et al*., 2004).

VOCs from tailpipe emissions have been tightly controlled to 1 or 2% of their pre-controlled levels (Marr *et al*., 2000). Evaporative emissions contribution to ambient VOCs has become significant as the tailpipe emissions have been reduced. Concerted efforts were made during the 1990s in reducing evaporative emissions (Guo *et al*., 2006; Marr *et al*., 2000). The maximum allowed vapour pressure (measured at 38°C) of gasoline was reduced from 62 kPa prior to 1992, to 54 kPa for 1992-1995 and to 48 kPa from 1996 onward (Batterman *et al*., 2005). The fuel specifications in Nigeria have not followed this trend (NNPC, 2006). This factor implies that the level of VOC emission from vehicles plying Nigerian roads is very high. Increasing stringent emission standards has led to installation of more robust and durable tailpipe and evaporative emission control equipment on new vehicles sold from 2000 onward (Batterman *et al*., 2005; Godwin and Ross, 1996).

The objective of this study was to quantify the diurnal emission rate for current in-use gasoline powered vehicles in Nigeria and identify the highest emitter.

MATERIALS AND METHODS

The vehicles tested were well tuned to manufacturer's specifications. Tests were performed with commercial Premium Motor Spirit (PMS) purchased from a major oil marketer (Texaco Filling Station, Akpakpava road, Benin). The specifications of the vehicles and fuel

Corresponding Author: O. Obodeh, Department of Mechanical Engineering, Ambrose Alli University, P.M.B. 14, Ekpoma, Edo State, Nigeria

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 4600rpm
Maximum torque	144Nm at 3000rpm
Maximum speed	5000rpm

Table 2: Fuel specifications

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

Source: NNPC (2006)

used for the tests are as shown in Table 1 and 2. The tests were of two parts: Road test and laboratory test. The results of the road test for our earlier work (Obedeh *et al.*, 2007) were used in this research.

The laboratory tests were performed with three vehicles. They were classified as vehicle X (carburettor equipped vehicle), vehicle Y (fuel injected vehicle) and vehicle Z (fuel injected vehicle with evaporative control systems). The vehicles brand is Nissan 2.0 SLX blue bird car and they were equipped with the same apparatus as in the vehicle used in our previous work (Obodeh *et al.*, 2007). Vehicle Z, equipped with fuel evaporative control systems, was tested with the aim of determining the efficiency of the control equipment. Vehicles X and Y were not equipped with evaporative emission control systems, hence are representative of vehicles on Nigerian roads.

Before the commencement of the test, the fuel tank was drained and filled with fresh test fuel. The chamber door was opened and the purge fan turned on. The vehicles were placed in the chamber. This allows the fuel temperature to assume its natural relationship with the ambient temperature prior to the heating. The chamber temperature was induced to 18°C with the aid of air conditioner. The electrical heater was then switch on, while the purge fan was left on. As soon as the fuel temperature reached 20°C the purge fan was switched off, the mixing fan was switched on and the chamber door closed. The diurnal test starts by heating up the fuel from 22-47°C at constant heating rate within a period of 1 h. Flame Ionization Detector (FID) gas analyzer was used to record HC concentration in the enclosure.

RESULTS AND DISCUSSION

The road tests under actual driving conditions were performed to find out the relationship between fuel temperature and ambient temperature. The data from road tests were used to construct the temperature profile for simulation in the test. A compressed time, 1 h test procedure was adopted for the laboratory test. The compressed time test was used to measure the daily emissions. The concept of the compressed time procedure dated back to the era of uncontrolled fuel tank emissions, where the daily ambient heating resulted in vapour being driven from the tank and directly into the atmosphere (Haskew and Liberty, 1999). The total emissions from the tank could be reliably created in a compressed time one-hour period, instead of a approximately 10 h as occurs in nature. Figure 1 shows graphically the daily heating cycle of a typical Nigerian gasoline in a half full tank during a 22-47°C diurnal experience. The heating portion, where each temperature is higher than the previous hour, is 9 h long. The cooling cycle is 15 h long.

Fuel vapour temperature responses during the heating cycle are shown in Fig. 2. This illustrates that the vapour temperature rise continues for a longer period than the ambient temperature swing. The vapour temperatures do not follow the ambient temperature directly, but lag the ambient temperature changes and under the test conditions, have slightly lower temperature swings.

Comparison of the diurnal emissions estimates for the three vehicles is shown in Fig. 3. Two vehicles (X and Y) showed increased fuel temperature. This is as a result of an exponential rise in gasoline vapour pressure and greater vapour flows out of the fuel tank. Permeation is one of the identified sources of diurnal emissions and is highly sensitive to temperature. However, permeation rates decline with time, even at constant temperature. The forthgoing statement explains the shape of Fig. 3 towards the end of the test period.

Vehicle Y had a fuel injection system while vehicle X, which had a fuel carburetion system, produced higher emissions. Vehicle X emitted about 38g of fuel and vehicle Y about 20.4 g. The apparent deterioration is 1.9 times for

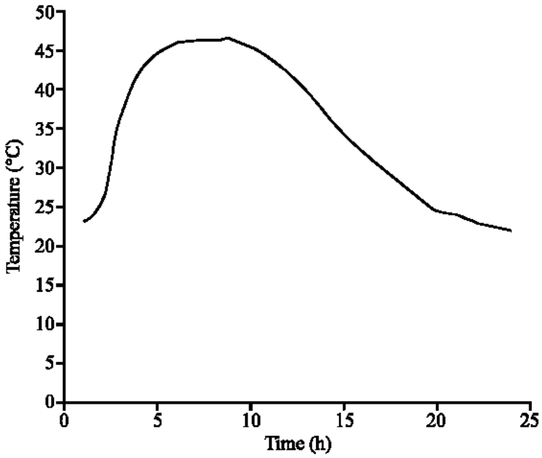

Fig. 1: Twenty four hour diurnal temperature cycle 22-47°C

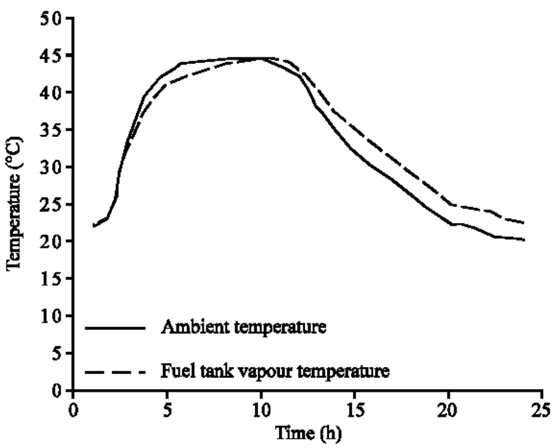

Fig. 2: Twenty four hour fuel vapour diurnal temperature cycle 22-47°C

the carburettor equipped vehicle. Vehicle Z, equipped with fuel injection system and carbon canister, emitted about 0.45 g of fuel during the test. This is about 2.4% of the amount emitted by vehicle Y. The US Environmental Protection Agency (US EPA) regulations allow a maximum of 2 g of evaporative emissions during a standard diurnal test (Reuter *et al*., 1994).

The test showed that carburettor equipped vehicles on Nigerian roads emit about 19 times more fuel than that amount allowed by international standards during the standard diurnal test (Reuter *et al*., 1994). This means that they emit about 1.8 times more than that emitted by their counterparts in South Africa (Van *et al*., 2004). The fuel injected vehicles emit 10.2 times more than that required by international standards and about 45 times more than that emitted by the counterparts equipped with pollution control devices. When compared with their counterparts

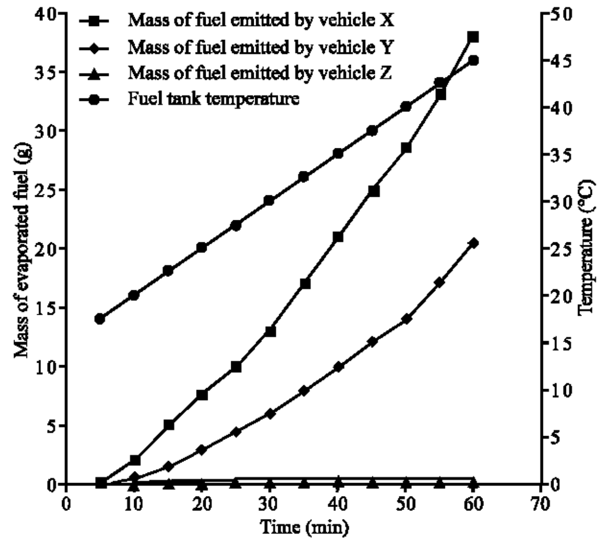

Fig. 3: Variation of mass of evaporated fuel and fuel temperature with time

in South Africa, they emit about 1.3 times more (Van *et al*., 2004). Comparison of carburettor equipped vehicle and fuel injected one, showed that the former emits about 1.9 times more than the latter. The forthgoing analysis showed that injected vehicles equipped with evaporative control equipment reduce fuel consumption and improve air quality.

CONCLUSION

Diurnal emissions were estimated by measuring the emissions from the tested vehicles during a compressed time (one-hour) tests where the liquid fuel in the fuel tank was externally heated from 22-47°C. The 1 h simulation produced the appropriate vapour generation.

Neither vehicle X nor vehicle Y meets international emission standards even though both had been tuned as close to the manufacturer's specification as possible and certain parts replaced as necessary. The resultant emissions for both vehicles were 38 and 20.4 g of fuel, respectively. The vehicle fitted with evaporative control system was well within the international standards. 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, gasoline powered vehicles should be equipped with evaporative control equipment. However, evaporative emissions systems that are used on carburettor equipped vehicles have a significant handicap. Each time the engine is shut off, engine heat is transferred to the carburettor and bowl vapours are created. The heavier HC emissions contained in the bowl are harder to purge and result in reduced canister capacity. Fuel injection system does not have a bowl and thus eliminates a major source of canister loading.

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