EFFECT OF FUEL ADULTERATION ON ENGINE CRANKCASE DILUTION

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Abstract: *Excessive crankcase dilution of lubricating oil in petrol driven vehicles across Dhaka city have been reported recently. A field survey revealed that, gradual increase in the volume of lubricating oil was experienced irrespective of vehicle model, vehicle age and brand of lubricating oil used. The problem was found to originate from adulteration of fuel, probably with the intention of gaining undue financial benefits, stimulated by the high fuel price. Samples were collected from fuel stations across Dhaka and compared with base fuels collected from Eastern Refinery. Investigation of fuel properties like – density, distillation curve and visual colour indicated that, condensates from gas fields in around 15% by volume is being mixed with petrol for adulteration. Heavier components of the condensate is causing high rate of crankcase dilution of the lubricating oil in engines. Such dilution is reducing viscosity of the lubricating oil significantly, which may lead to high rate of engine wear and poor performance.*

Key Words: *Crankcase Dilution, Fuel Adulteration, Distillation Curve, Fuel Density, Fuel Viscosity.*

INTRODUCTION

Crankcase dilution is a phenomenon experienced in engines where accumulation of unburned gasoline in the crankcase takes place. An excessively rich fuel mixture or poor combustion allows a certain amount of gasoline to pass down between the pistons and cylinder walls and dilute the engine oil [1]. Some of the combustion gases may pass across the piston ring reaching the crankcase, termed as "Blow-by". When a mixture of air and fuel enters the cylinder of an engine, it is possible for condensation of fuel to occur on the cooler parts of the cylinders. The condensate may wash the lubricating oil from the cylinder walls, travel past the piston rings and collect in the oil pan, thus diluting the lubricating oil, increasing volume and decreasing its viscosity. As a result this can lead to increased wear of engine components. Since the less volatile components of the fuel will have the greatest tendency to condense the degree of crankcase-oil dilution is directly related to the end volatility temperatures of the mixture. Crankcase dilution to a limited extent is allowed for an engine long in service. Typically this is less than 5% of the lubricating oil volume for an internal combustion engine before oil replacement is needed [2,3]. On the other hand, some consumption of lubricating oil is common during engine blow-by, but its amount is very small as long as the engine components like piston rings or valve guides do not wear out. The rate of oil consumption depends upon the quality and viscosity of the oil in the crankcase, the engine speed, the temperature and the amount of dilution and oxidization in the crankcase. Typically, lubricating oil consumption of about 1 liter per thousand kilometer vehicle run, requires a piston ring replacements in automotive engines [2].

In the recent years an unusual phenomenon have been widely experienced regarding the lubricating oil in spark ignition automotive engines, used in vehicles around Dhaka city, the capital of Bangladesh. After use for some period, an unusually large increase of volume of the lubricating oil have been experienced. The crankcase oil becomes diluted due to the mixing of less viscous gasoline components, its volume increases and viscosity decreases. This would increase component wear and hamper engine performance. The objective of this technical investigation was to – assess the extent of the problem, quantify the level of volume increase and to identify the cause of the phenomenon.

EXTENET OF THE PROBLEM

First in order to verify the claim and to assess the extent of the problem a field survey was carried out around different parts of Dhaka city. A specifically designed questioner was used for collecting information regarding the problem. The survey questioner included a number of queries regarding - the extent of the problem experienced, type and age of the vehicle engine, type of fuel used, type of fuel system and type of lubricating oil used. Altogether 73 sets of information was collected from the major stakeholders – which included 41 vehicle drivers, 18 auto repair mechanics, 5 lubricating oil vendors and 9 car diagnostic centers.

A number of findings were revealed from the analysis of information collected from the field survey:

- More than 80% of the drivers and almost all the mechanics had experience of the problem and most of them have noticed this in the last couple of years.

- The problem was almost entirely present in petrol driven vehicles only and rarely noticed by drivers using diesel fuel and CNG fuel only.
- The problem was present across a range of engine models produced by a number of different auto manufacturers.
- The problem was experienced both in new and used vehicles.
- Among the petrol driven engines it was present in both types – using carburetor and using electronic fuel injection systems.
- The problem was present in vehicles using a number of different brands of lubricating oils, which are commonly used in Bangladesh.

At the time of the survey the price of fuels per liter was – Octane TK. 67, Petrol TK. 65, Diesel TK. 40 (1 US$ = 70TK., Taka, Bangladesh currency). Presently these are - Octane TK. 77, Petrol TK. 74 and Diesel TK. 44. In order to make a quantitative assessment two petrol driven vehicles were monitored in the transport pool of the university (BUET). The lubricating oil capacities of their 1500 cc. engines were around 3.5 liters. After driving about 1400 km the lubricating oil volume increased by about half a liter in both of the vehicles, which is about 15% increase in volume. The viscosity of the lubricating oil (SAE 20W50) measured at room temperature (30°C) using a Saybolt's Universal Viscosimeter, was found to reduced significantly. The contaminated lubricating oil collected from the vehicles monitored showed a drop of viscosity from about 170 cSt (centistokes) at fresh condition, to less than 90 cSt, after 1400 km of vehicle run.

PROBABLE REASONS OF EXCESSIVE CRANKCASE DILUTION

Crankcase dilution to a limited extend, is typically experienced in any internal combustion engine. Low volatility components present in the fuel often are slow to vaporize after injection/intake into the cylinder. Some of these low volatility compounds and water formed during combustion can be condensed or deposited on the relatively cooler parts of the combustion chamber and cylinder wall. They can be absorbed or mixed with lubricating oil film and swept down into the crankcase by the normal scraping action of the piston's oil control rings. Some may be transferred to the crankcase with blow-by gases as shown in figure-1. The key feature of crankcase dilution is whether the amount is significant enough to cause any deterioration in the lubricant's performance. With most of the standard lubricating oils normal crankcase dilution creates only very small change in lubricant volume within their recommended replacement period [1,2].

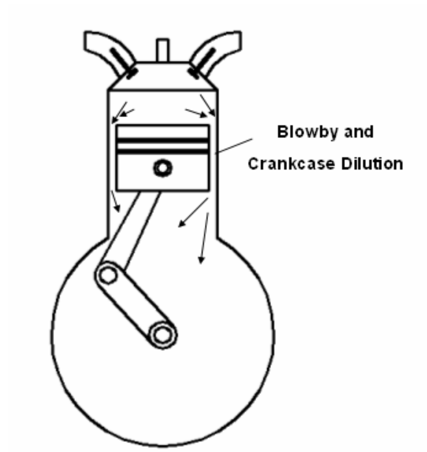

Figure 1. Crankcase dilution inside the engine

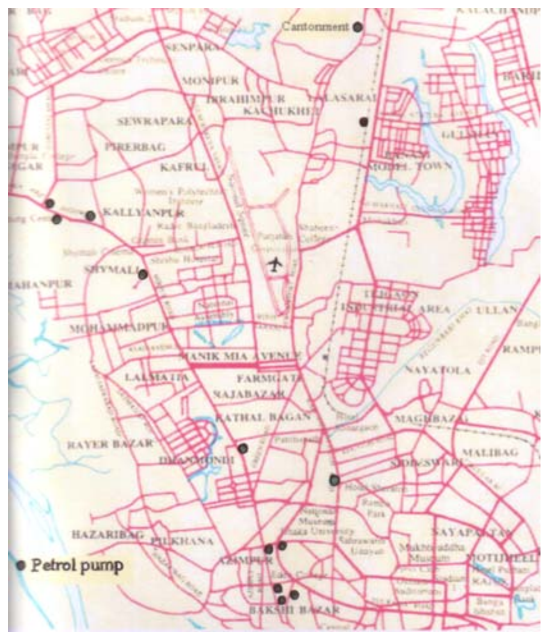

Figure 2. Location of fuel collections across Dhaka

The lubricating oil, the fuel and the engine hardware are the three components that may play a vital role in such increase in crankcase dilution. During the survey it was revealed that fuel dispensers, lubricating oil vendors and vehicle dealers each claimed to be confident regarding their products and pointed to others for the situation. There could be three main reasons for the unusual increase of volume of lubricating oil used in a petrol engine :

- The lubricating oil may be going through some undesired progressive chemical changes causing increase of its volume.
- Fuel may have been leaking or mixing in the lubrication system due to some mechanical malfunction or fault in the engine system.

- The proportion of low volatile components of the fuel may have been increased by contamination or adulteration causing excessive crankcase dilution.

The survey revealed that the problem of large increase of lubricating oil volume had been experienced in engines using different brands of lubricating oils. So it is very unlikely that lubricating oils of a number of different brands would experience similar chemical changes, eliminating the first reason. The survey also revealed that the problem was experienced in engine models made by different manufacturers and it existed both in new and used engines. It was experienced by engines having a carburetor as well as those with electronic fuel injection. Since engines of different age, model and fuel technology all are experiencing the problem, it is very unlikely that it is sourced from the engine hardware, eliminating the second reason. Moreover the problem was not reported by drivers using diesel or only compressed natural gas (CNG) as fuel. Since all engines experiencing the problem are using the petrol or octane fuel available in Dhaka city, the third reason seems to be most likely to be responsible for large increase in volume of the lubricating oil used. Hence the focus of the investigation was concentrated on possible fuel adulterations. Although less common in the developed world, the effect of fuel adulteration on engine performance have been studied experimentally [4,5] and statistically [6] resulting poor engine exhaust emission [7,8] in a number of places.

PHYSICAL QUALITY OF FUEL AVAILABLE IN DHAKA

Some properties of petrol and octane fuel available in Dhaka were investigated to assess the degree of contamination or adulteration of fuel, if any. The physical appearance and colour of the fuel was visually observed, the density was measured and distillation characteristic of the fuel samples were studied.

Fuel samples were collected from 14 different fuel stations within a span of several days. Figure 2 shows the distribution of these petrol stations across Dhaka city. Samples of Petrol (Octane Number, ON=88) and Octane (ON=95) fuels were also collected directly from Eastern Refinery Limited (ER) Chittagong, the only oil refinery of Bangladesh and this was considered as the base fuel (reference) for comparing the properties of fuel collected from the petrol pumps of Dhaka city. In addition fuel depots at Naryangang were visited and the market-price of several potential contaminants was studied. The prices per liter during the survey were reported to be – Petrol TK.65, Octane TK.67, Kerosene TK.45, Diesel TK.40, Condensate from gas-fields TK.26, Thinner (spirit) used in painting TK. 80.

Physical Appearance of Fuel Samples

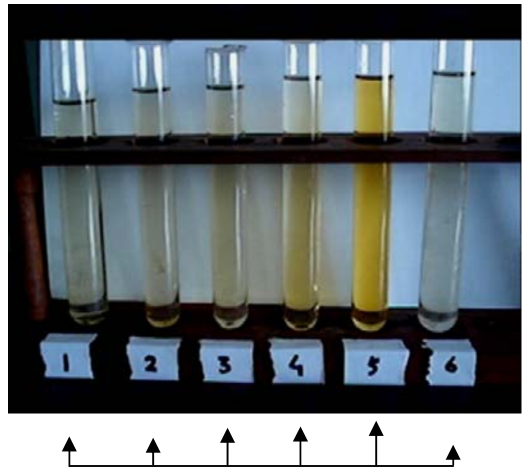

Figure 3(a). Colour comparison of petrol samples, arrow sizes indicate colour darkness.

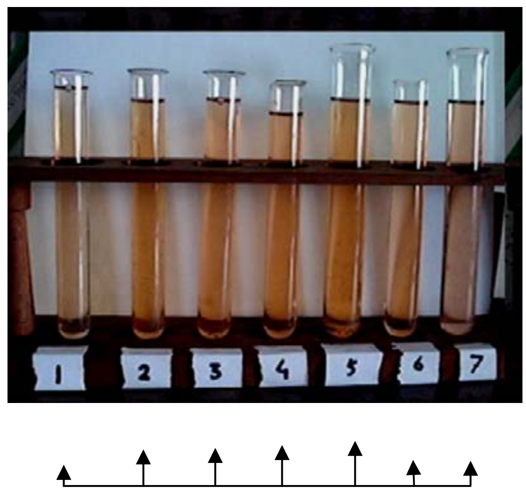

Figure 3(b). Colour comparison of octane samples, arrow sizes indicate colour darkness.

The variation in physical appearance (colour) was readily visible among samples collected from different petrol pumps. Apparently this is more prominent in petrol sample compared to octane samples collected. Figure 3(a) and 3(b) exhibits the colour differences, indicating fuel adulteration. The arrow sizes beneath indicates colour darkness of samples. In Bangladesh the government regulation requires a colouring scheme for fuels - petrol is made yellow, octane is orange, diesel is orange-brown and kerosene is blue.

Density of Fuel Samples

The densities of all fuel samples were measured at 20°C. The values were compared to the density of sample of base fuels collected from Eastern Refinery (ER). The density of ER petrol was measured to be about 722 kg/m^3 (g/cc) and 744 kg/m^3 for ER Octane. The petrol samples collected from Dhaka ranged from 726.2 to 747.1 kg/m^3. However the Octane samples ranged from 741.4 to 756.5 kg/m^3. The sample identification numbers as show in figure 4 are indicative only. Densities of few other fuels were also measured. Figure 5 shows the comparative densities of different fuels. The consistent higher densities of petrol indicated addition of heavier compounds with the fuel.

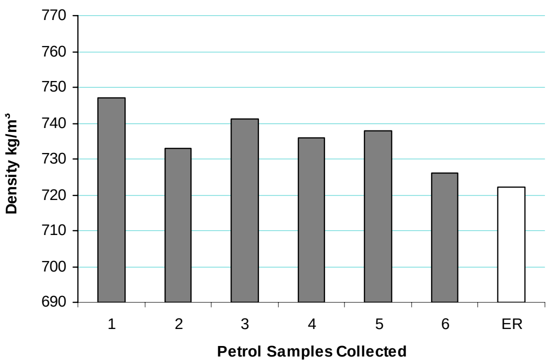

Figure 4(a). Comparison of densities of Petrol samples.

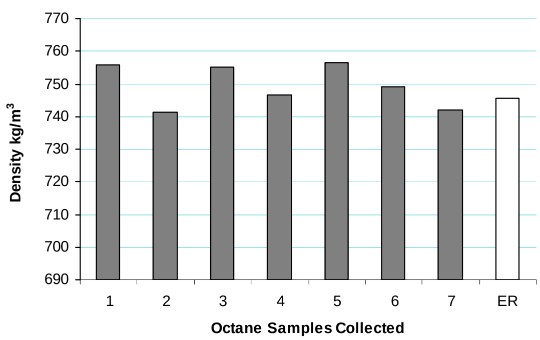

Figure 4(b). Comparison of densities of Octane samples

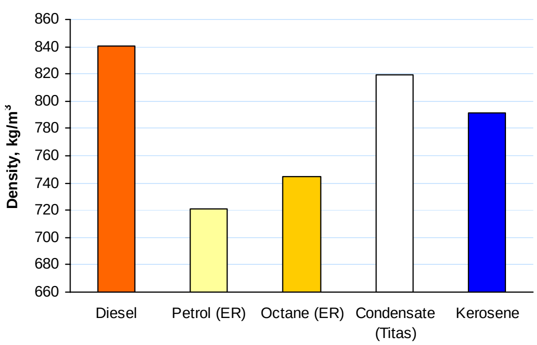

Figure 5. Comparison of densities measured of different types of colour coded fuels.

Distillation Curve of Fuel Samples

Distillation is the process of heating a liquid until it boils, capturing and cooling the resultant hot vapors, and collecting the condensed vapors. Distillation is a powerful tool, boiling point of a compound can be determined by distillation as it is a well-defined criteria. Thus it is one of the important physical properties of a compound by which it can be identified. Petrol is a complex mixture of large number of components which boil over a range of temperatures as shown in table-1[9]. The distillation properties of petrol are determined using a standard laboratory test like ASTM-D86. The results can then be plotted to produce a distillation curve as in the typical example shown in figure 6. The results can also be expressed as the percentage of the fuel volume evaporated at a specific temperature. The key characteristics of distillation properties of petrol are described by the percentage of fuel volume evaporated at 70, 100, 150ºC, and its final boiling point (FBP).

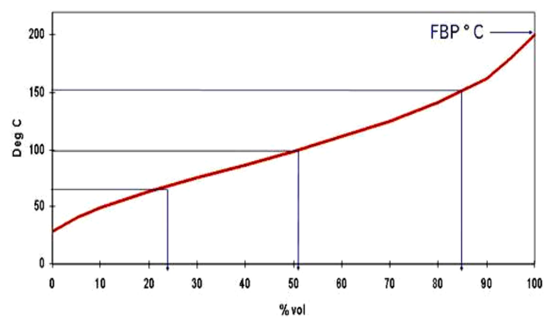

Figure 6. Typical distillation curve for gasoline.

Figure 7. Distillation-Unit used, DU-4 Professional

Table-1: Boiling range of some typical refinery products.

Product	°C	°F
Motor Gasoline	30 – 200	80 – 400
Kerosene	140 - 260	280 – 500
Diesel Fuel (#2)	180 - 340	350 – 650
Lube Oils	340 - 540	650 - 1000

A manually operated D86-78 Distillation Unit (DU-4), with condenser tube to the right (figure -7) composed of an electric heating assembly (with a maximum test temperature up to 400°C) and a cooling bath. The DU-4 consists of a stainless steel cabinet with an inspection window, flask support (adjustable in height) equipped with ceramic heating plate carrying 4 encased and gold plated heater rods. Lower part of the heating assembly had an electronic heater module using which heating energy could be adjusted up to 800 watts. The DU-4 is ideal for the examination of motor gasoline, aviation gasoline, aviation turbine fuel, special boiling point spirits, naphtha, white spirit, kerosene, gas oil, distillate fuel oil and similar petroleum products.

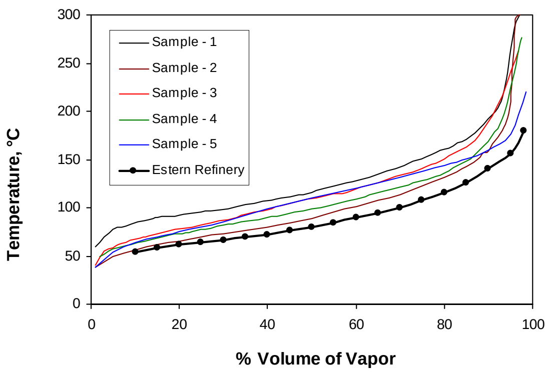

Figure 8(a). Distillation curve of Petrol samples.

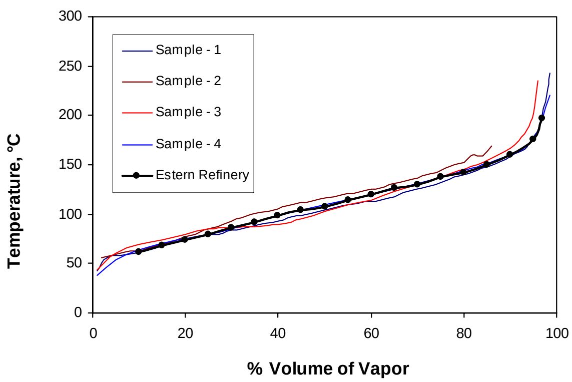

Figure 8(b). Distillation curve of Octane samples.

Figure 8(a) shows the comparison of distillation curves of several petrol samples collected with respect to the base fuel (ER). In all of the samples the distillation curves were recorded to be at higher temperatures (increase of 25-35°C) compared to the base fuel, clearly indicating the presence of components of lower volatility. As shown in figure 8(b) the rise is also present in some of the octane samples but as a whole the trend could not be generalized. This indicates greater degree of adulteration of petrol probably is happening compared to octane, this may be related to the fact that far more commercial vehicles are run on petrol.

The high price of gasoline may have triggered the increase in fuel adulteration. Analysis of the market price of a number of available compounds indicated the high possibility of condensate from gas fields, which are available at a much lower cost may have been used in fuel adulteration. Figure 9(a) shows the distillation curve of base petrol and base octane and the relative position of measured curves of – Natural Gas Condensate (Titas), Kerosene and Diesel. Artificial mixtures of gas-field condensate with base fuel were made at various proportions (5-20% v/v) and their densities and distillation characteristics were investigated. Figure 9(b) shows the comparison of the distillation curves of base petrol, base octane (ER), Titas condensate and an artificial mixture of 15% condensate with base petrol. As shown in figure 9(b) the distillation curve of the mixture lies very close to the average trend of distillation curves measured from collected petrol samples from different places of Dhaka city. The density of condensate was 819 kg/m^3 and the 15% mixture was 736 kg/m^3, very similar to the average (736.7 kg/m^3) of the density range of petrol samples collected.

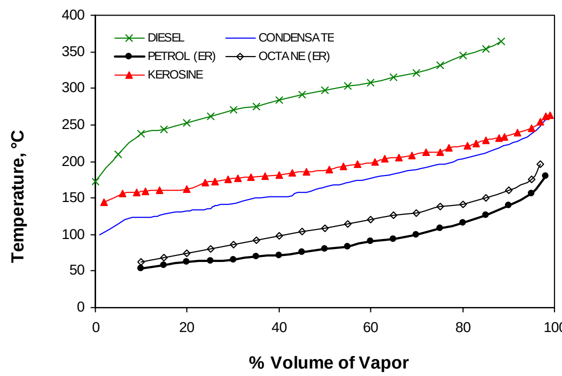

Figure 9(a). Distillation curve of different fuels samples.

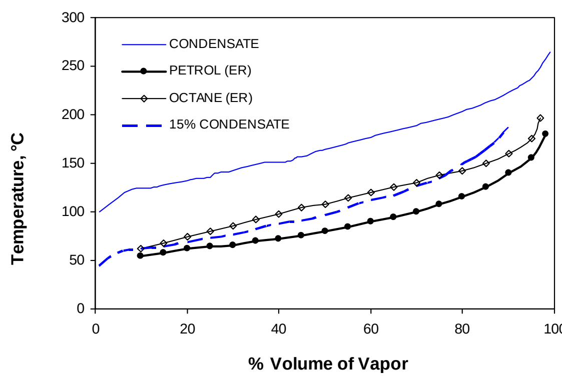

Figure 9(b). Distillation curve of 15% Condensate by volume with Petrol.

DISCUSSION OF RESULTS

Study of visual colour strongly indicated possible adulteration of petrol fuel samples. The density measurements in most cases were higher than the base fuels for petrol, but densities varied through a range for octane. This indicated the presence of components of higher densities being mixed and the fact that the degree of adulteration probably differs from pump station to pump stations in Dhaka. The presence of heavier hydrocarbons in the fuel shifted the distillation characteristics, especially the tail-end volatility of the fuel towards higher temperature.

The rise of the distillation curves are very conclusive of mixing of fluids of lower volatility in case of petrol samples. Addition of less volatile liquids shifts the distillation curve higher in temperature scale, causing some of these components to remain liquid inside the combustion chamber during combustion, which gradually dilutes the lubricating oil, causing this high rate of crankcase dilution. In case of octane samples there is indication of adulteration in some samples, but not sufficient to draw any conclusion regarding a generalized trend. It could be mentioned here that most of commercial vehicles are run on petrol, rather than Octane. It is very difficult to positively identify which fluid or fluids have been used for adulteration of petrol. Hence the possibility of using a number of prospective liquids for fuel adulteration was anaylsed.

Visually petrol is available coloured in yellow, diesel is orange-brown, kerosene is blue. So mixing one in other would cause a definite trend of color change. Diesel is close in colour but it has much higher distillation temperatures compared to petrol. Adulteration using Diesel would generally result in a higher effect in distillation curve than that experienced from the samples. Mixing diesel in small proportion would not give the lucrative economic benefit. Kerosene is also relatively costly and it would require additional de-colouration to achieve visual similarity. Thinner (spirit) is much more expensive and not easily available in large bulks. However since condensate is not recognized as an end-user fuel, is not artificially colour coded and is almost colourless. This makes it easer to mix with petrol or octane. The absence of coding colour, relatively lower cost and bulk availability makes it the strongest candidate for petrol adulteration.

Looking at the potential fluids - that can be mixed with petrol, the level of rise in the distillation curve experienced and very importantly their relative cost, condensates collected from gas fields or pipelines some how available in the market seems to be a very likely candidate. To verify such a possibility a range of artificial mixtures (5-20% of condensate by volume) of natural gas field condensates and base petrol were tested. Out of these the distillation curve of the mixture containing 15% condensate by volume with base petrol showed close similarity with the mean characteristics of distillation curves of collected samples.

The density of the mixture of 15% condensate by volume with base petrol was found to be 736 kg/m^3, very similar to the collected average density (736.7 kg/m^3) of petrol samples. As shown in figure 8(a) and 9(b) the distillation curve of the mixture lies in a region centrally to distillation curves measured from collected petrol samples from different places of Dhaka city. The similar density, distillation characteristics and financial factor very strongly indicates to adulteration of petrol using gas-field distillates, which have been supported by some information gathered during the field-survey. However detailed chemical or Photo-thermal analysis [5] of the fuel samples and contaminated lubricant could be more confirmatory but those were beyond the scope of this investigation.

The physical properties of the mixture indicated very high possibility of condensates being mixed in the order of 15-20% by volume for petrol fuel adulteration. This could be giving some financial benefit (in the order of Taka 6 per liter of petrol) to certain quarters, but as a result causing excessive crankcase dilution and deterioration of lubrication performance and hence compromising the engine life. The contaminated lubricating oil collected from the vehicles monitored in BUET measured at room temperature showed a drop of viscosity from about 170 cSt at fresh condition, to less than 90 cSt, over 1400 km of vehicle run, which is really concerning if it remains unattended by vehicle driver.

CONCLUSIONS

The problem of excessive crankcase dilution is widely present in the petrol driven vehicles across Dhaka city, irrespective of - vehicle make, model or age and brand of lubricating oil used. This was reflected in a field survey. The source of the problem lies in adulteration of fuel used, associated with the intention of acquiring undue financial benefits, stimulated by the high fuel price. Among the possible liquids mixed with petrol, condensates collected from natural gas-fields and transmission pipelines is the most likely candidate. Fuel samples were collected across Dhaka City and compared with base fuels collected from Eastern refinery. Investigation of some fuel properties like – visual colour, density and distillation curves indicated that, condensates around 15% by volume are being mixed with petrol for adulteration. Heavier components of the condensate is causing high rate of crankcase dilution of the lubricating oil in engines run on petrol. Such dilution is increasing volume and reducing viscosity of the lubricating oil significantly, which may lead to high rate of engine wear and poor performance.

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