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Fuel Adulteration, Problem and Mitigation Strategies: A Review

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Abstract

Comparatively Lower priced adulterants are commonly added to gasoline and diesel in India and other parts of the world also. Out of these lower priced, sub-standard, inferior adulterants some contribute towards the increase in the pollutants emitted from the internal combustion engines though all of them reduce the tax revenue of any country which directly affects the development of the whole mankind. This paper narrates the harmful outcomes of the different types of fuel adulterations on quality of air and discusses the different methods of adulteration detection and testing.

1. Introduction

Gasoline is a mixture of more than four hundred volatile and flammable liquid hydrocarbons ranging from 4 to 12 carbon atoms per molecule [1-2]. The liquid phase does not burn, only the vapors do. Gasoline has a flash point of - 7 °C and an auto ignition temperature of 307 °C [3]. It is a mixture of paraffinic, naphthenic, olefinic, and aromatic hydrocarbons. In addition to hydrocarbons, gasoline also contains small amounts of sulfur, atmospheric oxygen, and traces of nitrogen. This petroleum fraction distils within the temperature range of 30– 220 °C [4-5]. Gasoline is produced by blending different fuel streams coming from various production processes. Atmospheric straight run cuts together with products from catalytic reforming and cracking, isomerization etc. units are the most commonly used feeds for the production of the final gasoline. These fractions are referred to as gasoline components. The blend recipes are determined such that the properties' specifications of the final gasoline are met[6].Gasoline is blended primarily to achieve physical specifications for boiling range, vapor pressure, oxidation stability, and octane with the goal being desirable engine performance, namely cold/hot starts, acceleration, knock, resistance to vapor lock, etc [7-8].A number of analytical techniques are available to detect gasoline adulteration as flash point, refractive index and density but in this paper we are interested in fractional distillation.

Introduction of any foreign substance into gasoline or High Speed Diesel (HSD); illegally so that gasoline does not conform to BIS specifications IS-2796 and HSD does not conform to IS-1460 can be defined as adulteration in Indian context. The two common reasons for this adulteration are price disparity and availability of solvents with easy miscibility and similar chemical characteristics. The easiest methodology to reduce the per litre cost of the fuel being used, adopted by the people is to add adulterants to it. The use of such adulterants can be as high as 80% - 90% which is not only affecting the quality of the conventional automobile fuels but also contributing towards exponential enhancement of existing emission constituents. Fuel adulteration is originally an unintended consequence of reducing the difference in prevailing cost of different automobile fuels and an attempt to control fuel prices, in the name of fairness. Air pollution is the ultimate result.

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1.1 Types of Adulteration

Specific types of adulteration may be broadly classified as follows:

- Blending relatively small amounts of distillate fuels like specification requirements - than properly maintained diesel or kerosene into automotive gasoline.
- Blending variable amounts (as much as 30 percent) of gasoline boiling range hydrocarbons such as industrial solvents into automotive gasoline.
- Blending small amounts of spent waste industrial solvents such as used lubricants -which would be costly to dispose of in an environmentally approved manner - into gasoline and diesel.
- Blending kerosene into diesel, often as muchas20-30 percent.
- Blending small amounts of heavier fuel oils into diesel fuels.

1.2 Factors Promoting Fuel Adulteration

The factors which generally promote the practice of adulteration are as given below:

a. Difference in prevailing cost of existing automobile fuels which may be due to difference in the basic price and / or difference in govt. levies such as taxes, subsidy etc.
b. Easy availability of adulterants in the market
c. Less awareness among consumers
d. Uncontrolled regulations in the production, supply and marketing chain for intermediates and byproducts of refineries
e. Non-popularity of easy and reliable methods for on spot checking of quality of the conventional automobile fuels.

1.3 Fuel Quality

Except fuel quality, there are many other factors which cause an increase in the emissions from an automobile exhaust such as old and polluting vehicles, poor inspection & maintenance program, ineffective PUC system, poor traffic management etc. Some essential fuel quality requirements for Gasoline (Table 1) Euro and (Table 2) BS standards and for Diesel Euro & BS standards in (Table 3&4) respectively are tabulated below:

Table: 1. Gasoline Quality Requirements (Euro Norms) [9]

Property	Euro-I (1992)	Euro-II (1996)	Euro-III (2000)	Euro-IV (2005)
RON	95	95	95	95
MON	85	85	85	85
S% Wt., Max,	0.05	0.05	0.015	0.05
Bz., %Vol. Max,	5.0	5.0	1.0+	1.0
Arom., % Vol., Max	-	-	42	35
Olef., % Vol., Max.	-	-	18	-
Lead, gm/ Litre	0.013	0.013	0.005	0.005

Table: 2. Gasoline Quality Requirements (BS Norms) [9]

Parameter	BS-I (2000 E. Country)	BS-II (2005 E. Country)	BS-III (2010 E. Country)	BS-IV (2010 sel. cities)
Sulphar Content (PPM)	1000	500	150	50
RON (Regular)	88	88	91	91
Lead Content (g/l)	0.013	0.013	0.005	0.005

Table 3: Diesel Quality Requirements (Euro Norms) [9]

Property	Euro-I (1992)	Euro-II (1996)	Euro-III (2000)	Euro-IV (2005)
Cetane Number	49	49	51	54
S% Wt., Max	0.20	0.05	0.035	0.005
T 95, Deg. C. Max	370	370	360	360
PAHs., %Wt., Max	-	-	11	11

Table: 4. Diesel Quality Requirements (BS Norms) [9]

Parameter	BS-I (2000 E. Country)	BS-II (2005 E. Country)	BS-III (2010 E. Country)	BS-IV (2010 * cities)
Sulphar Content (PPM)	2500	500	350	50
Cetane Number	48	48	51	51

2 Methods for Estimation of Fuel Adulteration

The American Society for Testing and Materials International (ASTM International) has developed and documented the test methods for most of the widely used materials including petroleum products. Some of these tests involve determination of physical and chemical properties while others provide a measure of suitability of the fuel for use in automobiles from the point of engine performance / air pollution generated. Though no test is specifically designed to measure the adulteration of petrol by mixing diesel or diesel by mixing kerosene, some tests namely Density test, Evaporation test, Distillation test, Chemical Marker test, Gas Chromatography may be used to determine the adulteration of fuel also. [10]

2.1 Density Test (ASTM D4052)

Hydrometers and digital densitometers are used to measure the density of the fuel sample. The reported densities of gasoline, diesel and kerosene at 15ºC are in the ranges 0.74-0.75 kg/l, 0.835-0.855 kg/l and 0.79-0.80 kg/l respectively. The adulteration causes a change in the density which can be correlated with the adulteration (Table 5). The method has the advantage that density meter provides very good accuracy but suffers from the disadvantages, such as

(i) Need a controlled environment (for correct operation) which is unlikely to be available in the field at the distribution point and
(ii) The change in density is very small even for high level of adulteration as reported in the literature and reproduced below.

Table: 5. Density & kinematic Viscosity of Diesel Fuel & Adulterant Kerosene at Different Proportions [11]

S. No.	Diesel and Kerosene Proportions (v/v)	Density at 15°C(g/ml)	Kinematic Viscosity at 40°C (Cst)
1	Pure Diesel	0.8456	2.63
2	Prescribed Level	0.82-0.86	2 to 3
3	85:15	0.8400	2.33
4	75:25	0.8390	2.16
5	65:35	0.8321	1.89
6	50:50	0.8304	1.83
7	25:75	0.8234	1.5

However as evident from Table 5**,** the viscosity of the fuel shows a considerably stronger dependence on the % adulteration and therefore should be a preferred parameter to be calibrated against % adulteration.

2.1.1 Evaporation Test (ASTM D3810)

The evaporation techniques are capable of detecting very low concentrations (1-2%) of diesel in gasoline and fairly low concentrations (5%) of kerosene in gasoline.

2.1.2 Distillation Test (ASTM D86)

This technique exploits the difference in the boiling points of different liquids comprising the fuel sample. Accurate distillation data for uncontaminated fuel is essential for comparison and precise results.

2.1.3 Gas Chromatography (GC)

GC is powerful laboratory tool which can be used to detect hydrocarbon based adulterants. However it requires an experienced technician to operate the equipment and interpret the results. It is an effective method for detection of adulterants in gasoline and diesel but would require easily portable, robust and user friendly equipment.

2.2 Adulteration Estimation/Detection using Optical Fiber Sensor

A technique for detection/estimation of adulteration of petrol/ diesel by kerosene using optical fiber sensor has been reported by Roy S. [13]. The technique exploits the change in refractive index and therefore the evanescent absorption of monochromatic light in petrol/diesel when the same is adulterated by mixing kerosene. Optical fiber acts as a wave guide for light if the cladding has a lower refractive index than that of fiber material. When the light is reflected from the interface of the fiber and the cladding (or any other material surrounding the fiber), the field associated with the light wave extends beyond the interface into the surrounding medium. The amplitude of this field decreases exponentially with distance from the interface. If the surrounding material absorbs some part of the light propagating through the fiber, the power received at the other end of the fiber would be less by the amount absorbed by the surrounding medium. This idea has been implemented in the experimental set up shown below. The light source in Figure 1 is a He-Ne laser which is coupled with the optical fiber through a lens. The length of the fiber within the vessel containing the fuel under test is unclad so that the fiber is directly in contact with the absorbing medium that is, the fuel under test. The received power is measured by the power meter.

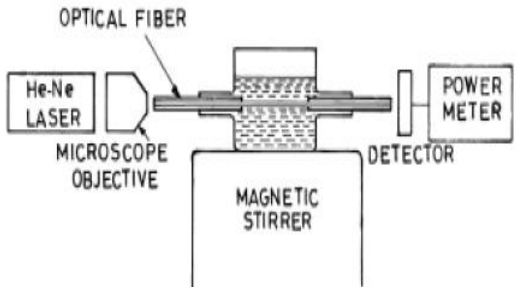

Fig: 1. Optical Fiber Sensor and Associated Experimental Set up [12]

Table: 6. Comparison of Diesel Fuel and Fuel Obtained from Used Lubricants [12]

Sr. No	Properties	Diesel fuel	Diesel Like Fuel
1	Density at 15°C (kg/m3)	820-845	818
2	Viscosity at 40°C (mm2/s)	2-4.5	3.49
3	Flash point (°C)	>55	57
4	Sulfur (ppm)	50	3500
5	Water (mg/kg)	<200	130
6	Lower heating value (kJ/kg) 42.700	42.5	
7	Temperature at 250°C, max. volume (%v/v)	65	20
8	Temperature at 250°C, min. volume (%v/v)	85	90
9	Volume at 95%, max. temperature (°C)	360	360

2.3 Consequences of Fuel Adulteration

Adulteration of conventional automobile fuels, which is a common practice in our country, can lead to economic losses, increased emissions and worsening the performance and parts of engines. Some of the effects of adulteration are as described below:

a. Malfunctioning of the engine, failure of components like Valve bend, Reddish deposits in fuel line and carburetor, Discolorisation of various engine components like bearings, gears, cam shaft, crank shaft and cam chain etc; Premature wear and tear of cylinder, piston & piston rings, Malfunction of spark plug etc. The problem gets further magnified for high performance modern engines.
b. Increased tailpipe emissions of UHC, CO, NOx, PM and can also cause increased emissions of other toxic substances.
c. Adulteration of fuel can cause health problems directly because of increased tailpipe emissions of harmful and sometimes carcinogenic pollutants. It may be noted that all forms of adulteration are not harmful to public health. Some adulterants increase emission of harmful pollutants significantly, whereas others have little or no effect on air quality.
d. Significant loss of tax revenue as various estimates have been made of that the extent of financial loss to the national exchequer as well as the oil companies as a result of diversion towards low value hydrocarbons mixed with petrol and diesel, evasion of sales tax etc.
e. Adversely effects vehicle performance like Starting Problem, Engine Misfiring, Weak Compression/ Low pick-up, Abnormal Engine Noise, Smoky Exhaust, and calls for major engine repairs.
f. Variation in fuel quality and specifications make it difficult for manufacturers to design and tune engine appropriately
g. Going forward, with sophistication in vehicle technology, adulteration will worsen the gains in availability sought to be achieved through technological routes.

3. Indian Initiatives to Control Fuel Adulteration

It is necessary to dispense auto fuels of the right quality to achieve the targeted emissions from vehicles. Therefore, adulteration of auto fuels should be discouraged in all its forms. Off late India has also taken some initiatives to tackle this problem. As per the Ministry of Petroleum &

Natural Gas (MoPNG) following Steps have been undertaken to control Adulteration of Fuel in the country:

(a) The Ministry of Petroleum & Natural Gas has caused oil companies takes various steps listed below to detect/ prevent adulteration of gasoline/ at retail outlets:

- Filter paper Test
- Density checks
- Blue dyeing of subsidized kerosene
- Regular/surprise Inspection of retail outlets
- Joint inspection of retail outlets by the industry teams
- Regular /surprise inspection by mobile laboratories
- Special vigilance drives, etc.

(b) Further, in order to prevent diversion of kerosene meant for distribution under public distribution system for adulteration, MoPNG has directed the oil companies to ensure upliftment by the wholesalers as under:

- 60% by 10th of the month
- 25% during next week, Balance
- 15% during the following week.

(c) MoPNG has also advised State/UT Government from time to time

- To ensure upliftment of kerosene by the whole-sellers from oil companies as per upliftment pattern mentioned above
- To identify loopholes in the distribution system
- To review scale of distribution of kerosene to various cardholders, with regard to factors as availability of alternative fuels
- To discontinue allocation of kerosene to the cardholders having double LPG connection and to discontinue allocation of kerosene for uses other than cooking and illumination.

(d) The Government of National Capital Territory of Delhi has declared the city as kerosene free city.

3.1 Consumers Front: anti-adulteration tips

Consumers are the sufferers of this malpractice. Any quality conscious consumer has the right to be assured of the quality of the products and if he desires he can get his sample checked for adulteration. Some easy and important checks can be conducted at the retail outlet for Gasoline/High Speed Diesel are described below:

Filter Paper Test: For gasoline, first the mouth of nozzle is cleaned to remove stains. Then, a drop of petrol is put on the filter paper from the nozzle. The petrol dropped on the filter paper is allowed to evaporate with in 2 minutes. The petrol should evaporate without leaving any stain on the filter paper. If there is no stain and the colour left on the paper is pinkish, it is the colour of gasoline.

Density test: This is a very simple test for both gasoline and High Speed Diesel. This test takes approximately 5 to 10 minutes. Test specimen is to be taken in a glass jar followed by immersing a Hydrometer (separate Hydrometers for gasoline and Diesel) in it. A Thermometer is also used to record the temperature and it should not touch the walls of the jar. The readings of Thermometer and Hydrometer should be recorded and compared with the standard. If the variation between the observed density and recorded/ reference density is within + 0.0030, then the product density can be considered to be correct. If the difference is more than + 0.0030, then it indicates possibility of adulteration.

Water contamination checks: For both gasoline and High Speed Diesel can be done with the help of a dip rod and water finding paste, available with the retail outlets.

In case of lubricants: the seal of container date of manufacture and name of the manufacturer should be checked. For convenience of 2/3 wheelers, Retail Outlets provide 2-T dispensers/2-T mix dispensing units and also keep tamper proof 2-T pouches.

4. Conclusions

This paper presents the factors mainly responsible for the fuel adulteration. It also discusses the possible control strategies. It is the need of the time to seriously take the initiatives for the mitigation of the fuel adulteration. It is also very important to make the awareness at the non-government organizations to share the responsibility to control the fuel adulteration. This shall not only reduce the harmful emissions but may also prolong the engine life and reduce the maintenance expenses.

References:

[1] T. Lanzer, O. Meien, C. Yamamoto, A predictive thermodynamic model for the Brazilian gasoline, Fuel, 84, 2005, 1099-1104

[2] C. Jude, Igwe, E. Kalu, Agbaeze, I. Anthony, Obike, U. Christopher, Extraction, Characterization and Determination of Ethanol Fuel Composite Qualities of Saccharum officinarum, Pennisetum purpureum and Costus afer, Asian Journal of Plant Science and Research, 2(5), 2012, 643-649

[3] C. Lori, Hasselbring, Case study: Flame arresters and exploding gasoline containers, Journal of Hazardous Materials, 130(1-2), 2006, 64-68

[4] C. Rita, C. Pereira, M. D. Vanya, Effect of mono-olefins and diolefins on the stability of automotive gasoline, Fuel, 85, 2006, 1860-1865

[5] M. S. Dauda, R. Odoh, Impact of motor parks on the concentration of heavy metals in some selected urban areas of Benue State Nigeria, Der Chemica Sinica, 3(3), 2012, 745-752

[6] P. Nikos, P. G. Vassilis, Octane number prediction for gasoline blends, Fuel Processing Technology, 87(6), 2006, 505–509

[7] B. S. Murty, R. N. Rao, Global optimization for prediction of blend composition of gasolines of desired octane number and properties, Fuel Processing Technology, 85, 2004, 1595-1602

[8] T. Aina, C. O. Folayan, G. Y. Pam, Influence of compression ratio on the performance characteristics of a spark ignition engine, Advances in Applied Science Research, 3(4):3, 2012, 1915-1922

[9] A. Gupta, Automotive Fuel Specification in India– The Journey & Path Forward", A presentation in Indo-Japanese Conference on Fuel Quality & Vehicular Emissions, IHC, New Delhi, 2009

[10] A. K. Gupta, R. K. Sharma, A new method for estimation of automobile fuel adulteration, Air

Pollution Chapter 16, Vanda Villanyi (Ed.), InTech Publishers, 2010, 357-370.

[11] R. Yadav, K. V. Murthy, D. Mishra, B. Baral, Estimation of petrol and diesel adulteration with kerosene and assessment of usefulness of selected automobile fuel quality test parameters, International Journal of Environmental Science & Technology, 1(4), 2005, 253-255

[12] S. Roy, Fibre optic sensor for determining adulteration of petrol and diesel by kerosene, Sensors and Actuators B, 55, 1999, 212–216