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Assessment of Adulteration of Gasoline (MSP) and Diesel (AGO), in Selected Fuel Stations in Kisii County

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Abstract

The major transport fuels in Kenya are gasoline and diesel. A complaint on adulteration of these fuels at the point of sale or during transportation is a common occurrence in the country. The present studies on analysis of petroleum adulteration does not give a scope of what is happening at the newly and upcoming petrol stations outside the capital of city. Purposeful sampling was carried out on investigating gasoline and diesel adulteration sold at selected fuel stations in in a case study of Kisii County, and whether these products are within the standards set by Kenya bureau of Standards (KEBs). Samples of gasoline and diesel were collected from selected five fuel stations and two laboratory testing methods of ASTM D86 (Distillation) and ASTM D1298 (Density determination) were conducted at Vivo Energy Company laboratory in Nairobi. Currently, the number of fuel stations selling Gasoline and diesel is enormous in Kisii region. They involve four major oil companies namely, Shell, Total, Kenol/Kobil, Oil Libya, and now KNOCK which dominate the market as well as locally owned ones. Therefore, the sampling method that was employed to select randomly five specific filling stations comprising of one major and four Minor companies representing the population with parameters of interest, for analysis in this study.

Keywords: Adulteration • Gasoline • Distillation • Randomization • Non-probabilistic

Introduction

Gasoline is a refined product of petroleum consisting of hundreds of hydrocarbons, additives and blending agents which have different boiling points. Its boiling points range between 30°C and 202°C for one to obtain a distillation curve [1,2]. Additives and blending agents are added to hydrocarbons mixture to improve the performance and stability of gasoline. These compounds include: anti-knock agent, anti-oxidants, metal deactivators, anti-rust additives, anti-icing agents, pre-ignition additives, upper cylinder lubricants and dyes. The major hydrocarbon compounds in gasoline include alkanes, isoalkanes, cycloalkanes, alkenes, and aromatics. Commercial gasoline contains mainly C5 and C8 paraffin's (60% to 80%), with much smaller quantity of aromatics compounds (14% to 33%) and olefins (6.4 to 13%). Therefore, the density of gasoline is reported to be about 0.700-0.740 kg/l at 20°C and its vapor pressure is estimated to be 93.3 kpa at 25°C [3-6].

Gasoline is highly flammable with a flash point of -45°C and minimum and maximum explosion limits in air of 1.3 and 6% by volume respectively. The important qualities for gasoline are Motor Octane Number (MON), Research Octane Number (RON), volatility (starting and vapor lock), vapor pressure (environmental control) and copper corrosion test. For these reasons, additives such as Ethyl Tertiary Butyl Ether (ETBE), Methyl Tertiary Butyl Ether (MTBE), Tertiary Amyl Methyl Ether (TAME), and other oxygenates improve gasoline octane rating as well as enhance performance, provide protection against oxidation and rust formation and reduce carbon monoxide emissions. According to Minnesota Department of commerce on consumer guide on gasoline octane facts, it was reported that gasoline has an octane rating of at least 87 and in EU; it is required to have a minimum octane rating of 85. In Kenya, the minimum octane number required by the specification is 87 [7-9].

Diesel also known as automotive gas oil, and is produced from petroleum being called petrol diesel to distinguish it from diesel obtained from other sources such as biodiesel. Automotive gas oil is classified under distillation and is a hydrocarbon mixture obtained from fractional distillation of crude oil between 250°C-350°C and has a density of about 0.820-0.850 kg/l. Petroleum derived diesel is composed of about 75% saturated hydrocarbons with a primarily paraffins and 25% aromatics hydrocarbons which includes naphthalene's and alkylbenzenes. The average chemical formula for common diesel fuel is C12H26, ranging from approximately C10H22 to C15H32 [10-13]. The desirable qualities required for diesel fuels include controlled flash and pour point, clean burning, no deposits formation in storage tanks, and a proper diesel fuel octane rating for good starting and combustion.

The lighter end of a group of petroleum streams known as the middle distillates (Kerosene). It is known as dual purpose kerosene which may be obtained either from the distillation of crude oil under atmospheric pressure known as the straight run kerosene or from catalytic, thermal or steam cracking of heavier petroleum stream which is referred to as cracked kerosene [14]. In developing countries like Kenya, it's a common fuel for stoves, heaters, and lamps, and in developed countries is used as a fuel for home central heating systems. Kerosene is further treated by a variety of process including hydrogenation to remove or reduce the level of sulphur, nitrogen or olefinic materials. The precise composition of kerosene will depend on the crude oil from which it was derived and on the refinery process used for its production. Irrespective of this property of kerosene, it consists predominantly of C9 to C16 hydrocarbons and boils in the range between 145°C to 300°C (API, 1997). Therefore, the density of dual purpose kerosene is reported to be about 0.760 – 0.800 kg/l at 20°C. Kerosene finds considerable use as a jet fuel and as a domestic heating fuel.

It is widely believed by the public and experts in the petroleum sector that a large quantity of Kerosene is used to adulterate other fuel

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products namely Gasoline and Diesel [15]. Adulteration can be defined as the introduction of a foreign substance into gasoline or diesel, illegally or unauthorized with the result that the product does not conform to the requirements and specifications of the product. Therefore, It involves the addition of organic solvents, such as alkanes that are straight and branched from about C1 to C4, light aliphatic (C4-C8), heavy aliphatic (C13-C15), and aromatic hydrocarbons, especially, benzene, toluene, xylenes, hexane, complex hydrocarbon mixtures, mineral spirits, kerosene, rubber solvent, petrochemical naphtha, diesel, and thinner [16]. In the process, expensive consumer's products are often adulterated by deliberately adding a component of cheaper low quality products having similar physical and chemical characteristics. Since adulterants usually include those compounds which already exist in these fuels, and having similar physical and chemical properties, the fuel and adulterant cannot be distinguished easily leading to complications in identification and quantification of the adulterant by consumers [17-19].

Fuel adulteration is a common problem not only for Kenya but for several developing countries. Nigeria, Greece and Ethiopia are some of the countries that can be mentioned with regard to adulteration of fuel practiced [20,21].

As detailed in gasoline and diesel adulteration in India, kerosene is more difficult to burn than gasoline and diesel; so that its addition results in higher levels of HC, CO and PM emissions even from catalyst-equipped cars i.e., cars equipped with conversion of engine-out pollutants. The higher sulphur level of kerosene can deactivate the catalyst and lower conversion of engines-out pollutants. If too much kerosene is added, octane quality will fall below the octane requirement of the engines and engine knocking can result, hence possibly damaging the engine mechanically, therefore, the knock can increase PM, HC and NOx emissions. As we know, the latter two are the precursors of among others, ozone. With gasoline vehicles not equipped with catalyst, the exhaust smell from kerosene is often rather acrid, creating unpleasant conditions in crowded city streets [22-24].

Kisii is one of the fast growing towns in Kenya with increasing demand for fuel due to presence of many vehicles leading to mushrooming of filling station to meet the demand. Currently, there is an increase of second hand vehicles on Kisii roads most of which contribute largely to air pollution especial during morning and evening hours where traffic jams are the norm. As vehicles move at a slow speed, the combustion of the fuel is not complete in most cases and hence tail pipe emissions increase. Nevertheless, kerosene mixed with petrol, results in higher emissions because they do not form a uniform mixture leading to incomplete combustion and therefore, Increases emission level of hydrocarbons, carbon (II) oxide, oxides of nitrogen, and particulate matter. This harmful tailpipe emissions and cancer-causing pollutants intoxicate the air making the environment unhealthy for both plants, animals and the entire Kisii County populace.

Literature Review

In his review of fuel adulteration consequence in India, explained that the types of fuel adulteration are as follows: Blending kerosene into petrol, Blending kerosene into diesel, Blending of lubricants into kerosene as a substitute for diesel, and Blending of used lubricants into diesel.

In general, blending of variable amounts of hydrocarbons of different boiling range such as industrial solvents into automotive gasoline, blending small amounts of spent waste industrial solvent such as used lubricants into gasoline and diesel and blending small amounts of heavier fuel oils into diesel fuels are practiced [25]. In India "Fuel is consumed for a variety of purposes and relies heavily on import. This in turn gives rise to a host of concerns including, on pricing mechanism that on one hand influences technology adoption and resource allocation, while on the other hand impacts current account and fiscal balance. As a consequence, price of fuel and efforts to maintain its uninterrupted availability has engaged the attention of policy and decision makers" [26].

It is also explained in Energy Sector Management Assistance Program (ESMAP, 2005) technical Series, Senegal that evidence of ongoing malpractice in the downstream oil sector in Senegal exists, but it is difficult to quantify. It could be assumed that this malpractice takes place at a relatively small scale mainly at the secondary transportation (i.e., fuel trucks and other transport method) and retail level. This transpires mainly due to the lack of an inexpensive supply source. "Automobile fuel adulteration is a clandestine and profit-oriented operation adulteration of diesel by mixing kerosene is a common and widespread practice" [27].

The main primary factors which generally promote the practice of adulteration as outlined by Amit P. Gawande and Jayant P. Kaware, 2013 [28]. are as follows: Existence of differential tax levels amongst the base fuels, intermediate products and byproducts. The adulterants being taxed lower than the base fuels give monetary benefits when mixed with replacing a proportion of the base fuels, Differential pricing mechanism of fuels and adulterants and easy availability of adulterants in the market, Lack of monitoring and consumers awareness, Lack of transparency and uncontrolled regulations in the production-supply and marketing chain for intermediates and byproducts of refineries, and Non-availability of mechanism and instruments for spot-checking the quality of fuels [29] Some of the main effects of adulteration are as described below: Malfunctioning of the engine, failure of components like valve bend, reddish deposits in fuel line and carburetor, discoloration of various engine components like bearings, gears, cam shaft, crank shaft and cam chain etc.; Increased tailpipe emissions of HC, CO, NOx, and PM and can also cause increased emissions of other toxic substances. Adulteration of fuel can cause health problems directly because of increased tailpipe emissions of harmful and sometimes carcinogenic pollutants, and Significant loss of tax revenue as various estimates have been made of 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.

Since June 1999, the Government of Kenya has been adding a Bio-code marker to fuel as a trace, to designate fuel for local consumption (taxed) or for export (untaxed). The aim is to prevent fuel adulteration and preventing fuel traders from selling fuels designed for export on domestic market as way to avoid taxes. The system is said to have reduced adulteration and illicit trade, recovering US$ 30 million in taxes for government and US$ 50 million in sales for oil companies [30-33].

Importance of fuel quality

Fuel Quality should pass rigorous inspection of its quality control process in any country to help reduce any chance of producing or distributing fuel of inferior quality. The Kenya bureau of standards (KEBS) specifications for gasoline, kerosene and diesel is shown in Table 1.

	KEBS Specifications for		
Characteristics	**Gasoline**	**Diesel**	**Kerosene**
	Max **Min**	**Max** **Min**	**Max** **Min**
Lead content (ppm)	15 -	-	- - -
Density (Kg/l)	0.75 0.70	0.80 0.76	0.85 0.80
Sulphur content ppm	1500 -	5000 -	1500 -
Flash point °C	-45 -	60 -	39 -
Distillation °C	210 -	400 -	300 -

*Adapted from (KEBS, 2007), (KEBS, 1996), AND (KEBS, 2006)

Table 1. Kenya Bureau of standards specifications for gasoline (KEBS, 2007), Kerosene (KEBS, 1996) and Diesel (KEBS, 2006).

Research Methodology

The study area selected petrol stations at different places in Kisii County. Kisii the main urban and commercial center in the Gusii highlands and the south Nyanza region. The study area will be covered randomly a total of five samples all within Kisii County with samples namely Msp 1, Msp 2, Msp 3, Msp 4, Msp 5. All glassware which included measuring cylinders, pipettes, distillation flaks, beakers, boiling tubes, glass bottles were thoroughly cleaned with tap water and detergent. They were then rinsed with water and finally with deionized water. The glassware was dried in the oven at 100°C.

The gasoline and diesel samples were be then transported to vivo Energy laboratory, where a small Distillation test (ASTM D86) technique was used that exploits the difference in the boiling points of different liquids comprising of the fuel sample. Accurate distillation data for uncontaminated fuel is essential for comparison and precise results. One of the most important features of gasoline is the volatility that was measured by a distillation while determination of volatility of petroleum products was done using laboratory batch distillation unit to determine quantitatively the boiling range characteristics of products such as gasoline, light and middle distillates, aviation turbine fuels, low sulfur diesel fuels, special petroleum spirits, naphtha, white spirits and kerosene. Distillation is based on the composition, vapor pressure, expected initial boiling point, expected final end point, and combustion of the sample Density test (ASTM D1298) method was done using a glass hydrometers and digital densitometers. The values measured on a hydrometer were either the reference temperature or at another convenient temperature, and readings corrected to the reference temperature by means of the petroleum measurement tables (ASTM D1298. 2006) (Table 2).

Samples	Density (kg/m^3 @ 20°C) (for Msp)		Density (kg/m^3 @ 20°C) (for AGO)	Comments
Standard	**Max**	**Min**	**Max Min**	Adopted from (KEBS,2017), Specifications Respectively.
	750.0	701.0	867.0 817.0	
S1Msp	746.4		-	Within the specification
S1AGO	-		857.9	
S2Msp	781.3		-	Both Msp and AGO failed the test on Density Determination
S2AGO	-		798.5	
S3Msp	735.7		-	Both Msp and AGO passed the density determination test
S3AGO	-		823.2	
S4Msp	774.9		-	Both Msp and AGO failed the test on Density Determination
S4AGO	-		811.4	
S5Msp	742.6		-	Both Msp and AGO passed the density determination test
S5AGO	-		819.6	

Table 2. ASTM D 1298 (Density Determinat ion kg/m^3 @ 20°C) Spirit Premium (MSP) and diesel/Automotive Gas Oil (AGO) test results Vs. Density Standard.

Results

The result for ASTM D1298 analysis showed that three out of the five samples (samples 1, 3 and 5) are found to be acceptable i.e., the three samples were within established tolerance range. Therefore, two of the collected samples did not conform to the set standards set by KEBS. quantity of samples were transferred into a smaller glass bottles and stored in a cool dry place awaiting analysis.

Many ASTM tests for gasoline and diesel have been standardized and documented. Though no test is specifically designed to measure the adulteration of petrol by mixing with diesel or of diesel by mixing with kerosene, but some tests namely: Density test, Evaporation test, Distillation test, Chemical markers test, and Gas Chromatography was used to determine the adulteration of fuel. The study considered taking samples of gasoline and diesel from selected fuel stations in Kisii County and conducting two laboratory testing methods of ASTM D86 (Distillation) and ASTM D1298 (Density determination). Same samples were tested by the other test method i.e., ASTM D86 (distillation) and the result showed 3 stations out of five were found adulterated. This reveals that ASTM D1298 (density determination) method is not effective in identifying level of adulteration as compared to ASTM D86 (Distillation) method, as indicated in Figure 1.

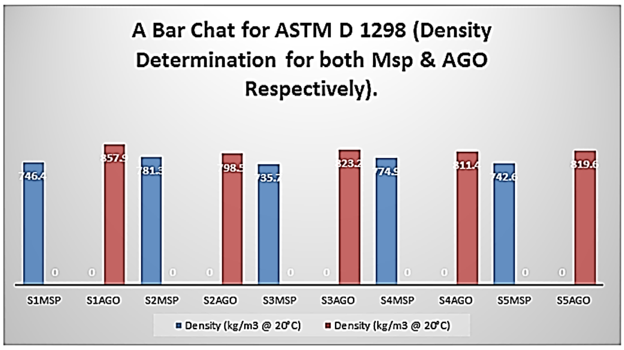

Figure 1. A Bar Chart for ASTM D 1298 (Density Determination kg/m3 @ 20°C) For Regular gasoline/Motor Spirit Premium (MSP) and diesel/Automotive Gas Oil (AGO) test results Vs. Density Standard.

ASTM D86 (Distillation)

Determination or an indication of the boiling ranges of fuel, and also a property of volatility of fuel. This parameter provides information, more pointedly to drivability issues particularly at cold-start/warm –up or hot start and other issues such as vapor lock and variability engine performance when temperature varies submission.

Table 3 Shows the results of distillation temperatures of the regular gasoline (Msp) and Diesel (AGO) standards and those of the samples. The result of analysis indicate that in this parameter three stations are out of the range for the samples and the remaining two are within the range specified by KEBS.

Samples	Distillation (Final End Point) (for Msp)	Distillation (Final End Point) (for AGO)	Comments
Standard	**Max**	**Max**	**Adopted from (KEBS, 2007), Specifications Respectively.**
Std	210	400	
S1 Msp	203.1	-	Within the specification
S1AGO	-	385.2	
S2 Msp	221.4	-	Both Msp and AGO failed the test on Density Determination
S2 AGO	-	413.5	

S3 Msp	215.8	-	Both Msp and AGO passed the density determination test
S3 AGO	-	406.3	
S4 Msp	218.9	-	Both Msp and AGO failed the test on Density Determination
S4 AGO	-	419.4	
S5 Msp	208.6	-	Both Msp and AGO passed the density determination test
S5 AGO	-	392.6	

Table 3. ASTM D 86 (Distillation) volume vapor at Final Boiling Point (FBP) of Regular gasoline/Motor Spirit Premium (Msp) and diesel/Automotive Gas Oil (AGO) test results Vs. Distillation Standard.

The final boiling point (FBP) is the key parameter in measuring the quality of petrol and it is determined from distillation process (Chakra, 2009). The result showed apparent discrepancy and variations in three samples. In general the quality characteristics of the Msp and AGO were tested with five samples for each of them and the experimental results showed that only in (4/10 × 100)=40% of the samples quality of all fuel in distillation was within the limit by KEBS specification as shown in the Figure 2.

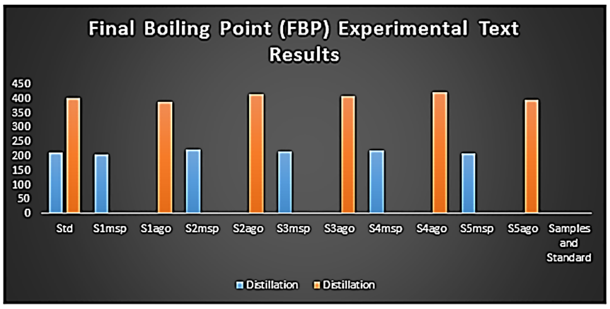

Figure 2. A Bar Chart for ASTM D 86 Distillation at FBP for Regular gasoline/ Motor Spirit Premium (MSP) and diesel/Automotive Gas Oil (AGO) test results Vs. Distillation Standard.

From the table it can be observed that sample No S2Msp and S4AGO, had the highest FBP as compared to all the samples and the standard at measured temperatures indicating that they had heavy adulterants which raised the boiling point at each volume collected.

Discussion and Conclusion

The result of the study was indicative that the quality of fuel/regular gasoline on the market is questionable. The sample result revealed that the Msp and AGO sold at Kisii retail stations does not meet the standard set by KEBS and indicated that there is adulteration practice. In addition, the laboratory fuel test result shows, density determination (ASTM D1298) is less capable of identifying the adulteration as compared to fractional distillation (ASTM D86).Generally, absence of consistent implementation of regulations in sustainable manner leaves an open door on the issue and because of the complex nature of fuel quality issues. Though major share of responsibility should lie on the government to monitor fuel adulteration a single body or oil companies simply cannot force into complying with fuel standards unless a comprehensive approach is taken to address such an issue, backed by legislation. The public should request information from the oil companies in regards to their fuel quality and should also demand specific information in regards to issues which require mechanical intervention (professional bodies) on their vehicles.

Recommendation

From the result it is learnt that though experiment indicated that there is practice of adulteration at Kisii County fuel stations, the results of this limited study on fuel indicate a clear need to significantly strengthen fuel quality monitoring. The steps involved in setting up an effective system are to examine the regulatory framework, including handling of noncompliance and requirement of cooperation among stakeholders. The current regulatory system of fuel quality system is very weak, largely resulting from the weak enforcement leading to unfair adulteration practice and lack of accountability in the petroleum industry.

In order to deter fuel adulteration and improve government controlling of this practice, the following action are recommended:

1. Upstream testing and downstream quality check.

2. Stiff noncompliance penalties; both financial and criminal. This includes fines and shut down of business for the retailers and oil companies.

3. Fuel marking: marker is used as a quick check on adulteration; it is added to lower value fuel and an invisible chemical marker that is detectable by a few drops of fuel into a test tube with the product sample.

4. 4). Secure industry cooperation (mandatory/voluntary self-testing and mandatory reporting). Make oil companies accountable for quality of fuel at the fuel station end. It is a reputational damage, name and shame program could potentially be a persuasive tool to induce companies to monitor the quality of fuel sold by their own suppliers and their competitors.

5. Develop alternative testing procedure for more accurate detection regarding availability of information about fuel quality at stations and improve consumer's confidence, the following actions could be taken:

➢ Media coverage, Periodic Public rating of retail outlets based on independent inspection, testing and audit of the outlet.

➢ Consumers front: forming anti-adulteration groups. Consumers are sufferers of this malpractice and any consumer conscious of quality has the right to be assured of the product quality and if the consumer demands, should be able for samples checked for adulteration.

➢ Create awareness session *via* various media to public.

➢ Awarding for quality, awarding those stations consistently maintaining fuel quality.

Generally, the ministry of petroleum and natural gas should take the following initiatives to control adulteration of fuel in the country. The ministry should cause the oil companies to take various steps listed blow to detect/ prevent adulteration of petroleum products at retail outlets: filter paper test, density checks, dyeing/marking subsidized kerosene, regular/surprise inspection of retail outlets by the oil companies, and joint inspection of retail outlets by industry teams, regular/surprise inspection by mobile laboratories, also develop controlling means that should ensure kerosene reaches to the targeted poor citizens.

There is a possibility that kerosene is diverted to fuel adulteration Purpose and further study needed to investigate the location of where the kerosene is sold, consumed, and in general the where about of kerosene sales.

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