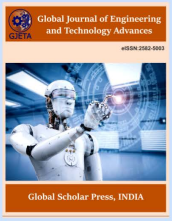
Global Journal of Engineering and Technology Advances
eISSN: 2582-5003
Cross Ref DOI: 10.30574/gjeta
Journal homepage: https://gjeta.com/



(Research Article)

Check for updates

Comparative analysis of petroleum products from artisanal refineries and standard products

Blessing Amabogha * and Ebinimi Gbeinzi

Department of Chemical Engineering, Federal University, Otuoke, Yenagoa, P.M.B 126, Bayelsa State, Nigeria.

Global Journal of Engineering and Technology Advances, 2024, 18(03), 001–012

Publication history: Received on 05 January 2024; revised on 27 February 2024; accepted on 01 March 2024

Article DOI: https://doi.org/10.30574/gjeta.2024.18.3.0031

Abstract

Physicochemical properties of artisanal refined premium motor spirit (PMS), artisanal refined Household Kerosene (HHK), regular refined HHK and regular premium motor spirit (PMS) sampled from the Eastern Kolo Creek and a tank farm depot in Delta State, Nigeria was investigated. This was to compare the physicochemical properties of the samples with each other and their compliance with American Society for Testing and Materials (ASTM) standards. The finding revealed that the artisanal refined products quality did not comply with ASTM standards. The research octane number, motor octane number, Reid vapor pressure, and specific gravity of the standard PMS were ASTM compliant while only the final boiling point of the artisanal refined PMS was within ASTM range. Based on the findings, the artisanal refined products might have been poorly refined or adulterated and could constitute problems in automotive engines if used. However, this crude technology can be upgraded and the gasoline quality improved through alkylation, isomerization, and cyclization. Artisanal refiners should be trained to become proficient with the intent of becoming incorporated into the upstream petroleum sector.

Keywords: Artisanal Refineries; Premium Motor Spirit (PMS); Household Kerosene (HHK); Physiochemical properties

1. Introduction

Petroleum, meaning literally "rock oil, "is the term used to describe a myriad of hydrocarbon-rich fluids that have accumulated in subterranean reservoirs, Speight (2002). It is usually found with gases in its free form or in its dissolved form. Petroleum (also called crude oil) varies dramatically in colour, odour, and flow properties that reflect the diversity of its origin, Speight (2002). Little wonder Achuba (2006) described petroleum as a brown to black viscous liquid found beneath the sedimentary rock on the earth crust. Petroleum, originally distilled and sold as fractions with desirable physical properties, has been recorded as the world's main source of energy and petrochemical feedstock. In recent times, crude oil is distributed in diverse forms which includes: gasoline, diesel and jet fuel, kerosene, lubricant oils, asphalts etc. or it is converted to petrochemical feed stocks. Some feed stocks include: ethylene, propylene, butene, butadiene, and isoprene.

In brief, a refinery is a complex network of integrated unit processes for the purpose of producing a variety of products from petroleum (Speight and Ozum, 2002). The quality of petroleum to be refined is measurable from the analysis of its physical properties which include: relative density, specific gravity, or viscosity, refractive index, or by empirical tests such as pour point or oxidation stability that are intended to relate to behaviour in service. Refining in recent times employs the effects of heat, catalyst, and other parameters to rearrange petroleum molecules into products. Basically, standard Refining of crude follows three basic steps which includes: Separation, conversion and treatment. While Separation involves division of petroleum into different fractions depending on the nature of the crude material, Conversion demands alteration for the production of desired products, usually by skeletal alteration, or even by alteration of the chemical type of the petroleum constituents and Finishing is all about removal of impurities from the

* Corresponding author: Blessing Amabogha

product as well as introduction of additives. Conversion processes are, in essence, processes that change the number of carbon atoms per molecule, alter the molecular hydrogen-to-carbon ratio, or change the molecular structure of the material without affecting the number of carbon atoms per molecule. This refining method gives rise to the following products: gasoline (PMS), kerosene (DPK), diesel (AGO), bitumen, asphalt, liquefied natural gas (LPG), and others depending on the prevailing conditions. Gasoline is obtained from crude oil through blending of atmospheric distillation naphtha and products from other complex refinery processes Handwerk (2001) while HHK is obtained from fractional distillation of crude samples. According to Udo et. al (2020) Petroleum products such as Gasoline is in high demand in developing countries because of an increase in population, with a resultant increase in vehicular and industrial activities. Furthermore, refineries are producing at below installed capacities or are not functioning at all, which has resulted in the inability to refine enough petroleum products to meet local consumption. Artisanal refining activity in the Niger Delta, Nigeria is increasing (Yabrade and Tanee, 2016). Illegal artisanal refineries are said to be growing fast in number and scale, now producing 5-20% of all the gasoline and diesel consumed in Nigeria from the estimated 175,000 barrels of crude oil stolen each year. Owing to the rising need for the use of energy and the increasing number of illegal refineries emanating in Nigeria, hence the need to carefully analyze the resulting petroleum products from the illegal refineries to ascertain its degree of compliance to local or international standards, its health, economic and environmental effects. The artisanal refiners use the thermal cracking technique to convert the raw crude into petroleum fractions known as bunkering oil. According to Evbuomwan and Alete (2020), The resulting product is believed to contain a lot of impurities and unsaturated hydrocarbons, causes cracking sound in vehicle engines; knock vehicles, motorcycles, and generators engines; corrode and fouling of fuel tanks; burn residential houses, properties, and end users; and pollute the environment. This can be attributed to the fact that standard routes of refining are not employed, the refining is carried out without reflux, there is no heater and heat exchanger equipment, and there is no pump and cooler installations and adequate process control. The products are retailed at prices lower than the regular petroleum products and as expected has high demand especially in the Niger Delta regions, other times, the products are blended with Imported petroleum products and sold at cheaper rates. In artisanal refining, crude is heated in an open fire with drums perforated at the top and connected to pipes to collect the resulting condensed fumes and deliver to the receiver. This local refining skill is believed to have been drawn from indigenous technology (Goodnews and Wordu, 2019). The fractions obtained from the bunkering refinery include gasoline, kerosene, diesel, and residue. For the purpose of this research, PMS and HHK will be the main focus. When these petroleum fractions are obtained, from standard refineries, they are subjected to analysis to ascertain its compliance to standards. According to Vempatapu and Kanaujia (2017), physicochemical properties like distillation profile, research octane number (RON), motor octane number (MON), and Reid vapor pressure are frequently used to detect the adulteration and quality of gasoline. While API, flash point, temperature, specific gravity are used to detect the quality of HHK. It is on this basis that this research was designed to compare the physicochemical properties of regular automotive gasoline and locally refined gasoline and their compliance with ASTM standards. The analysis of petroleum products is necessary to determine the properties that can assist in resolving a process problem as well as the properties that indicate the function and performance of the product in service.

2. Materials and methods

Quality assurance analysis was carried out on the samples that were collected randomly from artisanal refineries along the Eastern Kolo Creek in Niger Delta, Nigeria. Two samples each of Premium motor spirit and regular house hold kerosene samples was randomly obtained from a legally approved depot in Warri tank farm to ensure products compliance to international standards.

2.1. Materials

The following materials were used for products analysis: HHK- House Hold kerosene, PMS- Premium Motor Spirit, Reid vapor pressure tester, Flash point tester, Octane rating tester, Distillation column, Round bottom flask, Measuring cylinder, Refrigerator, Gas cylinder, Sampling cans, Hydrometer, Thermometer.

2.2. Methods

2.2.1. Density at 15 °C (Gravity)

Density is Mass of a substance per unit volume. Determination of the density or relative density of petroleum distillates and viscous oils that can be handled in a normal fashion as liquids at test temperatures between 15 and 35 °C. Density is a fundamental physical property that can be used in conjunction with other properties to characterize both the light and heavy fractions of petroleum and petroleum products. Determination of the density or relative density of petroleum and its products is necessary for the conversion of measured volumes to volumes at the standard temperature of 15 °C. Density is important for consistency and good fuel economy. Higher density produces more power and more smoke.

How to take density measurement

ASTM D4052 Standard Test Method for Density and Relative Density of Liquids by Digital Density Meter:

A small volume of liquid sample is introduced into an oscillating sample tube and the change in oscillating frequency caused by the change in the mass of the tube is used in conjunction with calibration data to determine the density of the sample.

Alternative test methods: ASTM D1298, IP 160 and IP 365, ISO 3675, ISO 12185, JIS K 2249

Typical specifications:

- Gasoline: Min 715-720 to Max 775-780 kg/m3
- Jet kerosine: Min 775 to Max 840 kg/m3 or 37-51 °API
- Diesel: Min 800-820 to Max 845-860 kg/m3

2.2.2. Distillation

Atmospheric distillation of petroleum products using a laboratory batch distillation unit to determine quantitatively the boiling range characteristics of such products as light and middle distillates, automotive spark-ignition engine fuels, aviation gasolines, aviation turbine fuels, diesel fuels, special petroleum spirits and naphtha's. Test results are commonly expressed as percent evaporated or percent recovered versus corresponding temperature, either in a table or graphically, as a plot of the distillation curve.

Test Methods

ASTM D86 Standard Test Method for Distillation of Petroleum Products and Liquid Fuels at Atmospheric Pressure:

Based on its composition, vapor pressure, expected IBP and/or FBP, the sample is placed in one of four groups. Apparatus arrangement, condenser temperature, and other operational variables are defined by the group in which the sample falls. 100 ml of the sample is distilled under prescribed conditions for the group in which the sample falls. The distillation is performed in a laboratory batch distillation unit at ambient pressure under conditions that provide one theoretical plate fractionation. Systematic observations of temperature readings and volumes of condensate are made. The volume of the residue and the losses are also recorded.

Determination of the initial and final boiling point of the samples will be conducted according to the ASTM-D86 standard test method (ASTM, 2006b). The gasoline sample (100 ml) was added into a round bottom flask. The distillation machine was switched on and the temperature was adjusted to 300 ◦C. The initial boiling point (IBP) temperature of the gasoline samples were recorded immediately when the first drop of gasoline entered the measuring cylinder. The temperature of the distillation machine was increased to take the final boiling point (FBP) reading. Also, the total recovery (TR) temperature was recorded.

Alternative test methods: ISO 3405, JIS K 2258, ASTM D2887

Typical specifications

Gasoline

- 10% recovery: Max 45-65 °C (Max 113-149 °F)
- 50% recovery: 65-100 °C (149-212 °F)
- 90% recovery: 130-175 °C (266-347 °F)
- Final boiling point: Max 205 °C (Max 401 °F)

Jet kerosine

- 10% recovery: Max 205 °C (Max 401 °F)
- Final boiling point: Max 300 °C (Max 401 °F)
- Distillation residue: Max 1.5 vol%
- Distillation loss: Max 1.5 vol%

Diesel

- 90% recovery: Max 320-340 °C (Max 608-644 °F)
- 95% recovery: Max 340-370 °C (Max 644-698 °F)
- Final boiling point: Max 350-365 °C (Max 662-689 °F)

Flash point

Flash point measures the tendency of the specimen to form a flammable mixture with air under controlled laboratory conditions. It is only one of a number of properties that shall be considered in assessing the overall flammability hazard of a material. Flash point is used in shipping and safety regulations to define flammable and combustible materials. Flash point can indicate the possible presence of highly volatile and flammable materials in a relatively nonvolatile or nonflammable material. For example, an abnormally low flash point on a sample of kerosene can indicate gasoline contamination.

D93: Determination of the flash point of petroleum products in the temperature range from 40 to 360 °C by a manual Pensky-Martens closed-cup apparatus or an automated Pensky-Martens closed-cup apparatus.

ASTM D93 Standard Test Methods for Flash Point by Pensky-Martens Closed Cup Tester:

A brass test cup of specified dimensions, filled to the inside mark with test specimen and fitted with a cover of specified dimensions, is heated and the specimen stirred at specified rates, by either of two defined procedures (A or B). An ignition source is directed into the test cup at regular intervals with simultaneous interruption of the stirring, until a flash is detected.

Alternative test methods: ASTM D3828, IP 170 and IP 523, EN 22719

Typical specifications

- Jet kerosine: Min 28.0 °C (-2 °F) (ASTM D56)
- Diesel: Min 55 °C (131 °F) (ASTM D93)

2.2.3. Octane Number

Octane rating is a measure of the auto ignition resistance of PMS and other fuels used in spark ignition internal combustion engines. It can be said to be a measure of anti-detonation of PMS. Octane number gives the percentage by volume of Isooctane and heptane that would have the same anti knocking capacity as the fuel under consideration.

ASTM D2700 Standard Test Method for Motor Octane Number of Spark-Ignition Engine Fuel:

- Fill the sample cup to mark with the PMS sample.
- Connect the machine to a power source and turn it on.
- Clear the measuring chamber and cover with the chamber cover.
- Press measure
- Put sample cup in the measuring chamber aligning the designated white threads, cover and press measure.
- Repeat the above step aligning the second thread.
- Remove sample, cover chamber and press measure.
- Result is automatically generated. Alternative test methods: ISO EN 5163

Typical specifications

- Gasoline (MON): Min 82 -88

Typical specifications:

- Gasoline (RON): Min 91 – 98.

This will be conducted according to the ASTM-D2699 standard procedure using knock meter model ZX101C.

Antiknock can be calculated using the mathematical formular:

$$\text{Antiknock index (AKI)} = (R + M)/2$$

where, R = Research Octane Number, M = Motor Octane Number (Nadkarnim Kishore R. A., 2000).

2.2.4. Vapour Pressure

A method covering the use of automated vapor pressure instruments to determine the total vapor pressure exerted in vacuum by air-containing, volatile, liquid petroleum products.

ASTM D5191 Standard Test Method for Vapor Pressure of Petroleum Products (Mini Method)

A known volume of chilled, air-saturated sample is introduced into an evacuated, thermostatically controlled test chamber, the internal volume of which is five times that of the total test specimen introduced into the chamber. After injection into the test chamber, the test specimen is allowed to reach thermal equilibrium at the test temperature, 37.8 °C (100 °F). The resulting rise in pressure in the chamber is measured using a pressure transducer sensor and indicator. Only total pressure measurements (sum of the partial pressure of the sample and the partial pressure of the dissolved air) are used in this test method, although some instruments can measure the absolute pressure of the sample as well.

Determination of Atmospheric Pressure

Reid vapor pressure analysis of the samples will be carried out according to the ASTM test method D323 using the Reid vapor pressure analyzer (P-700-1.00 model). The gasoline sample (50 ml) will be introduced into the Reid vapor pressure machine and submerged into the Reid vapor pressure water bath. The temperature adjusted to 38 °C. After 30 min, the light fraction of the gasoline sample will be vaporized and the pressure of the escaping vapor recorded.

Typical specifications

- Gasoline: Min 45-60 and max 85-105 kPa

2.2.5. API Gravity

A measuring cylinder (100 ml) was swirled with a small portion of the test sample, blown dry, and 50 ml of the test sample added. A hydrometer, calibrated from 0.50 to 0.85, was immersed into the sample and the specific gravity (S.G) was recorded. Also, a thermometer was inserted into the measuring cylinder and the final temperature of the sample was recorded and corrected to °F. This was done according to the ASTM test method D1298 (ASTM, 2006a). The API gravity was calculated with this formula:

$$\text{API Gravity} = (141.5/\text{Specific Gravity}) - 131.5$$

3. Results and discussion

3.1. Distillation Profile for AGO Samples

Distillation (or volatility) characteristics of a diesel fuel exert a great influence on its performance, particularly in medium- and high-speed engines. Distillation characteristics are measured with a procedure (ASTM D-86, IP 123) in which a sample of the fuel is distilled and the vapor temperatures are recorded for the percentages of evaporation or distillation throughout the range. The volatility requirement of diesel fuel varies with engine speed, size and design. However, fuels having too low volatility tend to reduce power output and fuel economy through poor atomization, and those having too high volatility may reduce power output and fuel economy through vapor lock in the fuel system or inadequate droplet penetration from the nozzle. In general, the distillation range should be as low as possible without adversely affecting the flash point, burning quality, heat content, or viscosity of the fuel. If the 10% point is too high, poor starting may result. An excessive boiling range from 10% to 50% evaporated may increase warm up time. A low 50% point is desirable in preventing smoke and odor. Low 90% and end points tend to ensure low carbon residuals and minimum crankcase dilution. The temperature for 50% evaporated, known as the mid-boiling point, usually is taken as an overall indication of the fuel distillation characteristics where a single numerical value is used alone. For example, in high-speed engines, a 50% point above 575 °F (302 °C) probably would cause smoke formation, give rise to objectionable odor; it will also cause lubricating oil contamination, and promote engine deposits. At the other extreme, a fuel with excessively low 50% point would have too low a viscosity and too low a heat content per unit volume. Thus a 50% point in the range of 450–535 °F (232–280 °C) is most desirable for the majority of automotive-type diesel engines. This average range usually is raised to a higher temperature spread for larger, slower-speed engines. Although determining the volatility of diesel fuel is usually accomplished through a boiling range distribution (ASTM D-86, IP 123).

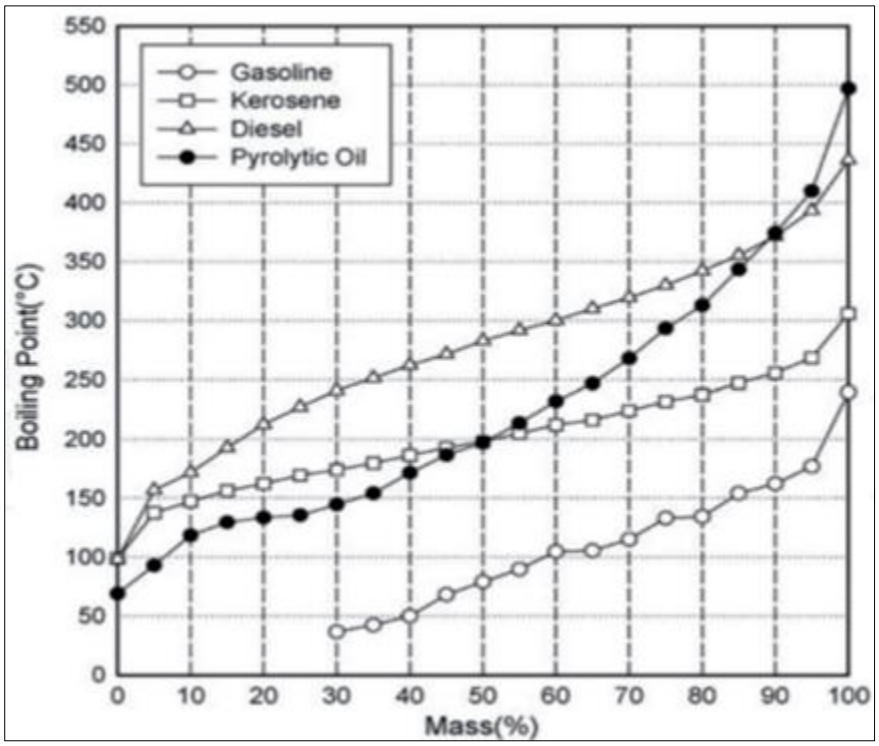


Figure 1 Distillation profile of different petroleum products. Doi: http://dx.doi.org/10.5772/intechopen.90639

Table 1 Distillation profile results for PMS samples from illegal refining source and certified suppliers

Distillation profile (%)	**PMS Illegal refinery 1 (℃)**	**PMS Illegal refinery 2 (℃)**	**PMS 3 (℃)**	**Standards (□)**
IBP	46	55	45	
5	64	65	58	
10	75	80	66	70 max
20	89	99	87	
30	98	115	92	
40	106	123	103	
50	115	130	110	125 max
60	123	141	122	
70	131	153	139	
80	143	169	157	
90	159	183	178	180 max
95	175	199	197	
FBP	194	212	205	210 (max)
% Recovery	97%	92%	99%	
% Loss	2%	5%	0.5%	
% Residue	1%	3%	0.5%	2 max

From the above comparative result, the initial boiling points (IBP) of the illegally refined PMS samples are higher than the IBP of the well refined samples.

Also, the distillation profiles of the 2nd locally refined sample exceeded the standard values at different points; this is an indication that the sample is not well refined.

It is worthy of note that the percentage recovery for the locally refined sample was way lower than that of the well refined sample and as well below the recommended standard. This implies that for sample 1, for every 100% PMS sample, at least 1% impurities are present and 2% is lost as vapor while for sample 2, at least 3% impurities are present while 5% was lost as vapor, unlike sample 3 with negligible traces of impurities. The low recovery rate of samples 1 and 2 can be traced to poor refining techniques which accommodate impurities in final product.

One of the widely used methods for measuring fuel volatility is the distillation test ISO 3405 (2000, 2011). The volatile properties of diesel have a significant impact on the performance of engines as Low volatility results in high distillation endpoints as obtained in the bunker samples. This indicates that heavy hydrocarbons have a long burning time and are inadequately burned. This leads to smoke formation, power loss, and increased fuel consumption. If highly volatile, fuel can cause "vapor lock" accidents on the line. Álvarez F., J. A., Callejón A, I., Forns F. (2005) also noted that Very high FBP can result in incomplete combustion of the less volatile components, fuel droplets reaching the cylinder wall and causing dilution of the lubricating oil. This increases wear and produces coked deposits in the combustion chamber and waste segments. The distillation test profile measures the percentage of fuel recovered at different temperatures as the Temperature increases. The test result is a curve obtained under standardized conditions of Temperature versus percentage recovered as plotted in the graph below. It is expedient to note:

3.2. Distillation profile results for PMS samples from illegal refining source and certified suppliers

3.2.1. A graph of temperature against percentage recovery

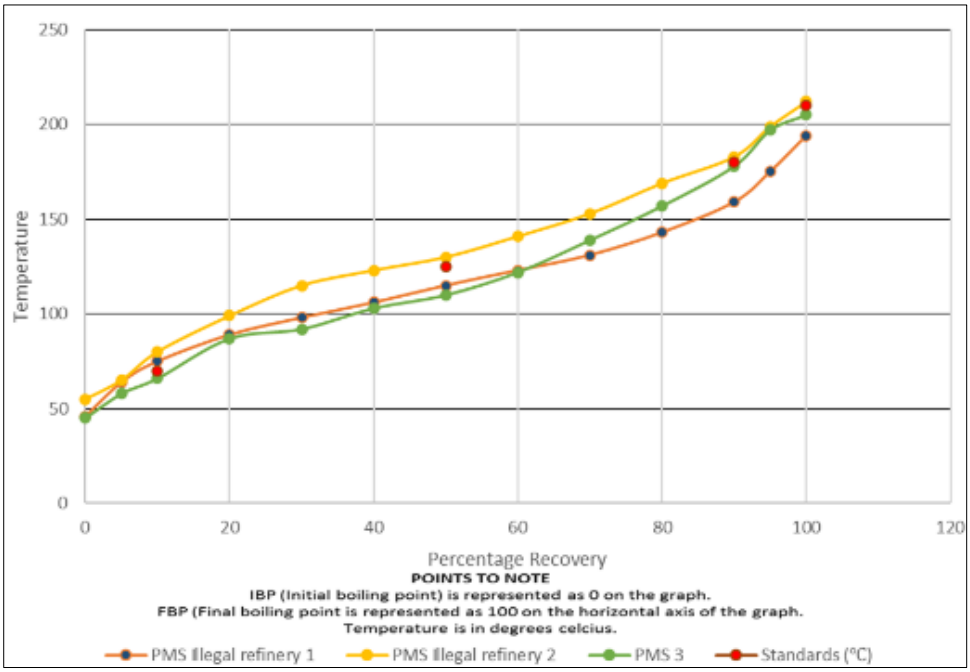


Figure 2 Distillation profile results for PMS samples from illegal refining source and certified suppliers

Table 2 RVP and Octane rating number for analysis results for PMS samples from illegal refining source and certified suppliers

	PMS SAMPLE 1	PMS SAMPLE 2	PMS SAMPLE 3	STANDARD
RVP (Reid vapor pressure)	5.3	7.0	7.9	9 (Max)
OCTANE RATING (research)	92.2	90.0	92.0	90 (min)

The quality that the octane number measures is the anti-knock characteristic of petrol or gasoline.

As the charge of fuel and air is compressed in the cylinder of a spark ignition engine, the temperature/pressure of the charge may reach a point at which it ignites on its own, prior to the timing of the spark. This is called pre-ignition and causes the engine to ping or knock. The out of timing explosion of the fuel charge puts extra stresses on the engine and is detrimental over time. Pre-ignition becomes more likely as the compression ratios of engines increase. Octanes are among the hydrocarbons that comprise the hydrocarbon mixture we know as gasoline or petrol. Octanes, specifically iso-octane are reasonably resistant to pre-ignition. Mixtures containing only iso-octane and heptane are used as repeatable standards for comparison to fuel mixtures. The octane rating means the fuel you pump into your auto has the same anti-knock performance as iso-octane/heptane mixture having the same percentage of iso-octane as the rating. Thus, 87% octane gasoline will behave the same with respect to knocking as a mixture of 87% iso-octane and 13% heptane, and 90 octane fuels will behave the same as a mixture of 90% iso-octane and 10% heptane.

3.3. Distillation Profile for HHK Samples

Table 3 Distillation profile results for HHK samples from illegal refining source and certified suppliers

DISTILLATION PROFILE (%)	HHK Illegal Source 1((℃)	HHK 2 ((℃)	Standards ((℃)
IBP	55	153	
5	120	163	
10	143	177	205 max
20	152	179	
30	168	185	
40	188	189	
50	203	193	
60	220	180	
70	235	196	
80	257	225	
90	275	230	
95	290	237	
FBP	330	266	300 max
% Recovery	97%	99%	
% Loss	2%	Nil	1.5 max
% Residue	1%	1%	

3.3.1. A graph of temperature against

An abnormally high final boiling point and percentage residue of a kerosene may indicate contamination with higher-boiling constituents, although the presence of trace quantities of very heavy oils sufficient to cause high char values might not necessarily be revealed by these features. Thus the boiling range of kerosene is an important aspect of kerosene properties. The boiling range (ASTM D-86, IP 123) is of less importance for kerosene than for gasoline, but it is an indication of the viscosity of the product, for which there is no requirement for kerosene. The nature of the distillation range (ASTM D-86, IP 123) is of significance with regard to burning characteristics. The initial boiling point and the 10% point chiefly affect the flash point and ease of ignition, whereas the mid boiling point is more relevant to the viscosity.

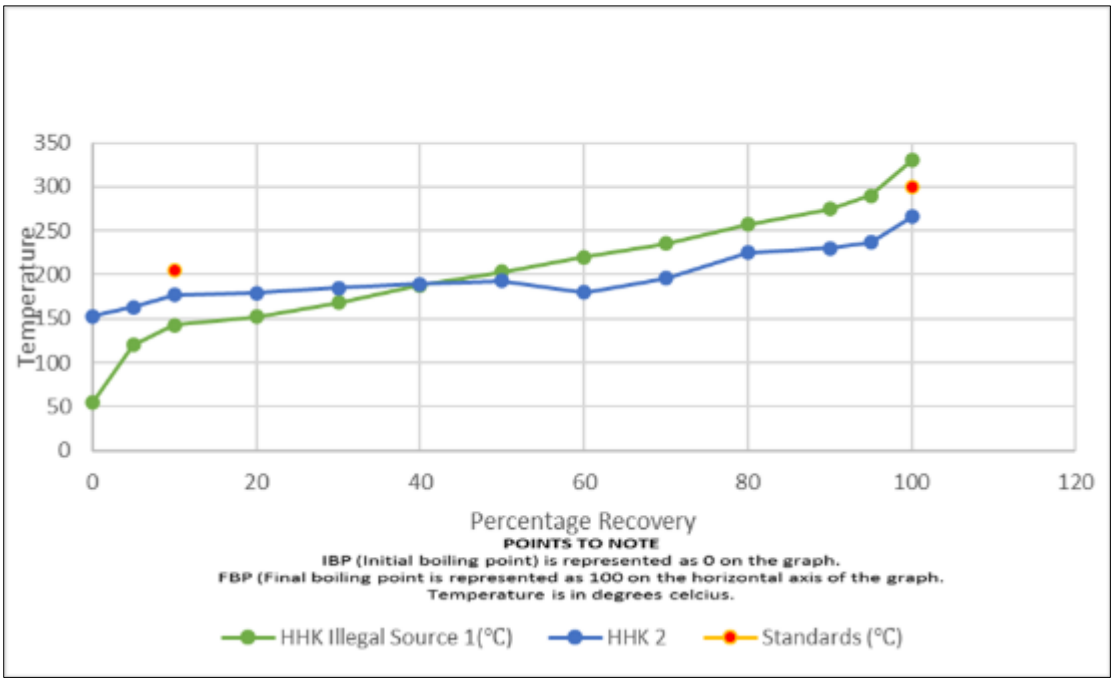


Figure 3 Distillation profile results for HHK samples from illegal refining source and certified suppliers

3.3.2. Flash Point for HHK Samples

The flash point of fuel is the temperature to which the fuel must be heated to produce an ignitable vapor-air mixture above the liquid fuel when exposed to an open flame. The flash point test is a guide to the fire hazard associated with the use of the fuel and can be determined by several test methods, but the results are not always strictly comparable. The minimum flash point is usually defined by the Abel method (IP 170), although the Pensky–Martens method (ASTM D-93, IP 34) may also be specified. In practice, flash point is important primarily for fuel handling. A flash point that is too low will cause fuel to be a fire hazard, subject to flashing test methods and possible continued ignition and explosion. In addition, a low flash point may indicate contamination by more volatile and explosive fuels, such as gasoline. Flash point is significant for safety in handling and use but not directly related to engine performance.

3.3.3. Other analysis results for HHK samples

Table 4 HHK flash point, density and API analysis results for ATK samples from illegal refining source and certified suppliers

	HHK SAMPLE 1	**HHK SAMPLE 2 g/ml**	**STANDARD**
FLASHPOINT	31 ℃	45 ℃	45 ℃(min)
DENSITY	0.8130	0.7630	0.7199-0.7797
API	42.55	54.0	

Flash point is basically volatility test and indicates how flammable a product is. Lower flash point values indicate that the samples in question will be more flammable compared to its standard. This is mostly caused by contamination with more volatile components.

House hold kerosene are products that should be home friendly and low flash point of this product will make it unsafe for use as the flammability of such products will automatically increase.

3.4. Density (Specific Gravity)

Density (or specific gravity) is an indication of the density or weight per unit volume of the diesel fuel. The principal use of specific gravity (ASTM D-l298, IP 160) is to convert weights of oil to volumes or volumes to weights. Specific gravity

also is required when calculating the volume of petroleum or a petroleum product at a temperature different from that at which the original volume was measured. Although specific gravity by itself is not a significant measure of quality, it may give useful information when considered with other tests. API gravity (ASTM D-1298, IP 160) is an arbitrary figure related to the specific gravity in accordance with the following formula: °API = (141.5/ (specific gravity @ 60/60 °F)) - 131.5.

4. Conclusion

Previous studies have shown that illegally refined gasoline in Nigeria has a low octane rating, which can negatively impact engine performance. However, the results of the current research indicate that the illegally refined gasoline samples met ASTM standards for octane rating, which may be due to the quality of crude used. Additionally, the flash point of kerosene was found to be low. This is believed to be a result of a lack of purification and poor refining techniques, as well as a lack of equipment and proper handling methods.

The findings of this study suggest that artisanal refined gasoline may have been poorly refined or adulterated, which could cause issues in automotive engines. The results of this research align with the understanding that artisanal refined petroleum products often do not meet the necessary standards.

This research work has also shown that adulteration of petroleum products has become prevalent in our times. Subsidy and price differential among HHK, PMS and AGO encourages diversion, scarcity, adulteration and consequently, explosions that have continually negatively affected individuals, homes and industries. Adulteration of petroleum products could be deliberate or inadvertent. Most of those involved in adulteration do it for economic gains. Adulterated petroleum products had been implicated in most explosions that were recorded in Nigeria. Each time such explosion occurred, the victims were usually abandoned both by the governments and the NNPC.

Compliance with ethical standards

Acknowledgments

Winifred Odili assisted during the laboratory and in collecting the samples, and she is greatly appreciated.

Disclosure of conflict of interest

The author declares no conflict of interest.

Author contribution statement

Blessing Amabogha developed, designed the experiments and wrote the paper and also performed the experiment Ebinimi Gbeinzi analyzed and interpreted the data.

Data availability statement

Data included in article/supp. material/referenced in article.

References

[1] Achuba, F.I (2006), The Effect of Crude Oil on Growth and Metaboliam of Cowpea Seedling, J. Environmentalist, Vol. 26, Pp 17-20.

[2] Adebayo E.A (1999), Introduction to Petroleum Processing, Clemol publishers, No.3 Kachiaroad, Bajume motors building,P.O.Box 1659, Kaduna, p 50.

[3] Adegeye, A.O., Ayodele L.A and Ufito L.A (1993), Effect of Oil Exploration on Forest and Wildlife Resources in Delta State of Nigeria, Proceedings of foresters association of Nigeria (FAN'93), Ikeja Lagos, Pp 45-52.

[4] Álvarez Flórez, J.A., Callejón Agramunt, I., Forns Farrús, S. Motores Alternativos de Combustión Interna (Alternative Internal Combustion Engines). España: Ediciones UPC; 2005. 513 pp. ISBN. 9788483018187.

[5] Al-Qahtani, M.R.A (2011), Effect of Oil Refinery Sludge on Plant Growth and Soil Properties, Res. J. Environmental Science, vol. 5, Pp 187-193.

[6] Arcadio, P. S and Gregoria A. S (2015) Environmental Engineering: A Design Approach 1st edition, Pearson India Education Service Pvt. LTD, India, P 15.

[7] Asimiea, A and Omokhua, G (2013), Environmental Impact of Illegal Refineries on the Vegetation of the Niger Delta of Nigeria, Journal of Agriculture and Social Research, vol. 13(2), Pp 121-126.

[8] ASTM (2005), Annual Book of ASTM Standards, American Society for Testing and Materials, West Conshohocken, PA.

[9] Altgelt, K.H. and Gouw, T.H. 1979. Chromatography in Petroleum Analysis. Dekker, New York.

[10] ASTM C1109. 2015. Standard Practice for Analysis of Aqueous Leachates from Nuclear Waste Materials Using Inductively Coupled Plasma-Atomic Emission Spectroscopy. Annual Book of Standards. ASTM International, West Conshohocken, PA.

[11] ASTM C1111. 2015. Standard Test Method for Determining Elements in Waste Streams by ASTM International, West Conshohocken, PA. ASTM D20. 2015. Standard Test Method for Distillation of Road Tars. Annual Book of Standards. ASTM International, West Conshohocken, PA.

[12] ASTM D56. 2015. Standard Test Method for Flash Point by Tag Closed Cup Tester. Annual Book of Standards. ASTM International, West Conshohocken, PA.

[13] PA. ASTM D86. 2015. Standard Test Method for Distillation of Petroleum Products at Atmospheric Pressure. Annual Book of Standards. ASTM International, West Conshohocken, PA. ASTM D87. 2015. Standard Test Method for Melting Point of Petroleum Wax (Cooling Curve). Annual Book of Standards. ASTM International, West Conshohocken, PA.

[14] ASTM D92. 2015. Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester. Annual Book of Standards. ASTM International, West Conshohocken, PA.

[15] ASTM D93. 2015. Standard Test Methods for Flash Point by Pensky-Martens Closed Cup Tester. Annual Book of Standards. ASTM International, West Conshohocken, PA.

[16] ASTM D97. 2015. Standard Test Method for Pour Point of Petroleum Products. Annual Book of Standards. ASTM International, West Conshohocken, PA.

[17] ASTM D287. 2015. Standard Test Method for API Gravity of Crude Petroleum and Petroleum Products (Hydrometer Method). Annual Book of Standards. ASTM International, West Conshohocken, PA.

[18] ASTM D323. 2015. Standard Test Method for Vapor Pressure of Petroleum Products (Reid Method). Annual Book of Standards. ASTM International, West Conshohocken, PA.

[19] ASTM D341. 2015. Standard Practice for Viscosity-Temperature Charts for Liquid Petroleum Products. Annual Book of Standards. ASTM International, West Conshohocken, PA.

[20] ASTM D445. 2015. Standard Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity). Annual Book of Standards. ASTM International, West Conshohocken, PA.

[21] ASTM D1160. 2015. Standard Test Method for Distillation of Petroleum Products at Reduced Pressure. Annual Book of Standards. ASTM International, West Conshohocken, PA.

[22] ASTM D1217. 2015. Standard Test Method for Density and Relative Density (Specific Gravity) of Liquids by Bingham Pycnometer. Annual Book of Standards. ASTM International, West Conshohocken, PA.

[23] ASTM D1298. 2015. Standard Test Method for Density, Relative Density, or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method. Annual Book of Standards. ASTM International, West Conshohocken, PA.

[24] Boym, G., William, L., and Ali, G (2007), Petroleum Production Engineering, A computer assisted approach, 1st edition, Elser science and technology books, University of Louisianaat Lafayette, Pp 4-6.

[25] David, C., Tamm, G. N., Devenish, D. R., and Finelt Kalt, A. L. (2018). Analysis of Gasoline Octane Costs. U.S. Energy Information Administration, Baker and O'Brien, Inc. 1333 West Loop South Suite 1350 Houston, Texas 77027.

[26] Dott, R.H. Hypotheses for an organic origin (1969), In Sourcebook for Petroleum Geology, Part 1. Genesis of Petroleum. R.H. Dott and M.J. Reynolds (Eds). AAPG Memoir 5, Tulsa,; pp. 1-244.

[27] Evbuomwan B.O and Alete O. G (2020) Comparative Analysis of Locally Refined Petroleum Product (Diesel) In Niger Delta Region, Nigeria American Journal of Engineering Research pp-25-32

[28] Goodnews, M. M., and Wordu, S. A. (2019). Analysis of trend and emergent factors of artisanal refining in the niger delta region of Nigeria. Int. J. Innovat. Human Ecol. Nat. Stud. 7, 43–55.

[29] Godwin J., Joachim J., Emaime J., Ifiok O., and Igwe R. (2020), Comparative Analyses of Physicochemical Properties of Artisanal Refined Gasoline and Regular Automotive Gasoline, Front. Chem., Sec. Physical Chemistry and Chemical Physics https://doi.org/10.3389/fchem.2020.00753 Petroleum and Geochemistry Research Group, Department of Chemistry, Akwa Ibom State University, Uyo, Akwa Ibom State, Nigeria 2NNPC Towers, Abuja, Nigeria

[30] Hendsbee, J. A., Thring, R. W., and Dick, D. G. (2006). Raney nickel for the desulphurization of FCC gasoline. J. Can. Petrol. Tech. 45, 1–4. doi: 10.2118/06-11-06

[31] ISO 3405:(2000), Petroleum products. Determination of distillation characteristics at atmospheric pressure.

[32] Kenney, J.F(1996), Considerations about recent predictions of impending shortages of petroleum evaluated from the perspective of modern petroleum science, Energy World, 240, 1618.

[33] Speight, J.G. (1987). Initial reactions in the coking of residua. Preprints. American Chemical Society, Division of Petroleum Chemistry, 32(2): 413.

[34] Speight, J.G. (1994), Chemical and physical studies of petroleum asphaltenes. In: Asphaltenes and Asphalts, I. Developments in Petroleum Science, 40. T.F. Yen and G.V. Chilingarian (Editors). Elsevier, Amsterdam, the Netherlands, Chapter 2.

[35] Speight, J.G. (2000), The Desulfurization of Heavy Oils and Residua, 2nd Edition. Marcel Dekker, New York.

[36] Speight, J.G. (2001), Handbook of Petroleum Analysis. John Wiley & Sons, Hoboken, NJ. Speight, J.G. (2005), Natural bitumen (tar Sands) and heavy oil. In: Coal, Oil Shale, Natural Bitumen, Heavy Oil and Peat. Encyclopedia of Life Support Systems (EOLSS). Developed under the Auspices of the UNESCO. EOLSS Publishers, Oxford, UK.

[37] Speight, J.G. (2009), Enhanced Recovery Methods for Heavy Oil and Tar Sands. Gulf Publishing Company, Houston, TX.

[38] Speight, J.G. (2014), The Chemistry and Technology of Petroleum, 5th Edition. CRC Press/Taylor & Francis Group, Boca Raton, FL.

[39] Speight, J.G. (2015), Handbook of Petroleum Product Analysis, 2nd Edition. John Wiley & Sons, Hoboken, NJ.

[40] Speight, J.G. and Ozum, B. (2002), Petroleum Refining Processes. Marcel Dekker, New York.

[41] Speight, J.G., Wernick, D.L., Gould, K.A., Overfield, R.E., Rao, B.M.L., and Savage, D.W. (1985), Molecular weights and association of asphaltenes: A critical review. Revue de l'Institut Français du Pétrole, 40: 27.

[42] Udo GJ, Awaka-Ama JJ, Uwanta EJ, Ekwere IO and Chibueze IR (2020) Comparative Analyses of Physicochemical Properties of Artisanal Refined Gasoline and Regular Automotive Gasoline. Front. Chem. 8:753. doi: 10.3389/fchem.2020.00753

[43] U.Z. Faruq, M. Runde, B.G. Danshehu, H.N. Yahaya, A.A. Zuru and A.B. Muhammad (2012) Comparative Studies of Gasoline Samples Used in Nigeria 87-92

[44] Vempatapu, B. P., and Kanaujia, P. K. (2017). Monitoring petroleum fuel adulteration: a review of analytical methods. Trends Analyt. Chem. 92, 1–11. doi: 10.1016/j.trac.2017.04.011CrossRef Full Text | Google Scholar

[45] Yabrade, M., and Tanee, B. G. (2016). Assessing the impact of artisanal petroleum refining on vegetation and soil quality: a case study of warri south west salt Wetland of Delta State, Nigeria. Res. J. Environ. Toxicol. 10, 205–212. doi:10.3923/rjet.2016.205.212