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Effect of Adulterating Household Kerosene with Condensate Fuel

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Abstract

Seven combustible mixtures of condensate / kerosene were evaluated with the aim to delimit the extent at which the adulteration of kerosene (HHK) with condensate samples from two different sources becomes hazardous for domestic use. Results of the quality assurance test (low flash point, high flame height, high flame width, low smoke point) show that 3-100 % v/v of condensate in the adulterated blends are undesirable for domestic purposes. Condensate-adulterated kerosene has been tagged the 'killer product' because of the high degree of burns associated with its explosion.

Keywords: Autoignition, firepoint, vapour pressure, aromatic condensates, burning quality, household kerosene (HHK), smoke point, flash point, flame height, flame width.

Introduction

In Nigera, a considerable recoverable reserve of Petroleum condensates (reservoir gases that condense to colorless or light yellow hydrocarbons when produced) has been discovered in the Niger Delta, the most significant hydrocarbon province in the West African continental margin. Condensates from this region have been characterized as highly combustible with an API (American Petroleum Institute) gravity generally higher than 55^0 at a temperature of 15.6^0 C and normal atmospheric pressure. They also have a gas/oil ratio (GOR) exceeding 5000 standard cubic feet per barrel of oil (scf/bbl). They are mainly composed of saturated hydrocarbons in the light range (butanes, pentanes and hexanes). However, condensates with a high percentage of aromatic or naphthenic hydrocarbons have been found in the basins of the Gulf Coast, Canada, Russia and Isreal. Such condensates are superior to the typical paraffinic type as gasoline feedstock[1-5]. Aromatic Condensates are formed by evaporative fractionation during vertical migration particularly in deltas.

On the other hand the word 'kerosene' was registered as a trademark by Abraham Gesner in 1854 and for several years only the North American gas light company and the Downer company (to which Gesner had granted the right) were allowed to call their lamp oil kerosene. However, it eventually became genericized[6]. The heat of combustion of kerosene is similar to that of diesel, its lower heating value is 18,500Btulb or 43.1mJ/kg and its higher heating value is 46.2MJ/kg. Kerosene is a thin, clear liquid formed from hydrocarbons with density of 0.78 – 0.81g/cm^3. It is a middle distillate mixture of hydrocarbons meeting Bureau of India standard specification (BIS) (Is 1459/1974) with important characteristics of flash point at a minimum of 35^0C and a smoke point at minimum of 18mm[7]. Kerosene is obtained from fractional distillation of petroleum between 150^0C and 275^0C, resulting in a mixture of carbon chains containing 12 to 15 carbon atoms[8].

Our group attempted to characterize some condensate samples from two gas reservoirs, namely; Gbaran gas field, owned and controlled by SPDC, located in Bayelsa State of the Niger Delta and Utoruogu gas field owned and controlled by Chevron/Texaco located in Delta State still of the Niger Delta. Condensates were obtained from two wells within each reservoir. Experiments were carried out in this study to discover how and if the sources of these condensates affect their characteristics as well as their effect when used as adulterants on petroleum products. The essence of obtaining condensates from specific wells and comparing their effects on condensates from other wells and reservoirs is also to ensure repeatability and reproducibility. We used bulk quality assurance parameters such as flash point, flame height, flame width and smoke point to ascertain the extent at which such adulterations become hazardous to humans when used domestically, by implication, we shall attempt to expose the defects of the adulterated product and where they are none, to increase the quality assurance and trust of consumers.

Flash Point: The flash point of a fuel is the lowest temperature at which the fuel vaporizes enough to form a combustible vapour. These temperatures vary according to the fuel in question[9]. It is an index of the fuel's potential safety when being handled or when in storage[8]. JP-S fuels must have a flash point of at least 140^0F to have the high safety factor required for storage aboard in aircraft carrier in unprotected tanks. The flash point of a volatile liquid is the lowest temperature at which it can vaporize to form an ignitable mixture in air. Measuring a liquid's flashpoint requires an ignition source. This is not to be confused with the autoignition temperature, which requires no ignition source. At the flash point, the vapour may cease to burn when the source of ignition is removed. At slightly higher temperature, the fire point, is defined as the temperature at which the vapour continues to burn after being ignited. Neither of these parameters is related to the temperatures of the ignition source or of the burning liquid, which are much higher[10]. Flash point refers to both flammable liquids as well as combustible liquids. There are various international standards for defining each, but most agree that liquids with a flash point less than 43°C are flammable, and those above this temperature are combustible[11]. Every flammable liquid has a vapour pressure, which is a function of that liquid's temperature. As the temperature increases, the vapour pressure increases. As the vapour pressure increases, the concentration of evaporated flammable liquid in the air increases. Hence, temperature determines the concentration of evaporated flammable liquid in the air. Each flammable liquid requires a different concentration of its vapour in air to sustain combustion[9].

Burning Quality: This refers to the qualitative determination of the burning properties of kerosene (HHK) to be used for illuminating purposes. It is an exclusive test for HHK. The corresponding Institute of Petroleum (IP) test method (IP 10) featured a quantitative evaluation of the wick-char-forming tendencies of kerosene (HHK) whereas Test Method D 187 features a qualitative performance evaluation of kerosene (HHK). Both methods subject the kerosene to somewhat more severe operating conditions than would be experienced in typical designated applications. The average rate of burning, the change in the shape of the flame (flame height and flame width), the density and color of the chimney deposit are reported. It is desirable to dedicate a suitable room for the exclusive conduct of kerosene burning tests. However, kerosene burning tests can be conducted in any part of a room that is adequately ventilated and reasonably free of drafts[12].

Smoke Point: This refers to the maximum height, in millimetres, of a smokeless flame of fuel burned in a wick-fed lamp of specified design. The test method for the determination of smoke point of HHK provides an indication of the relative smoke producing properties of kerosene and aviation turbine fuels in a diffusion flame. The smoke point is related to the hydrocarbon type composition of such fuels. Generally the more aromatic the fuel the smokier the flame. A high smoke point indicates a fuel of low smoke producing tendency. The smoke point (and Luminometer number with which it can be correlated) is quantitatively related to the potential radiant heat transfer from the combustion products of the fuel. Because radiant heat transfer exerts a strong influence on the metal temperature of combustor liners and other hot section parts of gas turbines, the smoke point provides a basis for correlation of fuel characteristics with the life of these components[13].

Material and Methods

Materials and Methods: House hold kero (HHK) was collected from the Nigerian National Petroleum Corporation (NNPC) while the petroleum condensate samples were collected from Gbaran and Utoruogu reservoirs of the Niger Delta Nigeria.

Blending of Condensate/Ago Samples: Test samples (condensate / HHK mixtures) were blended into 7 different proportions (ie Pure HHK, Pure Condensate and 1, 2, 3, 4, 5 % (v/v) condensate / HHK blend. The blends and pure samples were refrigerated at 35^0 F (2^0 C) to avoid evaporation of volatile components[2].

Determination of the Flash Point of Condensate/HHK Samples: Abel flash point testers are used in measuring the flash point of HHK and blended samples because of the high volatility of HHK as well as that of the condensate. A 100 ml of the sample is Introduced into a flash point tester. Introduce naked flames on the sample through an intermediary medium in the form of a liquid. The naked flame is intermittently introduced into the sample through the medium every 2^0C rise in temperature. The heating is minimal and therefore good for light samples. The temperature at which the flame is extinguished is the flash point.

Determination of the Burning Quality of Condensate/HHK Samples: Dry the wick of the lantern in an oven at 105°C for 1 h. While still hot, soak the wick in the sample and insert the wick into the wick guide. Rinse the reservoir several times with the sample. Filter the sample through a coarse textured filter paper, to remove suspended matter and pour 900 ml into the reservoir and assemble the lamp. After the wick has been trimmed and the chimney washed, allow the lamp to burn for 0.5 h and readjust the flame to the standard dimensions. At the end of this period weigh the lamp, while burning, to the nearest 1 g on a platform balance. Weigh again after 1 h. If the rate of sample consumption differs from 22 +/- 4 g/h, check the flame dimensions and wick condition for further trimming. Allow the sample to burn continuously without further adjustment of any kind for the duration of the test, which shall be 16 h (or other specified period) of continuous burning after the first weighing. At the end of this period reweigh to the nearest 1 g and record any changes in height, width, or shape of the flame to the nearest 1 mm and examine the density and color of the chimney deposit[12].

Determination of the Smoke Point of Condensate/HHK Samples: Soak a piece of extracted and dried wick, not less than 125 mm long, in the sample and place it in the wick tube of the candle. Carefully ease out any twists arising from this operation. Introduce as near to 20 ml of the prepared sample as available, but not less than 10 ml, at room temperature, into the clean, dry candle. Place the wick tube in the candle and screw home. Light the candle and adjust the wick so that the flame is approximately 10 mm high and allow the lamp to burn for 5 min. Raise the candle until a smoky tail appears, then lower the candle slowly. Determine the height of this Flame to the nearest 0.5 mm. Record the height observed. Make three separate observations of the flame height at the smoke point by repeating the flame-appearance sequence specified above. If these values vary over a range greater than 1.0 mm, repeat the test with a fresh sample and another wick. Remove the candle from the lamp, rinse with heptane, and purge with air to make ready for re-use[13].

Results and Discussion

Flash Point of Kerosene (HHK) And Blended Samples: The flash point of kerosene (HHK), Condensate and Condensate /HHK blended samples were obtained in table 1. According to ASTM, the minimum allowable flash point for HHK is 45 ^{0}C . Table 1 show that only a maximum of 2 % Gbaran-15(1) and Gbaran-15(2) condensate could pass the flash point test when blended with HHK, this implies that HHK blended with up to 3 % of the condensate from the Gbaran-15 reservoir may cause explosion. On the other hand, up to 3 % of the condensates obtained from the Utoruogu reservoir passed the flash point test when blended with HHK. This draws the inference that condensates from Utoruogu reservoir are safer in terms of handling than condensates from Gbaran-15 reservoir.

Burning Quality of HHK and Blended Samples: The burning quality of HHK is considered in terms of its flame height, flame width, burning rate as well as the colour and density of its chimney deposits.

Flame Height of HHK and Blended Samples: The flame height of the control sample and adulterated Gbaran-15 condensate / HHK blends were given in table 2. From the table it can be deduced that the flame height increases with increase in the amount of Gbaran-15(1) and Gbaran-15(2) condensates. According to ASTM, the safest maximum flame height for HHK is 36.2 mm and the most efficient minimum flame height for HHK is 32.2 mm. Table 2 shows that the minimum allowable amount of Gbaran-15(1) condensate that can pass the flame height test after being blended with HHK is 2%, whereas the minimum allowable amount of Gbaran-15(2) condensate that can pass the flame height test after being blended with HHK is 1%, making Gbaran-15(2) condensate a better condensate in terms of its effect on the burning quality of HHK, however both condensates failed the burning quality test according to ASTM. An amount of Gbaran-15(1) condensate added to HHK above 2 % will definitely not be a safe act and might cause explosion, whereas an amount of Gbaran-15(2) condensate above 1 % might be harzardous when blended with HHK. It is also shown that only a maximum of 2 % Utoruogu condensate passed the flame height test just like Gbaran-15(1) condensate. It was also deduced from the table that pure HHK passed the flame height test.

Flame Width of HHK and Blended Samples: Table 3 shows the flame width of HHK and adulterated Gbaran-15(1) and Gbaran-15(2) condensate / HHK blends. Just like the flame height, it can also be deduced that the flame width increases with increase in the amount of condensate. According to ASTM, the safest maximum flame width for HHK is 37.8mm and the most efficient minimum flame width for HHK is 33.8mm. Table 3 show that the minimum allowable amount of Gbaran-15(1) condensate that can pass the flame width test after being blended with HHK is 2%, whereas the minimum allowable amount of Gbaran-15(2) condensate that can pass the flame width test after being blended with HHK is 1%, confirming Gbaran-15(2) condensate a better condensate in terms of its effect on the burning quality of HHK, however both condensates failed the flame width test according to ASTM. It is also shown that only a maximum of 2 % Utoruogu condensate passed the flame width test just like Gbaran-15(1) condensate. It was also deduced from the Table that pure HHK passed the flame width test.

Burning Rate of HHK And Blended Samples: Table 4 show the burning rate of HHK and adulterated Gbaran-15(1) and Gbaran-15(2) condensate / HHK blends. From the table it can be deduced that the burning rate increases with increase in the amount of Gbaran-15 condensate blended with HHK. According to ASTM. The safest maximum burning rate for HHK is 26.5g/h, while the most efficient minimum burning rate is 22.5g/h. Burning rate refers to the quantity of the sample burnt in every hour. From the table it can be deduced that the minimum allowable amount of Gbaran-15(1) condensate that can pass the burning rate test is 2%. 3% of Gbaran-15(1) condensate blended with HHK will definitely exceed the ASTM maxima in terms of burning rate, whereas only a maximum of 1 % Gbaran-15(2) condensate passed the burning rate test when blended with HHK. It can also be shown that Gbaran-15(1) condensate exceeded ASTM maxima in terms of burning rate while pure HHK fell within ASTM maxima in terms of burning rate. The burning rate of condensates from Utoruogu reservoir were also shown. Results from the Table show that only a maximum of 2 % Utoruogu condensate passed the burning rate test when blended with HHK.

Table 5 show the colour and density of deposits obtained after burning HHK and blended samples. The colour and density of the deposits are recorded as light, none, white, yellow and medium. Colours and densities that are in accordance with ASTM specifications are recorded as light, none and white, while those that are not in accordance with ASTM specification are recorded as yellow and medium. These Tables indicate that only HHK and its blend with a maximum of 2% fall within ASTM maxima

Smoke Point of Kerosene (HHK) and Blended Samples: The smoke point of control sample (HHK), condensate and adulterated Gbaran-15(1), Gbaran-15(2), Utoruogu-FI(1) and Utoruogu-FI(2) condensates / HHK blends were given in Table 6. From the table, it can be deduced that the smoke point decreases with increase in the amount of condensate added. Fuels with very low smoke points have been found to be more flammable than the ones with high smoke points. Two readings were obtained to confirm repeatability. According to ASTM, smoke point of HHK for household purposes must not be below 30mm. It can be deduced that only an adulteration of a maximum of 2% of all the condensates under study could pass a smoke point test when blended with HHK. These tables also show that the smoke point of these condensates fall below the ASTM maxima. The fact that condensates have low smoke point may not be unassociated with the fact that condensates generally are made up of more parrafins than aromatics. The more the aromatic content of the fuel the smokier the fuel[13].

Table- 1
Flash Point of HHK and Condensate/HHK Blended Samples

	HHK	5:95(%)	4:96(%)	3:97(%)	2:98(%)	1:99(%)
GBARAN-15(1)	54^0 C	25^0 C	30^0 C	36^0 C	45^0 C	52^0 C
GBARAN-15(2)	54^0 C	25^0 C	32^0 C	40^0 C	47^0 C	53^0 C
UTORUOGUFI(1)	54^0 C	31^0 C	38^0 C	46^0 C	49^0 C	53^0 C
UTORUOGUFI(2)	54^0 C	31 ^{0}C	37 ^{0}C	46 ^{0}C	49 ^{0}C	53 ^{0}C

Table–2
Flame Height of HHK and Condensate / HHK Blended Samples

	COND	**HHK**	**5:95(%)**	**4:96(%)**	**3:97(%)**	**2:98(%)**	**1:99(%)**
GBARAN-15(1)	56.3mm	34.7mm	42.2mm	39.2mm	37.3mm	36.1mm	35.2mm
GBARAN-15(2)	56.4 mm	34.7mm	42.9mm	39.5mm	38.6mm	37.0mm	36.6mm
UTORUOGUFI(1)	54.3mm	34.7mm	40.8mm	38.3mm	37.7mm	36.0mm	35.1mm
UTORUOGUFI(2)	54.2mm	34.7mm	40.3mm	38.0mm	37.3mm	35.9mm	35.1mm

Table–3
Flame Width of HHK and Condensate/HHK Blended Samples

	COND	HHK	5:95(%)	4:96(%)	3:97(%)	2:98(%)	1:99(%)
GBARAN-15(1)	9.1mm	35.8mm	44.0mm	41.6mm	39.2mm	37.6mm	36.5mm
GBARAN-15(2)	59.3mm	35.8mm	48.0mm	42.1mm	39.6mm	38.2mm	36.9mm
UTORUOGUFI(1)	56.9mm	35.8mm	46.0mm	40.7mm	38.5mm	37.6mm	36.2mm
UTORUOGUFI(2)	56.9mm	35.8mm	46.0mm	40.7mm	38.4mm	37.3mm	36.0mm

Table–4
Burning Rate of HHK and Condensate/ HHK Blended Samples

	COND	HHK	5:95(%)	4:96(%)	3:97(%)	2:98(%)	1:99(%)
GBARAN-15(1)	48.5 g/h	24.8 g/h	34.1 g/h	32.2 g/h	28.4 g/h	26.5 g/h	25.5 g/h
GBARAN-15(2)	48.4 g/h	24.8 g/h	34.2 g/h	32.6 g/h	28.8 g/h	26.7 g/h	25.7 g/h
UTORUOGUFI(1)	48.1 g/h	24.8 g/h	32.0 g/h	29.8 g/h	27.2 g/h	25.7 g/h	25.1 g/h
UTORUOGUFI(2)	48.1 g/h	24.8 g/h	32.0 g/h	29.6 g/h	27.1 g/h	25.5	25.1 g/h

Table–5
Colour/Density of Chemney Deposit of HHK and Condensate / HHK Blended Samples

	HHK	5:95(%)	4:96(%)	3:97(%)	2:98(%)	1:99(%)
GBA-15(1)	None/None	Yellow/ Medium	Yellow/ Medium	Yellow/Medium	White/Light	None/Light
GBA-15(2)	None/None	Yellow/ Medium	Yellow/ Medium	Yellow/Medium	White/Light	None/Light
UTOFI(1)	None/None	Yellow/ Medium	Yellow/ Medium	Yellow/Medium	White/Light	None/Light
UTOFI(2)	None/None	Yellow/ Medium	Yellow/ Medium	Yellow/Medium	White/Light	None/Light

Table–6
Smoke Point of HHK and Condensate /HHK Blended Samples

	COND	HHK	5:95(%)	4:96(%)	3:97(%)	2:98(%)	1:99(%)
GBARAN-15(1)	14.6 mm	42.8 mm	20.2 mm	22.6 mm	25.7 mm	31.2 mm	35.6 mm
GBARAN-15(2)	14.6 mm	42.8 mm	20.3 mm	22.6 mm	25.7 mm	31.2 mm	35.4 mm
UTORUOGUFI(1)	15.6 mm	42.8 mm	22.2 mm	24.9 mm	27.7 mm	33.4 mm	37.1 mm
UTORUOGUFI(2)	15.6 mm	42.8 mm	22.2 mm	24.9 mm	27.7 mm	33.4 mm	36.9 mm

Table-7
Characterisation of Gbaran-15(1) Condensate

Component	**Mol %**	**Grp mol%**
C2	0.07	0.07
C3	0.16	0.16
I-C4	0.12	0.12
N-C4	0.34	0.34
I-C5	0.35	0.35
N-C5	0.50	0.50
C-C5	0.00	0.00
N-C6	2.16	2.16
MC-C5	1.14	
Bz	0.05	
cC6	3.18	
N-C7	7.06	11.43
MC-C6	6.70	
Tol	2.64	
N-C8	8.73	18.07
Ethyl B	0.13	
P and M- XY	1.74	
O- XYL	2.68	
C9	10.02	14.57
C10	10.26	10.26
C11	5.28	5.28
C12	5.69	5.69
C13	6.75	6.75
C14	5.27	5.27
C15	4.92	4.92
C16	3.15	3.15
C17	2.11	2.11
C18	1.96	1.96
C19	1.11	1.11
C20	0.65	0.65
C21	0.53	0.53
C22	0.52	0.52
C23	0.41	0.41
C24	0.29	0.29
C25	0.26	0.26
C26	0.23	0.23
C27	0.20	0.20
C28	0.11	0.11
C29	0.09	0.09
C30+	2.46	2.46
	100.00	100.00

Molar mass		157.68			
Density		0.8134			
Mol.% C7+	96.30	**Mol%C12+**	36.70	**Mol. % C20+**	5.75
Mol.wt C7+	160.84	**MolwtC12+**	232.83	**Mol.wt.C20+**	426.54
DensityC7+	0.82	**DensityC12+**	0.87	**DensityC20+**	0.96

Table-8
Characterisation of Gbaran-15(2) Condensate

Component	**Mol %**	**Grp mol%**
C2	0.02	0.02
C3	0.06	0.06
I-C4	0.06	0.06
N-C4	0.21	0.21
I-C5	0.24	0.24
N-C5	0.41	0.41
C-C5	0.00	0.00
N-C6	2.41	2.41
MC-C5	1.30	
Bz	1.14	
cC6	2.89	
N-C7	6.48	11.81
MC-C6	6.18	
Tol	2.46	
N-C8	5.07	13.72
Ethyl B	0.08	
P&M- XY	1.43	
O- XYL	2.20	
C9	8.50	12.21
C10	7.32	7.32
C11	6.22	6.22
C12	6.02	6.02
C13	8.24	8.24
C14	7.04	7.04
C15	6.52	6.52
C16	4.23	4.23
C17	3.08	3.08
C18	2.80	2.80
C19	1.48	1.48
C20	0.80	0.80
C21	0.69	0.69
C22	0.61	0.61
C23	0.53	0.53
C24	0.44	0.44
C25	0.34	0.34
C26	0.26	0.26
C27	0.21	0.21
C28	0.14	0.14
C29	0.08	0.08
C30+	1.78	1.78
	100.00	100.00

Molar mass		164.09			
Density		0.8168			
Mol.% C7+	96.58	**Mol%C12+**	45.30	**Mol. % C20+**	5.89
Mol.wt C7+	167.11	**MolwtC12+**	224.39	**Mol.wt.C20+**	392.55
DensityC7+	0.82	**DensityC12+**	0.86	**DensityC20+**	0.94

Conclusion

The quality assurance parameters considered in this study are very key in choosing kerosene suitable for household purposes. The volatility and burning quality of kerosene are of utmost importance in determining the quality of kerosene. The volatility of kerosene is measured in terms of flash point while the burning quality is measured in terms of the flame height, flame width, colour and density of chimney deposits as well as the smoke point. The volatility characteristic of the condensates used in this study were affected by the sources of condensate as condensates from Utoruogu reservoir tend to have a higher flash point than those from Gbaran reservoir, however the burning quality of condensates from both reservoirs (Gbaran and Utoruogu) were unaffected except for a slight drift in the burning quality of Gbaran-15(2) condensate making it the poorest of the condensates used in terms of burning quality. An assessment of our results points to the undesirability of the adulterated Gbaran condensate / kerosene and Utoruogu condensate / kerosene blends for household purposes, especially in the case of 3 – 100 % (v/v) condensate / kerosene blends. This is due to the low flash point, high flame height and width, low smoke point of the adulterated blends.

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