

# Density, Distillation, FT-IR and FIA for Rapid Determination of Adulterant Kerosene in Gasoline and Diesel

Chebii Paul, Munyendo Were, Kiprop Ambrose, Mitei Yulita Cheruiyot, Joseph Barmao

**Abstract-** Use of adulterated fuels has been escalating over the years due to lack of appropriate analytical tools for rapid detection resulting in detrimental effects to motor engines, environment and to the economy. Kerosene is a widespread adulterant added to gasoline and diesel. It is extensively used because of its financial gains and ease of blending. In this study attempt has been made to develop a combination analytical tool for rapid detection of kerosene adulteration by evaluating samples of gasoline and diesel; determining the adulteration intensity; compare detection limits of Fourier Transform Infrared (FTIR) and Fluorescent Indicator Adsorption (FIA); then evaluate detection aptitude of the methods. Suspected adulterated gasoline and diesel were collected systematically in seven selected locations within Eldoret, Kenya. References were traced from Eldoret pipeline depot up to the shipper's dispensing station. Arrays of six blend mixtures of kerosene with either gasoline or diesel were prepared as custom proportions for comparison as adulteration contour. Density tests, fractional distillation, FIA and FTIR spectroscopy were carried out for characterization. Results showed appreciable density variation at different levels with the lowest density of 0.7373 and 0.8199 Kg/l obtained for gasoline and diesel respectively compared to 0.7374 and 0.8345 Kg/l for the standards which implied an element of adulteration. Fractional distillation provided appropriate indicator for adulteration as evident from the samples distillation end points of 234.0°C being a rise by 20.0°C for gasoline while 382.0°C for diesel being a fall of 4.0°C. FTIR provided preliminary qualitative data by peaks in the region 2950 – 3200 cm<sup>-1</sup> which varied in intensity with adulteration. FIA showed exhaustive results qualitatively as it was able to classify samples as olefins, saturates and aromatics. The study therefore fronts Density tests, Fractional distillation, and FTIR and FIA techniques for rapid determination of adulterant kerosene.

**Keywords:** Density, Distillation, FIA, FTIR, Kerosene.

## I. INTRODUCTION

Diesel, gasoline and kerosene is a mixture of hundreds of hydrocarbons of different boiling points. The hydrocarbons present in petroleum vary in composition depending on the origin of raw crude oil. The hydrocarbons present may therefore be classified basically into four classes namely; paraffin's, cycloparaffins, olefins and aromatics. Gasoline being the major fraction boils and distills over temperatures ranging as wide as from 30°C to 210 °C [1, 2]. It is also a mixture of volatile, flammable liquid hydrocarbons derived from petroleum [3].

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Gasoline is classified as a motor spirit and it is used as fuel for internal combustion of engines such as in motor vehicles. Other hydrocarbon constituents in this boiling range are those that have 4–12 carbon atoms in their molecular structure generally paraffin's (cyclo-paraffins and branched materials), olefins, and aromatics. Gasoline boils at about the same range as naphtha (a precursor to gasoline) but below kerosene [4]. Kerosene referred to as paraffin or paraffin oil is intermediate in volatility between gasoline and diesel oil that distills between 125°C and 260°C [5]. It is a refined petroleum distillate with a flash point of about 35°C. It is found to be suitable for use as an illuminant when burned in a lamp. Kerosene is also considered as dual purpose since it could 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 streams which is referred to as cracked kerosene [6]. Diesel is usually referred to as petrodiesel to distinguish it from diesel obtained from other sources such as biodiesel [7]. It is classified under distillates and is a hydrocarbon mixture obtained from fractional distillation of crude oil between 250°C and 350°C. Diesel and gasoline are the main transport fuels in Kenya which makes them the target for adulteration. The magnitude of the problem of fuel adulteration has grown into alarming proportions in the past few years [8]. In Kenya adulteration is carried out by the introduction of foreign substance into a petroleum product which results in the product not conforming to the requirements and specifications. When introduced the adulterants alter and degrade the quality of the base transport fuels [9]. Past research showed that addition of kerosene in gasoline results in higher levels of hydrocarbons emissions of carbon monoxide and particulate matter, even in catalyst equipped cars [10]. The choice of the adulterant is based on several factors including the financial gains, ease of blending, availability and the similarity of the chemical and physical properties of the fuel adulterant [11]. The overlapping properties of kerosene and diesel have been noted to attract illegal mixing of kerosene in high priced diesel for monetary gains [12]. Adulteration of this fuel is increasing because fuel dealers want to make huge benefits from their sale not taking into consideration the detrimental effects to motor engines, the environment and to the economy. The menace is widespread throughout the world and Kenya is no exception [13]. Adulteration of these consumer products is of great concern to the nation. Gasoline (mogas) and diesel (distillates) are most widely adulterated with kerosene due to their heavy demand, high prices and occasional supply scarcity [14]. A substantial number of petroleum dispensing sites have taken advantage of the lack of adequate enforcement mechanism to

adulterate petroleum products. However the government of Kenya through the Energy Regulatory Commission (ERC) is trying to put in place measures to limit this problem by penalizing culprits but in the latest report fuel adulteration is still persistent and rampant [15]. This is one of the reasons for oil marketers suggesting that tax on kerosene be reinstated to curb its use in adulterating products by some operators [15]. In Kenya the purity standards of fuels are governed by the (ERC) established under the Energy Act No 12 of 2006 [16].

In Kenya, data related to adulteration of gasoline and diesel fuel with different composition of kerosene is lacking. Recent analysis by energy and regulation commission on adulteration was only done at Petroleum outlets in western region and no petrol station in Eldoret was banned for offering for sale, adulterated product [16]. In most of the laboratories the samples are analyzed for adulteration based on physical parameters which are quite inaccurate. Unfortunately, adulterated diesel samples with 30% kerosene get passed on the basis of these specifications and methodologies that only focus on preliminary physical parameters like distillation range, specific gravity, and opacity measurement of intrinsic modulated fiber optical density [17]. Despite the fact that advanced analytical instruments like gas chromatography, mass spectrometry, distillation analyzer and flash point help the measurement of adulterations in diesel and different fuels, the results for hydrocarbons in diesel ( $C_9$  to  $C_{19}$ ) and kerosene ( $C_6$  to  $C_{16}$ ) do overlap hence to date definite conclusion cannot be drawn. The above methods are therefore not useful for detection of adulteration in lower concentrations. There is also lack of a rapid analytical methods for testing fuel samples and hence the motivation of this study to establish feasibility for use of analytical techniques which gives easily interpretable results to both scientist and consumers. It is of paramount importance to avail the end user with optimized indicators for detection of possible adulteration [18]. Thus to establish the extend of adulteration this work reports on an evaluation of Gasoline and Diesel samples for adulteration; determination of adulteration intensity for kerosene in Gasoline and Diesel by Fluorescent indicator adsorption (FIA) and Fourier Transform Infrared Spectroscopy (FTIR) and finally detection limits of the combinatory analytical techniques density test, fractional distillation, Fourier Transform Infrared Spectroscopy and Fluorescent indicator adsorption for gasoline and diesel adulteration.

## II. MATERIAL AND METHODS

In all cases analytical grade reagents were used unless stated otherwise. These included; FIA Standard Dyed Gel, purchased from Sigma –Aldrich Company, Nairobi Kenya. Isopropyl Alcohol and Ethyl alcohol (IPA) purchased from Lens Lab Enterprises, Eldoret Kenya. Acetone, reagent grade purchased from Unilab Kenya Limited, Nairobi, Kenya. Calibrated hydrometers in the ranges; 0.7000-0.7500 Kg/L. Model BS 718 Low ST L.50, Zeal, England. 0.7500-0.8000 Kg/L. model BS 718 Low ST L.50, T & A .UK. and 0.8000-0.8500 Kg/L Low S.T., G.H Zeal .UK. Meter rule with millimeter graduations. Hypodermic

syringe, 1ml. Gas-tight syringe with 18, 20, and 22 gauge needle, with a length of 102 mm. Glass slides and corkable glass bottles and metallic cans (not purchased) in the KPC laboratory. Fluorescent Indicator Adsorption Equipment with vibrator unit. A wall-mounted system that comprises a control box, measuring scales with slide markers, mounting clips for two columns and a 365mm UV light mounted vertically to optimise fluorescence when viewing boundaries and saturates zones. Separate pressure gauges and valves to provide individual pressure control to each column (Seta twin column adsorption 14080 from Stanhope –seta limited, U.S.A.). Fractional distillation machine (Water Herzog GMBH D -97922.Lauda-Konigshofen) made by Herzog Varien Instruments UK and Herzog Vaien Instruments Netherlands. M500 Scanning Fourier Transform Infra-Red Spectrophotometer, Buck Scientific Inc. Norwalk, CT U.S.A. Software for data collection, EZ-Scan software, RS-232 Data Transmission and control interface, March, 2010. An electronic analytical balance (Mettler Toledo AG Balance) made by Mettler –Toledo GM Bh. Laboratory and Weighing Technologies CH-8606 Greifensee, Switzerland.

### A. Sampling

Seven samples of suspected adulterated gasoline and diesel were systematically collected from different fuel stations around Eldoret. Six of the samples were from the outskirts of the town and the other one sample within the central business district (CBD). Samples which were used as standard were traced from Eldoret pipeline depot up to the shipper dispensing station located almost within the CBD. All products issued from Kenya Pipeline depots are presumed to be within specification hence used as pure samples (standards). The samples were coded according to the type and sampling site for confidentiality. Gasoline samples were coded M0, M1, M2, M3, M4, M5, M6, M7 while diesel samples were coded D0, D1, D2, D3, D4, D5, D6, D7.

### B. Controls and sample processing

Custom proportions mixture of gasoline and adulterant kerosene were prepared in: 100:00, 98:02, 96:04, and 94:06, 92:08 and 90:10 ratios. Similarly Diesel and kerosene were prepared in 100:00, 98:02, 96:04, 94:06, 92:08 and 90:10 ratios. The blends, pure and suspect adulterated samples were refrigerated at 2°C to avoid evaporation of volatile component before the start of analysis. The samples were then tested for fractional distillation, density test, and FTIR and FIA techniques.

### C. Density Test

The densities were determined for each sample by hydrometer method [19]. A 100 mL measuring cylinder was properly rinsed with samples to be tested, washed and blown dried then filled with samples to be analyzed. Calibrated hydrometers for gasoline and diesel with calibrations in the ranges 0.7000-0.7500 Kg/L and 0.8000-0.8500 Kg/L, respectively, were used. The hydrometer was submerged into the measuring cylinder with sample and density reading noted at the point of observation of the floating hydrometer. Temperature reading was then taken using thermometer. Densities at 20°C were then calculated for every sample.

#### D. Fractional Distillation

Distillation was done by simple fractional distillation apparatus run at atmospheric pressure. This is according to standard method [20]. A 100 mL of each sample was measured in measuring cylinder then poured into a round bottomed flask. For gasoline samples, anti-bombing granules were added to the flask to prevent explosion. Sample in round bottomed flask were put in the sample holder of distillation machine and then turned on. While regulating heating temperature, readings were taken for Initial Boiling Point (IBP) as soon as the first sample of distillate dropped into the measuring cylinder. Temperature was increased while monitoring the recovery volume with increased temperature up to the end point and the results noted.

#### E. Fourier Infrared Absorption Spectrum

The IR spectra of the solutions were analyzed over the range of 500 to 4000 $\text{cm}^{-1}$  wave number of the Infra-red region. Samples were diluted with a compatible solvent ( $\text{CCl}_4$ ) and a cast film with KBR was spread thin with another salt plate to make a smear film of the sample. Samples were run in M500 scanning Infra-Red Spectrophotometer attached to EZ-Scan Installation. A background spectrum of an empty (reference) was run and saved. The clean salt plates were placed into the sample compartment of the infrared spectrophotometer and a scan was run for the sample. A 2 minute routine scan was done on every sample to determine the exact absorption peaks and the spectrum output interpreted with the aid of hydrocarbon functional group correlation tables.

#### F. Fluorescent Indicator Adsorption Analysis

Approximately 0.75 mL of sample was introduced into "Seta Twin -Column Adsorption Apparatus" which has a special glass adsorption column packed with activated silica gel. The columns were freely suspended in the column-vibrating fixture. While vibrating the column along its entire length, about 10 ml of silica gel was added through a funnel into the charger section until the separator section to half full followed by about 2 mL layer of the FIA Standard Dyed Gel. Vibration was continued further while adding additional silica gel until the tightly packed gel extended 70 mm into the charger section. Sample was injected at 30mm below the surface of the gel in the charger section then filled with the charger section to its spherical joint with Iso - propyl Alcohol (IPA) for desorbing the sample down the column with regulated compressed pressure. The red-brown aromatic zone was first observed followed by first intense blue then yellow olefin zone and then clear saturate zone. The boundaries were observed over integral Ultraviolet illumination (365nm) and marked accordingly. This represented each amount of hydrocarbons as aromatics, olefins and saturates. The volume percentage of each hydrocarbon type was calculated from the length of each zone in the column (ASTM D1319).

adulterant. Consequently a fuel with reduced volatility is formed. The more kerosene is added into gasoline the further the density change. Results for density disparity in gasoline and diesel as a function of percentage adulteration have also been reported by Sharma and Gupta [21]. This change is exhibited by the results shown in table-1, i.e. from 0.7374 Kg/L to 0.7708 Kg/L respectively. The blended samples showed a change in density which can be correlated with the adulteration. Gasoline contains various aromatic compounds just as paraffinic fuels [22]. Aromatic hydrocarbons take the form  $\text{C}_n\text{H}_{2n-6}$ , with a lower ratio of hydrogen to carbon than other hydrocarbons typically found in gasoline. Since carbon is much heavier than hydrogen, the lower ratio results in increased fuel density and higher shares of carbon hence higher density [23]. From table-1 and figure-1 it is evident that density of gasoline samples increase with increase in kerosene adulterant. The density of diesel on the other hand decreases with increase of kerosene adulterant. Table-2 and figure-1 depicts the density of the adulterated gasoline and diesel which were varied between 0.7402 - 0.7500 Kg/L and 0.8199-0.8301 Kg/L respectively. The observations from the experiment suggested that most densities for suspected samples were not within the prescribed range. Gasoline samples from location M2, M5, M6 and M4 had been adulterated. M4 had the highest adulterant with density of 0.7500 Kg/L compared with standard sample 0.7374 Kg/L. Samples from M7, M3 and M1 showed a small variation however their densities are within the allowable limits of contaminations;  $\pm 0.003$  Kg/Immaterial of the extent of the kerosene added. In certain instances the change in density might be minimal even for high level of adulteration as indicated by custom proportions compared with procured samples. M7 had a density of 0.7397 kg/L which lies slightly higher than 2% (0.7390 Kg/L) adulteration for custom prepared sample and yet it is within the allowable contamination limit. The overall sensitivity of this method is therefore noted to be rather poor if the change in density is used as an indicator for adulteration that is why this research aspired combinatory methods to reach satisfactory conclusion on fuel adulteration.

### III. RESULTS AND DISCUSSION

From the results in table 1 it was evident that blending kerosene with gasoline primarily results in a fuel with heavier hydrocarbon components contributed by kerosene

Table 1: Density of Gasoline and Diesel Adulterated With Known Amount of Kerosene

Percentage Kerosene added (v/v)	Density of Gasoline (Kg/L)	Density of Diesel (Kg/L)
0	0.7374	0.8345
2	0.7390	0.8290
4	0.7410	0.8200
6	0.7505	0.8190
8	0.7670	0.8102
10	0.7708	0.8090
50	0.8010	0.7800

Table 2: Density of Gasoline and Diesel Procured From Different Fuel Stations

Gasoline Code	Density (Kg/L)	Diesel code	Density (Kg/L)
MO-Standard	0.7374	DO-Standard	0.8345
M1-Baharini	0.7399	D1-Baharini	0.8200
M2-kimumu	0.7402	D2-Kimumu	0.8322
M3-CBD	0.7373	D3-CBD	0.8344
M4-Langas	0.7500	D4-Langas	0.8199
M5-Pioneer	0.7400	D5-Pioneer	0.8220
M6-Huruma	0.7450	D6-Huruma	0.8298
M7-Kapsoya	0.7397	D7-Kapsoya	0.8301

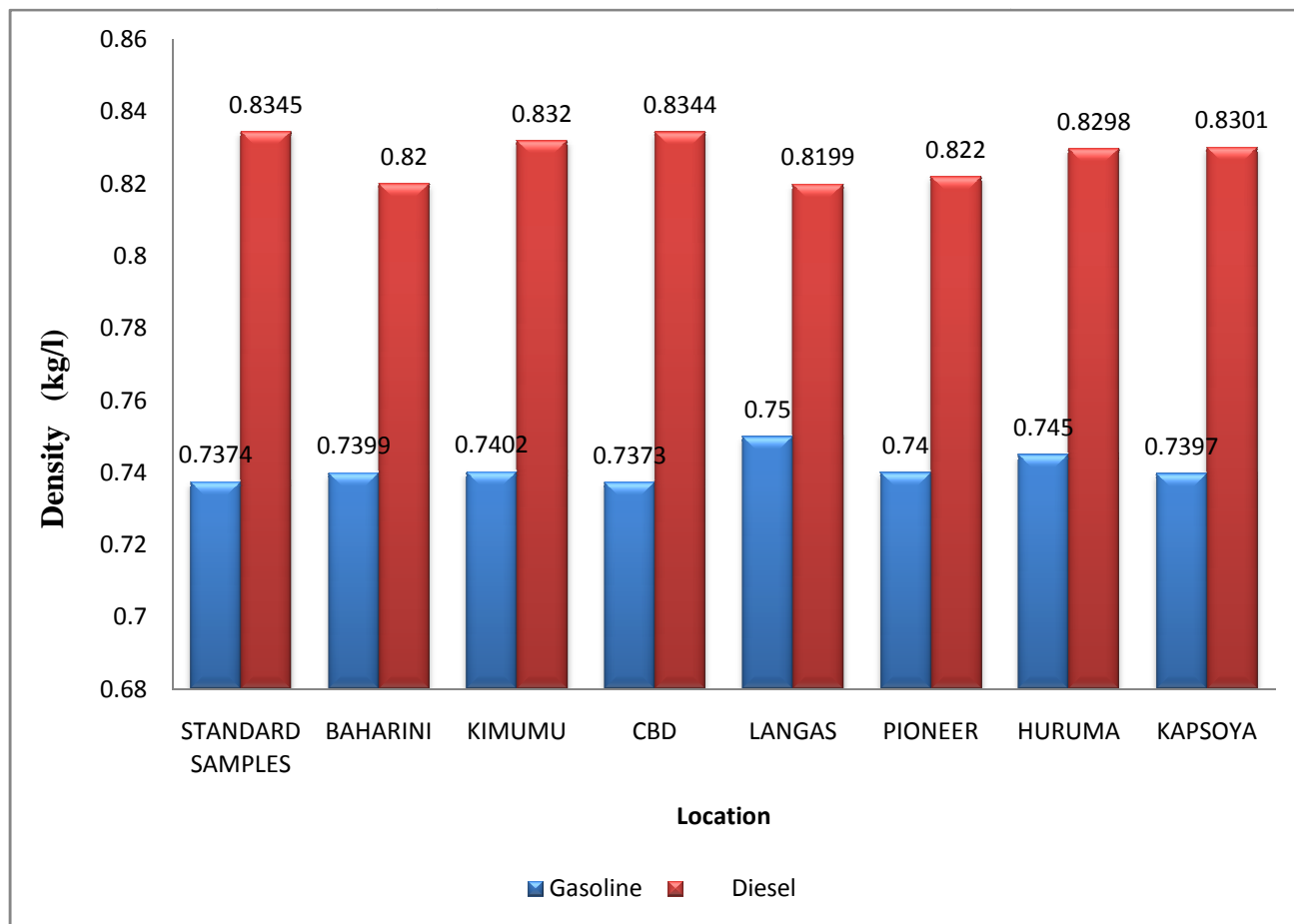


Figure 1: Bar graph showing densities for standard and procured fuel samples.

The final boiling points for gasoline and initial boiling points for diesel were closely scrutinized since they provided numerous clues for adulteration on procured

samples. Their results were also compared with the custom proportion samples in order to know the extent of adulteration

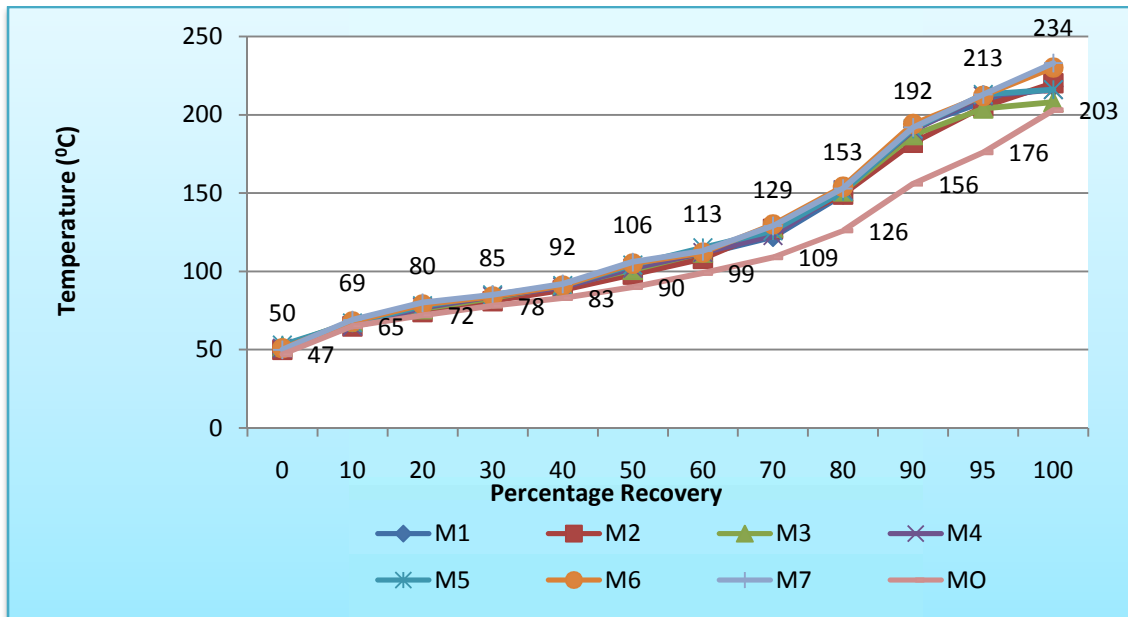


Figure 2: Distillation test for suspected Gasoline samples from different fuel stations

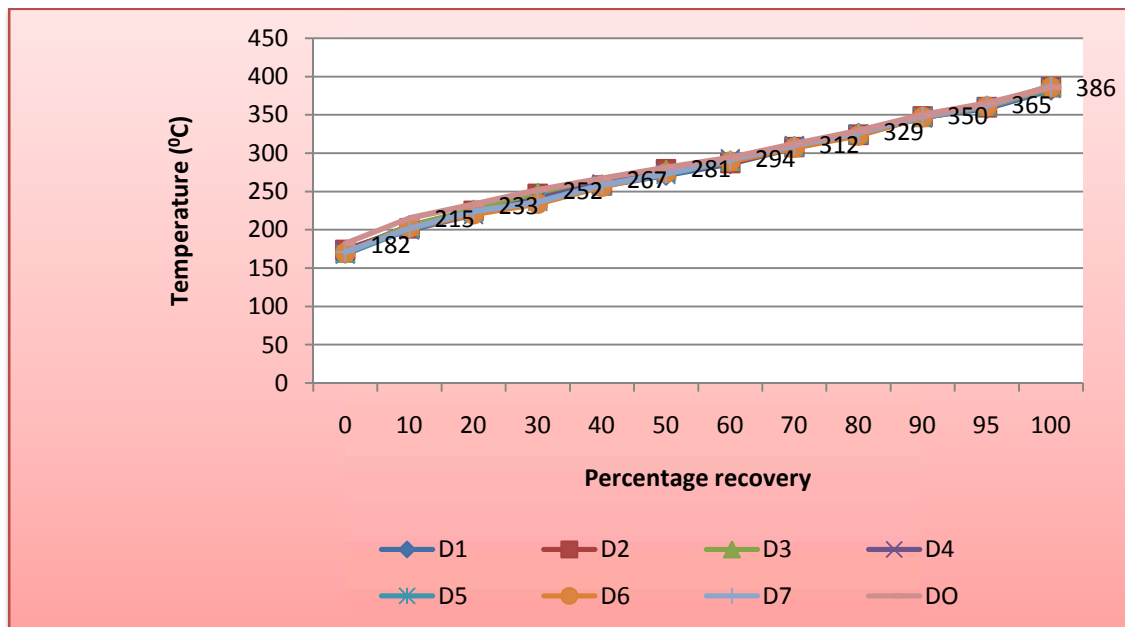


Figure 3: Distillation test for suspected adulterated Diesel samples from different fuel stations

Distillation usually gives an idea of the velocity characteristics of fuel. One of the most important features of gasoline is the volatility that is measured by a distillation experiment [24]. Gasoline and diesels are a combination of hundreds of hydrocarbons, many of which having different boiling points. Thus they boil or distill over a range of temperatures. Distillation curves in figures 2 and 3 show the profiles of various distillations that correlate with fuel quality. Figure 2 exhibited sharp contrast in the curves which correlate with fuel adulteration of gasoline unlike figure 3. From the results it is evident that there is no specific range to which kerosene raises the final boiling point with known amount of adulterant. All the suspected samples except M3 and M5 show positive sign of adulteration but the actual amount cannot be specified. Sample M7 of gasoline had the highest adulteration with the

highest Final Boiling Point of 234°C as seen in figure 2. Kerosene when added to diesel does not affect significantly the End Point of diesel but it lowers the initial boiling points appreciably. In figure 3 the initial boiling point of pure diesel is 182°C. It is clear that kerosene and diesel have similar distillation behavior entirely due to their almost similar distillation profile characteristics between 182°C and 281°C. That is why it is difficult to differentiate the adulterant kerosene in diesel. The performance of diesel and gasoline in automotive engines depends on distillation (boiling range). Slight adjustment on this boiling ranges by adulteration affects the engine starting, warming-up and the tendency of vapor lock at high operating temperatures [25]. Some of the fuel stations improve gasoline performance by adding fuel-power known as "V-power". The additive adjust the initial boiling point of gasoline for easy cold starting;

mid-range for rapid warming-up, smooth running, fuel economy and good acceleration power. The final end point adjustments of gasoline minimize engine deposits and volatile organic compound (VOC) from exhaust emissions [26]. Further research on fuel additives should be done to establish the impact of these additives initial boiling point and final boiling point of diesel.

#### Fourier Transform Infrared Spectroscopy (FTIR)

##### A. Gasoline

The raw spectra for pure samples were studied with respect to peak and frequency shifts. An individual absorbance spectrum was then analyzed after identifying the major peaks from the raw FTIR. The standard gasoline and diesel spectra were obtained over their range of  $500\text{--}4000\text{cm}^{-1}$ . The spectra had several peaks which were identified accordingly. The assignment of peaks to functional groups was carried out by comparison with the library of their

functional groups. Various authors have also reported the same functional groups at the same frequencies [27, 28]. The peak obtained at  $2990\text{cm}^{-1}$  was identified as the asymmetric C-H stretching vibration while  $722\text{cm}^{-1}$  was C-H rock from alkanes. The peak at  $1475\text{cm}^{-1}$  was C-H bend for alkanes while the peak at  $1650$  was C=C stretching for aromatic or alkene group. The peak at  $3480\text{cm}^{-1}$  was OH stretching band functional group which was not the subject of analysis but the peak appeared in all gasoline samples. Other peaks which appeared at  $2450$  and  $2140\text{cm}^{-1}$  were regarded as other functional groups not from gasoline, diesel and kerosene ('interference'). The absorption bands at  $2990$ ,  $2867$  and  $1475\text{cm}^{-1}$  were the only absorption peaks that decreased with increase in kerosene adulteration. Considering the entire CH stretching region, the integrated absorbance decreased with increasing percentage of kerosene as shown in figure 4 and figure 5.

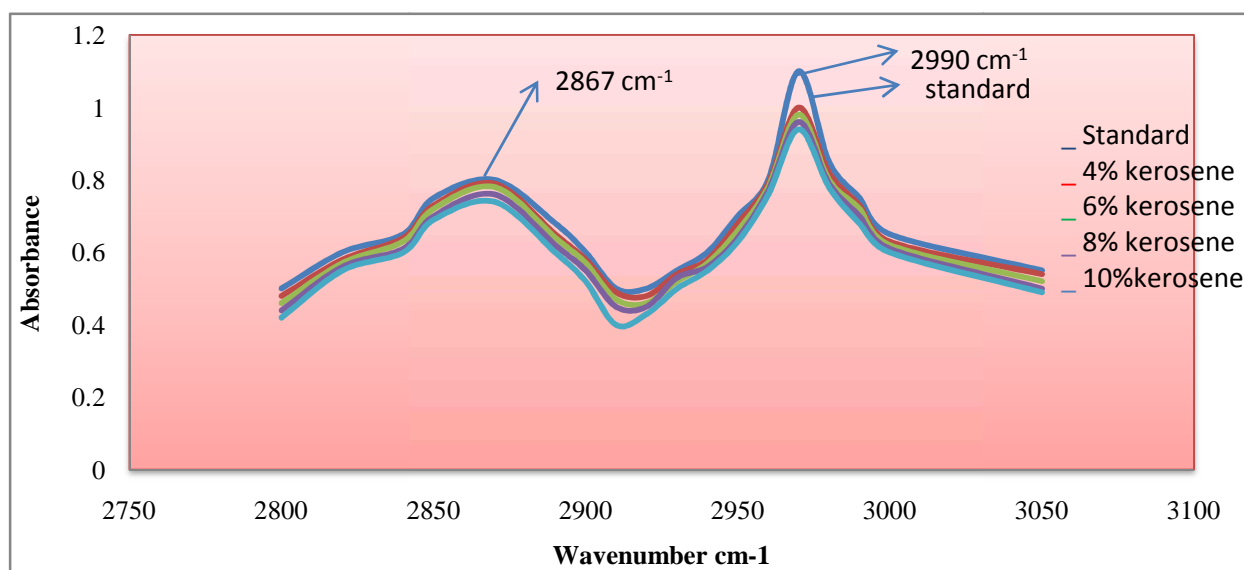


Figure 4. FTIR Spectra of standard custom proportion samples of gasoline ( $2800\text{--}3050\text{cm}^{-1}$ )

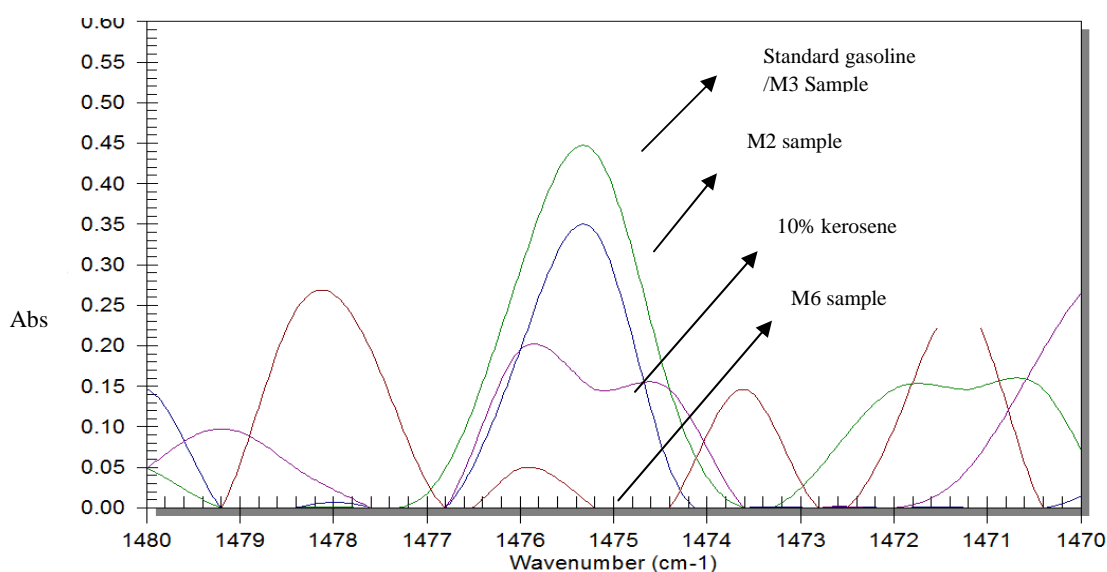


Figure 5. The FTIR spectra for standard gasoline, procured gasoline M2, M6 and 10% custom proportion gasoline ( $1480\text{--}1470\text{cm}^{-1}$ )

It is evident from figure 5 that M2, M6 and the rest of procured samples are adulterated and the trend of

adulteration is duplicated from the results just as density test and fractional distillation results suggested. The decrease in

both absorption peaks at  $1475\text{cm}^{-1}$  -CH bending and  $2990\text{cm}^{-1}$  -CH stretching is brought about by the adulterant kerosene. The more the kerosene is added the more the peak diminishes and broadens as it shifts to another band. This is clearly shown by spectra M6 in figure 5. Adulteration results into spectra overlapping and degeneration into weak bands. Peak area integration can therefore be used to quantify the constituents of hydrocarbons however it does not give accurate compositions. The spectra of fuel were strappingly overlapping within the entire spectrum region. Presumably, some other adulterants had been added to this sample which might have quenched the C-H stretch signals drastically indicating unusually lower level of adulteration. This indicates that conventional calibration procedures would have insufficient application for quantitative determinations just as suggested by "Al-ghouti" in his research [2]. Even though these distinctive bands have been used for qualitative and limited quantitative use, their overlap foils use of specific bands for accurate and comprehensive quantitative use in determining the concentrations of all the hydrocarbon groups specified. As with the FTIR of gasoline and kerosene mixtures, there is no change in the peak intensity of gasoline in lower adulteration. This is consistent with the previous studies carried out by Patra and Mishra [29, 30].

## B. Diesel

Spectra for standard diesel was run then followed by custom proportion diesel samples. It was from these spectra that approximate adulteration level for procured samples was established. The spectra were recorded in the range of  $500-4000\text{cm}^{-1}$ . During the course of study a number of very weak spectral peaks apparently unique to diesel were detected in the Mid Infra-Red. Among them was CH stretching at  $3080\text{cm}^{-1}$  frequency. Besides the presence of C-H bonds diesel also showed sharp, medium bands corresponding to the C=C bond stretching vibration at about  $1600-1700\text{cm}^{-1}$ . Alkenes also showed a band for the =C-H bond stretch, appearing around  $3080\text{cm}^{-1}$ . However, this band could be obscured by the broader bands appearing around  $3000\text{cm}^{-1}$ . Much of the observed peaks were attributed to combination and overtone vibration frequencies of terminal methyl ( $-\text{CH}_3$ ) group found in higher proportions in diesel. The peaks appearing in the spectrum were however assigned respective functional groups. The peak at  $3080\text{cm}^{-1}$  is C-H stretch aromatics while  $2860\text{cm}^{-1}$  is C-H stretch alkenes and  $722\text{cm}^{-1}$  is C-H rock of alkenes. At  $1677\text{cm}^{-1}$  is C=C stretch of alkenes' H stretch appeared at  $3340\text{cm}^{-1}$  for alcohols-phenols. The absorption band at  $3080\text{cm}^{-1}$  appeared to be the only strong absorption peak that showed significant change with addition of kerosene adulterant to diesel. There is an increase in hydrocarbons with increase of kerosene in diesel [31]. Figure 6 and figure 7 shows the significant change in peak height with increase of kerosene adulterant in diesel.

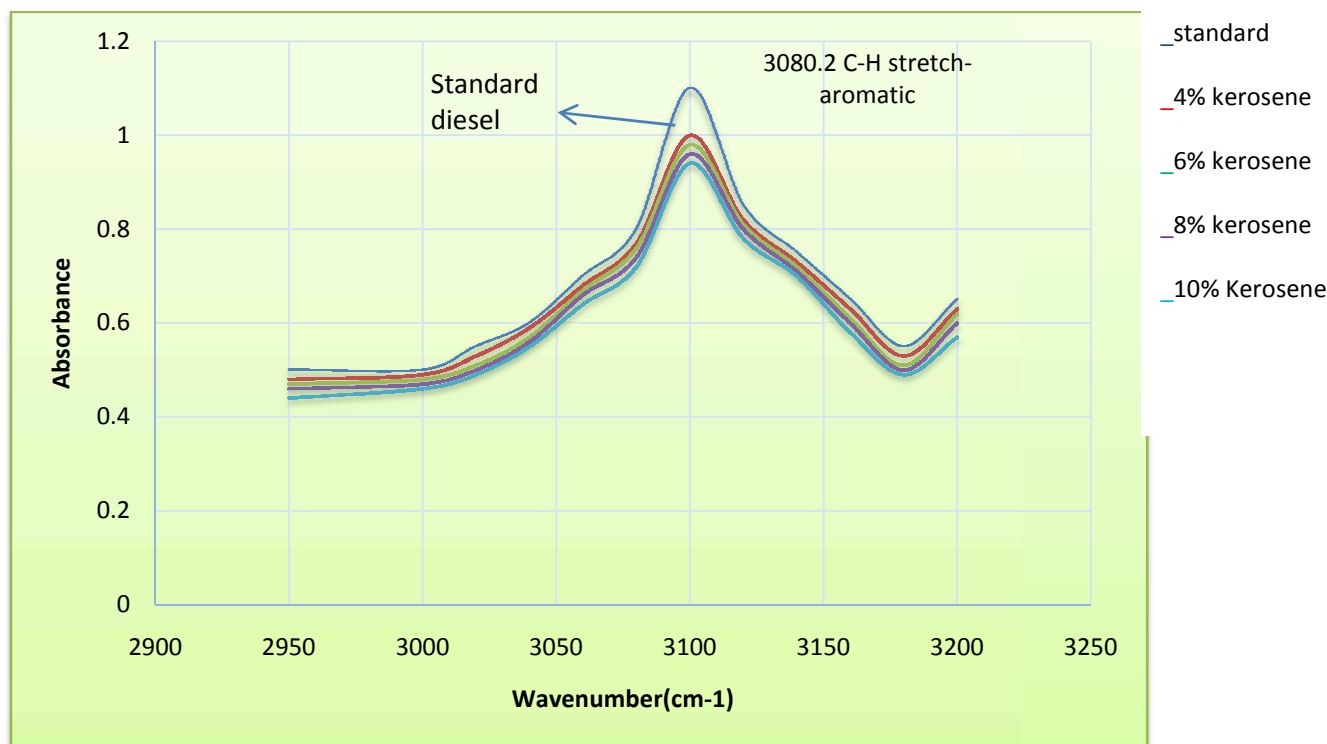
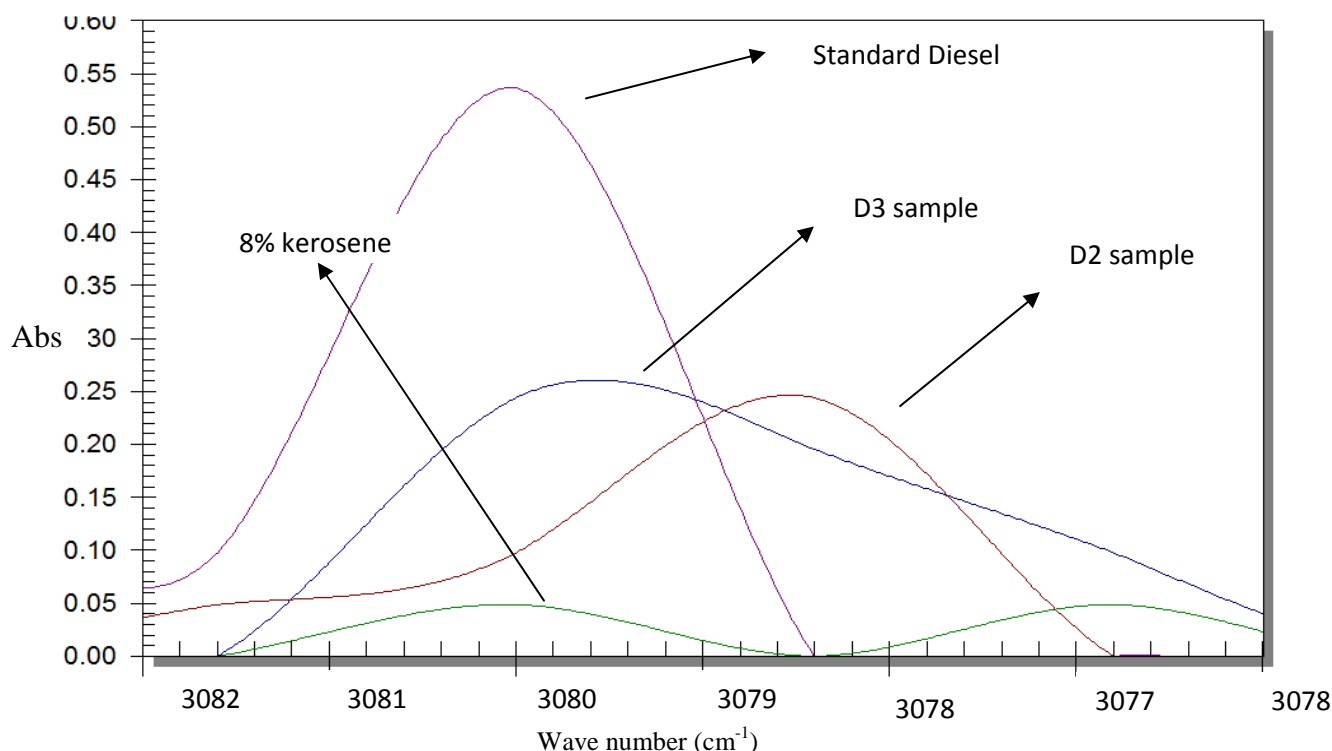


Figure 6. FTIR spectra of standard diesel and custom proportion diesel ( $2950-3200\text{cm}^{-1}$ .)



**Figure 7: FTIR spectra for standard, adulterated samples and custom proportion diesel (2950-3200  $\text{cm}^{-1}$ )**

It can be established from the figure 6 that the peak height decreases proportionally with increase of kerosene. This decrease is due to the reduced C-H intensity as more kerosene is added to diesel at region 2950-3200  $\text{cm}^{-1}$ . Similar region of spectra was also used to establish the adulteration of the procured samples. It was observed from figure-7 that the spectra changed in height with percentage of kerosene added however the shifting is accompanied by overlapping of the peaks. This is normally a complex area showing many bands, frequently overlapping each other which generally make analysis by FTIR more difficult. Samples D1, D4, D5, D6 and D7 had the highest amount of adulterant as indicated by fractional distillation test. Their peaks do not appear in the region and they are presumed to be of below 8% adulteration as shown in the figure 7. With addition of more adulterant their peaks shifted to different region other than 2950-3200  $\text{cm}^{-1}$  region. D3 sample showed slight adulteration as the peak broadened with the intensity weakening below the standard diesel. The shifting of

intensity to the lower wavelength with increasing composition of kerosene indicates that the signal is predominantly due to the low molecular weight poly aromatic hydrocarbons from kerosene [32]. The minimum at higher wavelength is dominated by the high molecular weight PAHs present in diesel. It was found that the maximum intensity at higher wavelength decreases with increasing kerosene content and it seemed that the emission intensity correlates with the levels of kerosene in the diesel.

### C. Fluorescent Indicator Adsorption (FIA) for Gasoline and Diesel

The FIA machine (seta twin column adsorption 14080) characterized hydrocarbon into aromatics, olefins and saturates. The fluorescent dyes adsorb in silica gel separated hydrocarbons in the column selectively, in respect to their hydrocarbon types, resulting in boundaries of aromatics, olefins, and saturate zones being visible under ultraviolet light.

**Table 3: FIA results for custom proportions of standard diesel and suspected adulterated diesel**

%Kerosene added(v/v)	%Aromatics	%Olefins	%Saturates	Code	%Aromatics	%Olefins	%Saturates
0	59.90	15.90	24.20	Standard	59.90	15.90	24.20
2	56.23	16.43	27.34	D1	57.56	23.65	18.79
4	55.87	16.98	27.15	D2	59.02	16.42	24.21
6	55.78	17.03	27.19	D3	59.70	16.09	27.88
8	55.01	18.46	26.53	D4	58.70	17.09	23.23
10	54.37	18.54	27.09	D5	56.77	24.56	18.67
100	36.87	38.20	24.93	D6	57.87	18.90	23.23
				D7	59.45	15.65	24.90

**Table 4: FIA results for custom proportions of standard Gasoline and suspected adulterated Gasoline**

% Kerosene added(v/v)	%Aromatics	%Olefins	% Saturates	Code	%Aromatics	% Olefins	%Saturates
0	29.70	06.40	63.90	Standard	29.70	06.40	63.90
2	30.54	06.90	62.56	M1	24.12	12.90	62.98
4	33.81	07.20	58.99	M2	26.77	14.56	58.67
6	34.82	08.40	56.78	M3	29.20	07.67	63.13
8	32.93	12.40	54.67	M4	29.82	12.31	57.87
10	38.68	14.87	46.45	M5	29.60	07.01	63.39
100	34.87	39.20	25.93	M6	24.12	12.90	62.98
				M7	28.70	17.09	54.21

FIA method analyzed two samples simultaneously by measuring the total volume percentage of saturated hydrocarbons, aromatics and olefins. The hydrocarbon concentrations for standard diesel were found to be 59.90% aromatics, 15.90% olefins and 24.20% as saturates. The percentage aromatics reduce with increase in kerosene adulterant. From table 3 it is evident that when 10% of kerosene is added to diesel there is a 5.53% decrease in aromatics, 2.64% increase in olefins and 2.89% increase in saturates. This translates to 11.06% possible adulteration of diesel. The hydrocarbon concentrations for standard gasoline were found to be 29.70% aromatics, 6.40% olefins and 63.90% saturates. From table 4 it shows that with 10% adulteration, aromatics and olefins increase considerably by

8.98% and 8.47% respectively while saturates decrease by 17.45%. This translates to a maximum possibility adulteration of gasoline to 34.9%. Gasoline can absorb high amount of kerosene adulterant due to its high volatility. The procured gasoline samples level of adulteration varies from 2.94% for M3 to maximum limit of 19.72% for M7. Diesel adulteration varies from 1.60% for D2 to maximum limit of 17.24% for D5. The results obtained from FIA are in agreement with results obtained by Density Test and Fractional Distillation and FTIR and hence it confirms perfect practical analytical combination methods for determining kerosene adulterant content in Diesel and Gasoline samples.

**Table 5. Detection levels of adulterant kerosene by Density Test, Fractional distillation, FTIR and FIA**

Code	Density Test	Fractional Distillation	FTIR	FIA	Product
MO	Nil	Nil	0%	0%	G A S O L I N E
M1	Moderate	High	>10%	13.00%	
M2	High	High	<10%	16.32%	
M3	Nil	Nil	Nil	< 3%	
M4	Very High	Moderate	>10%	12.06%	
M5	High	Nil	>10%	<3%	
M6	Very High	High	>10%	13.00%	
M7	High	very high	>10%	21.38%	D I E S E L
DO	Nil	Nil	0%	0%	
D1	Very High	High	>8%	15.50%	
D2	Moderate	Low	<8%	< 3%	
D3	Nil	Low	<8%	<3%	
D4	Very High	Moderate	>8%	6.28%	
D5	High	Very High	>8%	17.24%	
D6	Very High	High	>8%	5.92%	
D7	High	Moderate	>8%	<3%	

#### IV. CONCLUSION

Seventy two percent of the gasoline samples sold in Eldoret town were found to be adulterated. The rest twenty eight percent of the samples were adulterated with sample M2, M6 and M7 being the worst hit failing in the entire test

done. Forty two percent of diesel were found to be within the specifications and the rest of the sample showed signs of contaminations with sample D5 and D1 being the notorious ones. In conclusion the study therefore fronts Fractional distillation, density tests, FTIR and FIA as a combination technique that is an accurate reliable analytical tool able to

give easily interpretable results to both the scientists and consumers.

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