African Journal of Engineering and Environment Research Vol.7(2) 2025 pp 127- 147
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ISSN: 2714-2264

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African Journal of Engineering and Environment Research Vol.7(2) 2025 pp 127- 147
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ISSN: 2714-2264

AN EXPERIMENTAL INVESTIGATION OF THE PHYSIO-CHEMICAL PROPERTIES OF ILLEGAL REFINED PETROLEUM PRODUCTS

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[Date received: May 2025. Date accepted: June 2025]

ABSTRACT

The challenge of artisanal petroleum products has been a national issue. Artisanal petroleum products are diesel, petrol (gasoline) and kerosene are obtained from the illegal refineries located in the creeks. Artisan refineries are illegal because they do not have licence and technologies to operate, and physiochemical properties of their products had not been studied to ascertain the quality. Therefore, the study sought to investigate the physiochemical properties of the artisan-refined petroleum products such as diesel, kerosene and petrol (gasoline) in comparison with the imported sample (reference). The investigation was done using ASTM standard procedures. The results of pH readings for reference samples (Diesel, kerosene and petrol) and the artisan-refined samples (Diesel, kerosene and petrol) were 7.5, 5.9 and 7.25 and 6.7, 5.35 and 6.10 respectively. The flash points of artisan diesel, petrol and kerosene were 50, -32 and 39 respectively while the flash points of imported samples of diesel, petrol and kerosene were 48, -228 and 39 respectively. All other physiochemical properties such as specific gravity, API gravity and impurity, Kinematic viscosity, ASTM colour and Saybolt of the illegally refined product showed some variations with those of the reference samples. From the results, it could be deduced that artisan petroleum products had poor quality and did not meet ASTM specification. These irregular characteristics of the illegal products damage engines of automobiles, causes environmental pollution and health hazard to man.

Keywords: Petroleum; Physiochemical; Illegal; Refined; Products, Samples

1.0 INTRODUCTION

Fuel produced by artisanal refiners using indigenous technology continues to find its way into the Nigerian oil market despite the proscription of such refining activities in the Niger Delta, owing largely to the illegal means by which the artisans procure crude oil and related to doubt about the quality of products coming from their covertly operated facilities

Nigeria has four crude oil refineries, all in a moribund state (Adegbite, 2013), with an estimated total refining capacity of 445, 000 barrels per day (Kadafa, 2012). The Port Harcourt Refining Company is made up of two refineries, the first of which was commissioned in 1965 and built with an on-stream capacity of 60,000 barrels of light crude per day. The second refinery, commissioned in 1989, was built with a refining capacity of 150,000 barrels of crude oil per day (Odeyemi and Ogunseitan (1985); Kadafa 2012). The Warri Refining Company and Kaduna Refining Company each have one refinery with installed capacities of 110,000 barrels and 125,000 barrels of crude oil per day respectively (NNPC, 2016). The total of 445,000 barrels of crude per day, when refined, would be adequate to meet the domestic needs of the Nigerian state with a surplus for export, yet the country is a large net importer of diesel fuel and other petroleum products (Majekodunmi, 2013). The continuous shortg fall in supply of diesel fuel by the major importer, the state owned Nigerian National Petroleum Corporation (NNPC), has led to an increase in the adulteration of the product (Udeagbara et al., 2014).

As a nation-state grows, its demand for oil also increases (Curl and Donnell, 1977). Crude oil is a major energy resource, with by-products such as gasoline, diesel, jet fuel, kerosene etc. (Kong et al., 2019). Diesel fuel is produced from crude oil by various refining processes and it is used in compression ignition engines as a fuel (Beg et al., 2010). Diesel fuel contains a large amount of paraffin waxes (Xu et al. (2018), (Zhao et al., 2017). Its composition is influenced by several factors, including the origin of the crude oil, the addition of fractions from cracking processes, operating variables of the refinery and the insertion of additives to increase engine performance (Nespeca et al., 2018). Diesel fuel, kerosene and jet fuel (aviation turbine fuel) belong to the petroleum product class commonly known as middle distillates (ASTM D-975-17a). Unlike gasoline, which has petroleum derived compounds in the range of carbon number range C4–C12 and a boiling point range of 30–225^{o}C (Moreira et al., 2003), diesel has a carbon number range of C10–C19 and a boiling point range of 180–370 ^{o}C (Vempatapu and Kanaujia, 2017).

As in other developing countries, the adulteration of fuel is a very common occurrence in Nigeria (Osueke and Ofondu, 2011). According to Vempatapu and Kanaujia (2017) and Kulathunga and Mahanama (2013), the adulteration of automotive fuels such as diesel and gasoline is a flourishing business in developing countries. Ale (2003), in his research into fuel adulteration and tailpipe emissions in Nepal, alluded to the fact that the continuous rise in fuel adulteration is a result of financial incentives arising from differences in taxation imposed by the Nepalese government. In Nigeria, fuel adulteration is primarily carried out because of price differentials between products (Obodeh and Akhere, 2010). Igbani and Lucky (2015) and Isa *et al.* (2013) reported that the high demand for automotive fuels such as diesel and the inability of government agencies e.g. the Nigeria National Petroleum Cooperation (NNPC) to meet this demand had led to the Nigerian fuel market being flooded with adulterated products.

Diesel fuel is most commonly adulterated with the addition of kerosene (Babu et al., 2017; Yadav et al., 2005). According to Monteiro et al. (2008) and L. Wiedemann et al. (2005), fuel adulteration in Brazil involves the addition of aromatic hydrocarbons, heavy aliphatic ($C_{13} - C_{15}$) and light aliphatic ($C_4 - C_8$) compounds such as hexane, xylenes, rubber solvent, benzene, thinners, kerosene and mineral spirits. These adulterants are chosen on the basis of ease of blending, economic benefits, physicochemical similarities to the fuel and availability (Mabood et al., 2017). Vempatapu and Kanaujia (2017) in their work stated that the adulterants are selected because of a number of criteria while keeping in mind the specification of the final product.

All engines are designed and manufactured to operate on specified fuel (Ale, 2003). Diesel engines are very important power sources in the areas of power generation, transportation, construction engineering, and agriculture (Ashok et al., 2019). They are known to produce better fuel conversion efficiency, higher torque, higher durability and higher power output characteristics compared to gasoline engines (Ashok et al., 2019). The deliberate addition of adulterants to diesel fuel has a potentially detrimental effect on the fuel properties and on engine performance, such as fuel consumption, engine heating and engine start-up control. Likewise, the adulteration of fuel increases the emission of exhaust gases, hydrocarbons and particulate material (Corgozinho et al., 2008). In their work, Bhowmik et al. (2019) reported that the adulteration of diesel fuel reduces the brake specific energy consumption (BSEC) and the brake thermal efficiency (Bth) of compression ignition engines. According to Toche et al. (2015), fuel adulteration results in damage to motor vehicles and emission of gases, which are harmful to human health. Fuel adulteration leads to monetary losses to the consumer, greater emissions to the enhvironment and damage to engine parts (Babu et al., 2017).

The addition of high boiling point compounds to diesel leads to engine wear and increased ‘knock’, which also leads to starting difficulties, while low boiling point compounds cause vapour lock in, engines (Wiedemann et al., 2005). Similarly, Skrobot et al. (2007) added that adulteration of fuel with solvents causes poor engine performance, tax revenue losses and environmental pollution. In contrast, Ale (2003) added that not all types of adulteration are harmful to the health of members of the public, although adulterated fuel increases emissions of very harmful pollutants, and affects air quality. However, the determination of the physiochemical properties of the Nigerian illegal refined diesel samples is necessary because of the non-standard methods used in the refining of the petroleum. The crude oil is heated in metal drums using firewood (Umukoro, 2018). The crude oil evaporates and passes through two pipes attached to the barrel and inside a wooden water bath with the refined product emerging at the end of the pipe (Asuru and Amadi (2016); Umukoro (2018). Substantial amounts of these products have found their way into the Nigerian market, where unsuspecting diesel run small craft operators, diesel vehicle owners and diesel generator owners buy them for their daily use (Murdock (2012); EIA (2016).

1.1 Illegal Petroleum Refining in Nigeria

Crude oil refining, although a complex process, is based on a simple scientific principle called distillation – boiling, vaporization, cooling and condensation. The main goal of this is to separate mixtures into their constituent parts in pure form or, in the case of crude oil, into fractions depending on the ranges of boiling temperatures. The requirement to remove contaminants from both crude oil prior to refining and its products after refining increased complexity on a previously straightforward distillation or fractionation process. The other factors include the numerous auxiliary processes in the refineries that improve the octane rating of gasoline fractions, the cetane rating of diesel fractions as well as the ratio of lighter petroleum fractions to the heavier fractions in favour of the lighter ones. The above underline the fact that Petroleum refining is not just a mere distillation process – a process of heating, boiling, vaporization and condensation to obtain usable products. The operators of the illegal refineries do not have the technical expertise and financial capacity to be involved in these high technology processes and so confine themselves to just distillation – the boiling and vaporization of crude oil and recovering just a fraction of the vapours to get three products namely, 'petrol', 'kerosene' and 'diesel'. They use crude and locally fabricated pieces of equipment- drums, plastic containers, hoses, pumps to set up refineries. Heat energy required for the heating of the crude Oil components to boiling points is provided by open fire set under the drums, a makeshift 'distillation Column', using the residue of their refineries as Source of fuel and paying little or no attention at all to safety of workforce and the protection of the ecosystem. Different pipes for different products are welded to the 'distillation drums' and connected to product storage facilities which are not more than large plastic containers or dug pits separated from the soil by thick cellophane materials. Africa practice (2012) admits that the entire illegal refining business (which involves oil theft and the actual refining) is risky and involves the heating of the stolen crude in drums at very high temperatures to explosions. The products are also exposed to the elements of the weather; sun that causes evaporation of products into the atmosphere leading to air pollution and rain that contaminates the products with water droplets that further degrade their quality. The products are put in plastic containers and shipped to their marketing outlets in the hinterland without any auxiliary treatment to upgrade or eliminate impurities as done in conventional refineries.

1.2 Quality of Products of Illegal Refineries in Nigeria

Petroleum products are any petroleum-based products that can be obtained by refining and comprise refinery gas, ethane, liquefied petroleum gas (LPG), naphtha, gasoline, aviation fuel, marine fuel, kerosene, diesel fuel, distillate fuel oil, residual fuel oil, gas oil, lubricants, white oil, grease, wax, asphalt, as well as coke (Speight, 2014). The illegal refineries and their operators shave neither the technical equipment nor the technical competence and manpower required to produce petroleum products that can meet international standards. They equally lack the scientific and technical expertise to carry out any form of laboratory analysis and quality assurance/control checks on their products to determine quality and compare same with stipulated regulatory standards. Illegal refineries limit themselves to producing three basic petroleum products – petrol (gasoline), kerosene and diesel (automotive gas oil) without any attempt to improve their quality through reforming, alkylation, hydro-treating, blending and other post refining physical and chemical modification processes. This is unlike the conventional refineries that adopt a combination of the main fractionation process and the modification processes to produce top grade petroleum products that can guarantee high-grade performance in automobile engines and ensure atmospheric air is not unduly polluted.

Fig. 1: (a) Illegal Refineries storage pit exposed to weather. (b) Billowing fire for heating up crude oil not far away

Another aspect of refinery operations that influence products' quality is the pre-refining operations for the removal/reduction of impurities. While some of these impurities occur naturally along with the crude oil, others find their ways into crude oils through anthropogenic activities during oil well drilling and production activities. There are numerous chemical additives used in drilling fluids, cementing operations, corrosion/scale/wax asphaltenes inhibition operations, well stimulation and treatment as well as in improved oil recovery (chemical/gas flooding) and enhanced oil recovery (EOR) operations. These chemical additives find their ways into crude oil and natural gas and must be removed, or their concentrations drastically reduced to tolerable levels before refining. When the impurities and natural contaminants in crude oils are not removed as is usually the case with all the illegal refineries, some of them also find their ways into the product streams and further degrade the product quality. Or the refining process can transform them into even more toxic substances that are detrimental to products, the environment, refinery processes and equipment.

2.0 THE IMPACT OF THESE ILLEGAL ACTIVITIES INCLUDES

2.1 Socio-Economic Losses to the Nigerian State:

These illegal activities have posed a big threat to Nigeria‘s economy. Its socio-economic impacts include environmental degradation, loss of economic activities for the communities, loss of revenues to the government resulting in inadequate funding for development initiatives, increased criminality in Niger Delta region, lack of security due to illegal activities and infiltration of international collaborator and bad image for the country (Duru, 2013; Okere, 2013). As a result of vandalism, maintenance of oil terminals and declaration of force majeure, the militants nearly destroyed the oil industry and, by extension, the national economy which depends heavily on oil revenue (Tamuno, 2011 and Njoku, 2015). Oil thefts, illegal bunkering and pipeline vandalism have resulted in increasing loss of the nation‘s revenue which could have accrued from the sale of crude oil on international market.

Yusuf (2016), recently reported that Nigeria was at the risk of N1.458 billion ($7.29 million) daily revenue loss on its crude exports, and Shell declared force majeure on 162,000 barrels per day Bonny light crude export (force majeure is a legal declaration which a party uses to state that it ay not be able to meet its contractual obligations in a deal) (Yusuf, 2016). In February 2016 the NNPC was reported to have incurred N24.23 billion operational deficits, while in March 2016, the report indicated that it has declared N18.89 billion loss.

The financial losses by NNPC were reported to be due to ―a major slump in export sales due largely to shut-in of about 300,000 barrels of crude oil at Forcados Terminal following force majeure declared by Shell in February 15, 2016. The report noted that production shut-in occasionally by vandalism at Forcados Export line has continued to drag NNPC‟s performance (Daily Sun News, 2016). It was perhaps in view of these colossal financial losses suffered by

Nigerian state as a result of pipeline vandalism and oil theft that President Muhammadu Buhari called on international community to designate oil theft as an international crime similar to the trade in blood diamonds (The Guardian News, 2016). On the whole, Nigeria was reported to have lost N12.566 billion in one month, that is, March 2016, due to petroleum products theft and vandalization of the facilities of the NNPC (Eboh, 2016). According to Organization of Petroleum Exporting Countries (OPEC) source, Nigeria's oil production has dropped to 1.637 million bpd in April and further slide to 1.1 million bpd in May 2016 (Salau, 2016).

Also, due to the loss of revenue to illegal bunkering, Nigeria is no longer selling enough crude oil to meet her budgetary provisions. The government is failing to meet some of its obligation and domestic debt is rising rapidly. Noted that the negative impacts of vandalism and crude oil theft include the destruction of aquatic and farmlands, economic sabotage which explains the shortfall of Nigeria's budget and divestments by some International Oil Companies, IOCs, with attendant job losses thereby compounds the unemployment situation in Nigeria and economic recession ravaging the country today (Gaskia, 2013).

2.2 Environmental Pollution and Degradation in the Niger Delta Region:

The process of breaking, vandalising and tapping oil from oil installations may lead to the damage of oil pipelines; it causes many leaks that cause immense environmental degradation (Odalonu, 2015). Crude oil theft involves breaking of pipelines and siphoning of crude oil products. This act invariably leads to oil facilities damage and oil spillage. Oil spillage causes degradation of the environment; it destroys farms, lands and forests thereby reducing arable land for farming, Spills into water ways, destroy marine and aquatic life, flora, fauna, resort centers and result in the pollution of potable water (Badejo and Nwilo 2007). Oil theft activities and pipeline vandalism in the Niger Delta compounds oil spillages from other sources and exacerbates the problem of environmental degradation and pollution of water-ways (Ogbuefin, 2007). Vandalism is responsible for a large percentage of oil spills. Oil spills result in ground water poisoning, destruction of agricultural land, fishery and livestock and fast disappearing mangrove forests. There are complaints of oil contamination of boreholes which makes the water undrinkable in the region. This makes the water undrinkable even after some treatment. Also, some natives have been known to use or drink polluted water out of frustration and the negative effects cannot be over emphasized (Ufford, 2013; Alawode and Ogunleye, 2013). In fact, farmland, fish ponds, rivers, etc., have been destroyed and rendered unviable for agriculture, fisheries and aquaculture. Thus, thousands of households and families of the Niger Delta have been impoverished, or have become securely locked into poverty as a result of this scale of environmental devastation (Gaskia, 2013). This problem has left many Niger Delta

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ISSN: 2714-2264

communities further impoverished since their means of livelihood, fishing and farming, have been ruined by constant spills and leakages.

2.3 Economic losses to the International Oil Companies:

Attacks on oil production facilities have led to several shutdowns and declaration of force majeure by the International Oil Companies (IOCs), ultimately resulting in loss of revenue to the oil companies as well as the government (Alohan, 2013). The activities of vandals in Niger Delta have led to several shut-ins and shut-downs of operation by international oil companies and thus resulted in decline in production capacity as well as loses of revenues to the companies and government. International oil companies (IOCs) operating in Nigeria are counting heavy losses as surge in illegal bunkering and supply disruption have impacted on their earnings (Asu, 2013). However, there will be urgent need by the oil companies and Federal Government to repair the pipelines and clean-up of oil spills in the environment and this involve huge capital expenditure and it invariably leads to lose of revenues to the oil companies and government. And According to the Minister of Power, Works and Housing, Babatunde Raji Fashola, (Adedoyin, 2016) the attack on the Nigeria gas company‘s pipeline connected to Chevron Nigeria Limited‘s facility at Escravos, is costing the country a whopping sum of N470 million daily. The attack has impacted negatively on the Olorunsogo Nigerian National Integrated Power Project (NIPP) plant with 600 megawatts capacity, as well as other power plants.

The sabotaged gas pipeline which contributes to the Escravos Lagos Pipeline System (ELPS) has led to a loss of 160 Million standard cubic feet of gas per day (MMSFCD – Million Standard Cubic Feet per Day) of gas daily, at a cost of $2.50 per thousand standard cubic feet. This loss means about $400,000 loss to the country on a daily basis in gas volume. This is in addition to losses to be incurred daily from affected Power generation ($1,988,223 daily). The total daily loss to the country is therefore estimated at N470, 479,931. Repairs of the damaged pipeline are estimated as costing ($609,137). Raji Fasholu (Adedoyin, 2010), continuing, he said: For instance, available records show that six incidences of vandalism from December 2014 to February 2015 which affected the Trans Forcados Pipeline (at Oben, Sapele, Oredo) and Escravos Lagos Pipeline System (CNL) led to a loss of 1,100 mmscfd. According to industry experts, a loss of 200 mmscfd is equivalent to a Power reduction of 700MW. He Added that while the industry is currently generating about 4120Mwh/h on average (as at 17/01/2016), it is without doubt that performance would have been better without the additional setback caused by the vandals.

The money that could have been spent on other areas of oil exploration and production are

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(now) used for pipeline repair, maintenance and cleaning oil spills (Alawode and Ogunleye, 2013).

3.0 METHOD AND PROCEDURES

This work aimed at experimental study of the physiochemical properties of illegal refined petroleum products from Okirika local government area in Rivers State. The experiments were designed to capture these conditions as are often encountered in the refinery. To achieve this aim, the experiments were done in accordance with the American Standard Testing Methods (ASTM). Illegal refined diesel, fuel, and kerosene as well as crude oil sample from Okirika local government area and legal refined diesel, fuel, and kerosene from an established Port Harcourt refinery were used for this study.

The area understudy in this work is in OKrika and Eleme Local Government Areas of Rivers State. The town is situated on an island south of Port Harcourt, making it a suburb of the much larger city. Legal and illegal refined petroleum product samples of diesel, kerosene, fuel as well as crude oil sample were collected from a location in Okirika Island south as well as a refinery in Eleme, all in Niger Delta area of Rivers State as shown in Figure 2.

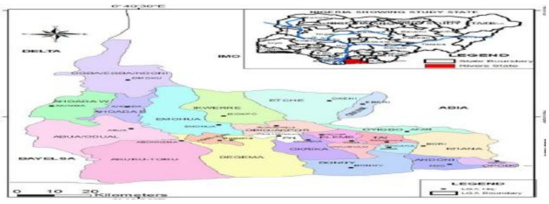

Fig. 2: Geographical map of niger delta showing Ememe and Okrika Eleme LGAs

3.1 Specific Gravity:

The pyrometer was cleaned thoroughly and was placed on an analytical balance. The mass was measured as M_1. The pycnometer was completely filled with a known volume of the liquid sample, air bubbles were avoided. The pycnometer was weighed with the liquid sample and its mass was recorded as M_2. The temperature of the liquid sample was measured with a thermometer and was recorded as T_1. The specific gravity of the liquid sample was calculated using the formula:

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$$SG\ @\ 60\ ^{o}F = \frac{Weight\ o\ liquid\ sample}{Weight\ of\ water} \quad (1)$$

API Gravity can be calculated as:

$$o_{API} = \left(\frac{141.5}{SG}\right) - 131.5 \quad (2)$$

Table 1: Classification of Different API Gravity of Crude Oil

S/N	Grade	API Gravity
1	Light	> 31.1
2	Medium	Bbetween 22.3 and
3	Heavy	31.1
4	Extra Heavy	< 22.3
		< 10.0

Table 2: Summary of Test Methods Used

S/N	Physio-chemical Properties	Unit	Test Methods
1	Specific Gravity	@ 60^{O}F	ASTM D891
2	API Gravity	@ 60^{O}F	ASTM D891
3	pH	-	ASTM D1293
4	Kinematic Viscosity	mm^2/s	ASTM D445
5	Flash Point	^{o}C	ASTM D92
6	Fire Point	^{o}C	ASTM D92
7	Cloud Point	^{o}C	ASTM D97
8	Pour Point	^{o}C	ASTM D97
9	Carbon Residue	%m/m	ASTM D 189
10	Calorific Value	KJ/kg	ASTM D240
11	Saybolt	-	ASTM D156
12	ASTM Color	-	ASTM D1500

4.0 RESULTS AND DISCUSSIONS

The results of physio-chemical properties of Crude Oil Sample as well as legal and illegal refined petroleum products of kerosene, diesel, and fuel obtained obtained from the locations in Okirika and Eleme Local Government Areas of Rivers State are presented and analyzed. The physio-chemical properties analyzed are pH, flash point, pour point, cloud point, calorific value, fire point, specific gravity, API gravity, color, and iimpurity content (carbon residue).

4.1 Results of the Physio-chemical Properties of Crude Oil

The physiochemical properties of crude oil sample were evaluated and the results recorded in Table 3. The results showed that all the properties such as flash point, fire point, specific gravity, API gravity, kinematic viscosity, ASTM colour, Saybolt, pour point, pH, Calorific value and impurity level were all at the allowable limits as shown in Table 3. This study focused on the quality of the product of the refining process the crude obtained.

Table 3: Results of the Physio-chemical Properties of Crude Oil

Properties	Unit	Value	Limit
Specific Gravity	@ 60 ^{o}F	0.80	0.79 – 0.86
Kinematic	mm^2/s	0.70	N/A
Viscosity	@ 60 ^{o}F	45.4	15 – 45
API Gravity	^{o}C	45	-60 - 49
Cloud Point	^{o}C	6.9	-57 - 32
Pour Point	MJ/kg	46	42 – 47
Calorific Value	-	60	N/A
pH	^{o}C	0.15	60 - 93
Flash Point	^{o}C		93 -149
Fire Point	%m/m		N/A
Carbon Residue			

4.2 Results of Legal and Illegal Refined Physio-Chemical Properties of Kerosene

The results of the physiochemical prop4erties of kerosene were obtained as recorded in **Table 4**. The pH of the illegally refined kerosene showed higher acidity than that of the legally refined sample. The effect is that the former has the capacity to cause corrosion of the transporting vessels and pipelines. The higher the level of acidity, the higher the chance of corrosion occurrence in pipelines. It was also seen that the calorific values of the two samples (illegal and legal) had differed. The illegally had calorific value of 44.8 KJ/KG whereas the pure sample had the 45.2 MJ/KG, which implied that the pure sample had higher heating capacity than the illegal sample. The examination of the flash point, pour point and fire points had different values for the two samples Table 4. The flash point and fire point of the illegally refined kerosene were higher than those of the pure sample. When the flash point and fire point of kerosene are higher, it means that it requires higher temperature to burn or initiate combustion. So, the legally refined kerosene is better that the artisanal sample. It was also found out that the impurity level of the illegally refined kerosene was higher than that of the pure sample. The kinematic viscosities of the two samples showed equal values, indicating they required the minimum heat energy to flow. The ASTM colour for the two kerosene samples were the same, but differed in Saybolt values. However, it is seen that the results showed illegally refined kerosene had poor qualities, which could affect it performance. **Figure 3** summarises the plot of the legal and illegal physiochemical properties of Kerosene.

Table 4: Results of Legal and Illegal Refined Physio-chemical of Kerosene

Physio-chemical Properties	Unit	Legal	Illegal	Limit
pH	-	5.9	5.35	N/A
Specific Gravity	@ 60 °F	0.83	0.81	0.8 – 1.0
API Gravity	@ 60 °F	39.0	43.2	10 – 50
Calorific Value	MJ/kg	45.2	44.8	45
Carbon Residue	%m/m	0.18	0.24	0.05
Flash Point	°C	36	39	38 -52
Fire Point	°C	46	47	220 (maximum)
Kinematic Viscosity	mm^2/s	1.30	1.30	1.39– 1.50
Saybolt	-	+30	-16	N/A
ASTM Color	-	0.1	1.0	N/A

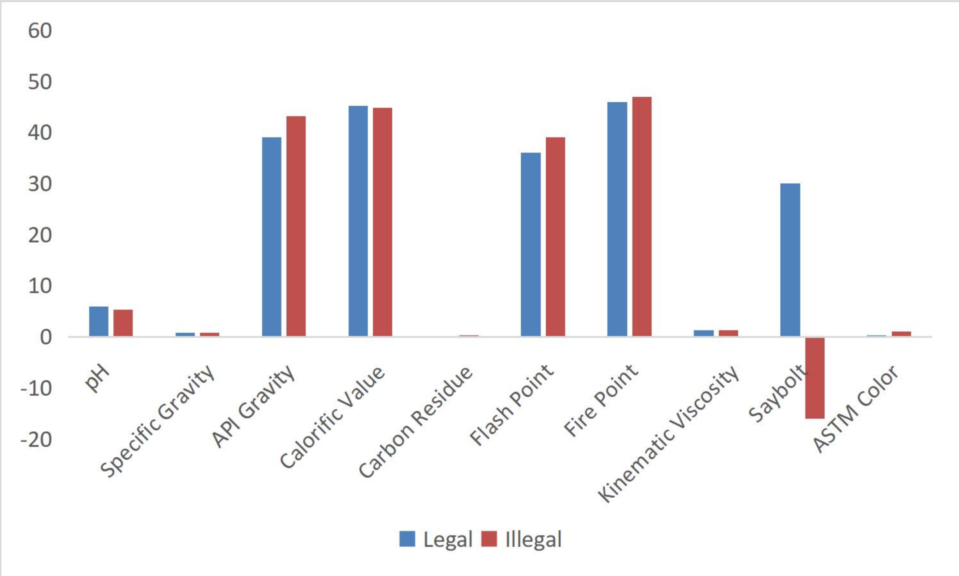

Fig. 3: Legal and illegal refined physiochemical properties of Kerosene

4.3 Results of Legal and Illegal Refined Physio chemical Properties of Diesel

The quality of diesel could be traced to its appreciable physiochemical properties. Deficiencies in the physiochemical properties could tell so much on its performance in the engine. The result of the investigation of the physiochemical properties of the artisanal diesel and pure sample showed some differences in their values as showed in **Table 5**. The illegally refined diesel is slightly acidic (pH of 6.7) while the reference sample is basic (pH = 7.5). The former seem to be corrosive in nature. Hence, illegally refined diesel can corrode its storage tank if it meets moisture or water. All other physiochemical properties such as flash points, fire point, kinematic viscosity, ASTM colour, Saybolt, calorific values and impurity level of the illegally refined diesel deviated slightly from those of the reference sample Table 6. The slight decrease or increase in the values of the illegally refined diesel with respect to the reference sample will affect its performance in diesel-ignition engine. Similarly, **Figure 4** summarises the plot of the legal and illegal physiochemical properties of Diesel.

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ISSN: 2714-2264

Table 5: Results of Legal and Illegal Refined Physio chemical of Diesel

Physiochemical Properties	Unit	Legal	Illegal	Limit
pH	-	7.50	6.70	N/A
Specific Gravity	@ 60 ºF	0.86	0.80	0.8 – 0.88
API Gravity	@ 60 ºF	33.03	45.38	30 – 42
Calorific Value	MJ/kg	44.5	44.2	42 -46
Impurity	%m/m	0.10	0.14	N/A
Flash Point	ºC	50	48	52 – 96
Fire Point	ºC	62	58	210
Kinematic Viscosity	mm^2/s	2.40	2.50	3.7-5.8
Saybolt	-	-16	-11	N/A
ASTM Color	-	7.0	9	N/A

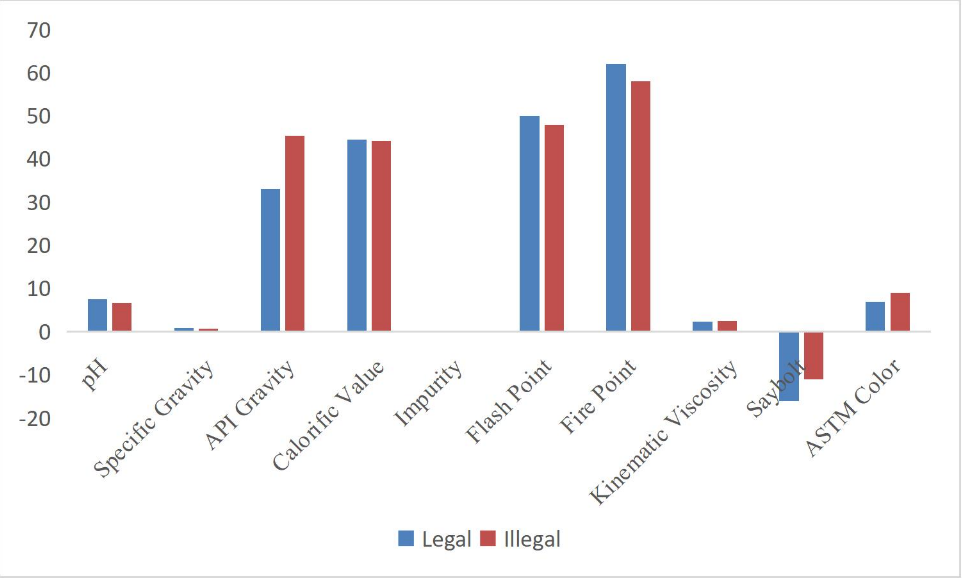

Fig. 4: Legal and illegal refined physiochemical properties of Diesel

4.4 Results of Legal and Illegal Refined Physio chemical of Fuel

The results obtained for the illegally refined fuel or gasoline and reference sample shows that the former had an acidic property (pH of 6.10) while the later was slightly alkaline (pH = 7.25) as shown in **Table 6**. The API gravity value for the illegally refined was found to be 70.6, which slightly higher than the allowable limit (10 – 70), but the reference sample has a value of 65, which is within the allowable limit. The sample from artisanal refining was lighter than the pure sample. The implication is that its flash point and fire point were lower than those of the pure sample were. It burns at lower temperature than the reference sample. However, calorific values for both samples did change significantly, as they were close, meaning that they had close heating capacities. The results of the Saybolt and ASTM colour showed slight difference. The ASTM colour value for the artisanal fuel was higher than that of the reference sample. The impurity level of the locally (illegally) refined crude was higher than that of the commercially refined sample. The presence of impurity in a concentration higher than the allowable limit could cause damage to the automobile engine. The kinematic viscosities of the two samples studies showed some levels of variations. The fire and flash points of the locally refined fuel were lower than those of the reference samples as shown in the **Table 6.** This implied that the locally refined could ignite combustion engine at lower temperature. **Figure 5** summarizes the plot of the legal and illegal physiochemical properties of fuel/gasoline.

Table 6: Results of Legal and Illegal Refined Physio chemical of Fuel

Physio-chemical Properties	Unit	Legal	Illegal	Limit
pH	-	7.25	6.10	N/a
Specific Gravity	@ 60 ºF	0.72	0.70	0.7 – 0.8
API Gravity	@ 60 ºF	65.0	70.6	10 -70
Calorific Value	MJ/kg	45.9	45.3	44 -46
Impurity	%m/m	0.08	0.10	0.01 -0.04
Flash Point	ºC	-32	-228	-43 - -45
Fire Point	ºC	-23	-18	247- 280
Kinematic Viscosity	mm^2/s	0.72	0.82	3 – 5.5
Saybolt Color	-	+20	-16	N/A
ASTM Color	-	1.0	1.5	N/A

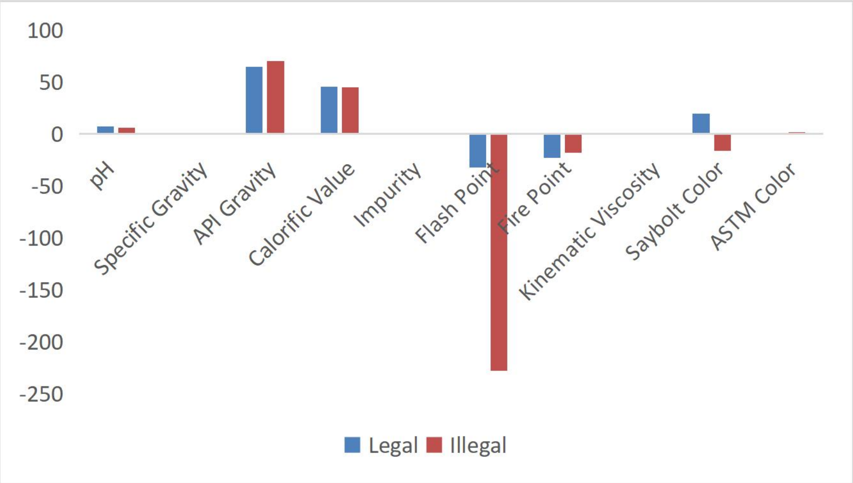

Fig. 5: Legal and illegal refined physiochemical properties of fuel/gasoline

5.0 CONCLUSION

This work aims at investigating the physiochemical properties of illegal refined petroleum products around Okrika and Eleme local government area of Rivers state. Different properties such as the viscosity, specific gravity, calorific value and others had been evaluated and results presented. From the analysis of the results, the following conclusions had been deducted:

- The pH values obtained from both illegal and legal petroleum products provide a fundamental understanding of their acidity or alkalinity. The results of pH readings for reference samples (Diesel, kerosene and petrol) and the artisan-refined samples (Diesel, kerosene and petrol) were 7.5, 5.9 and 7.25 and 6.7, 5.35 and 6.10 respectively.The results demonstrated that bunkered products exhibited a slightly more acidic nature compared to their standard counterparts. The finding suggests variations in the chemical composition, potentially influenced by the source of bunkered petroleum and the refining processes applied.
- Viscosity, a critical parameter influencing fluid flow and lubrication properties, showed discernible differences between bunkered and standard petroleum products. Bunkered products exhibited higher viscosity, indicative of a heavier and more viscous nature. This could be attributed to variations in crude sources, refining techniques, or the presence of impurities in the bunkered samples.
- Specific gravity, a measure of density compared to water, displayed disparities. Bunkered products generally exhibited specific gravity values slightly higher than those of standard products. This suggests the differences in the concentration of heavier hydrocarbons, impurities, or the presence of additives, all of which contribute to the

overall density of the bunkered petroleum products.

- The calorific value, a critical parameter reflecting the energy content of the fuels, revealed intriguing findings. Bunker products demonstrated a marginally lower calorific value compared to standard petroleum products. This variation could be attributed to differences in the composition of hydrocarbons, sulphur content, or the refining processes employed in their production.
- The fire point and flash point, critical safety indicators, demonstrated noteworthy differences. The flash points of artisan diesel, petrol and kerosene were 50, -32 and 39 respectively while the flash points of imported samples of diesel, petrol and kerosene were 48, -228 and 39 respectively.
- Bunkered products exhibited slightly higher fire and flashpoints compared to standard products. This suggests differences in the volatility and combustibility of the two types of fuels, with implications for storage, transportation, and combustion efficiency.

6.0 RECOMMENDATIONS

Having understood the variations in the physiochemical properties of bunkered petroleum product in comparison with standard products, the following are recommended:

- The government should promulgate and implement the laws and policies to regulate the quality of petroleum products allowed in the local market.
- Similarly, Government should put up measures to control the activities of those into illegal refining because of the environmental concerns associated with it.
- Finally, the federal government should invest in the modular refineries so that they can afford the required facilities to refine crude oil to products that the minimum API specifications on physiochemical properties.

7.0 ACKNOWLEDGEMENT

The authors would like to thanks the staff of Department of Petroleum and Gas Engineering and the laboratory staff of the Africa Center of Excellence in Oilfield Chemical Research (ACE-CEFOR), University of Port Harcourt.

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