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Evaluation of Engine Damage Caused by Artisanal Refined Gasoline Fuel Produced in the Niger Delta Region of Nigeria

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***Abstract**: The use of gasoline (also known as premium motor spirit i.e. PMS) and diesel fuel produced from artisanal refinery operated in the Niger Delta Region of Nigeria most times cause severe damages to vehicle engines and generators besides the environmental pollution it causes during production process. This paper aims at carrying out an evaluation of vehicle engine damage caused by artisanal refined gasoline fuel (ARGF) produced in the Niger Delta Region of Nigeria. The purpose of this work is to characterize a sample of the ARGF and examine the extent of damages it can cause to vehicle engines. A sample of the ARGF was taking from Oluokobo community in Ahoda West Local Government Area of Rivers State and analyzed in a laboratory. The results of the test reveals the following: Octane number, flash point, reid vapour pressure and specific gravity of 72.3, – 45ºC, 0.37 kg/cm^2 and 0.69 respectively. The chromatography analysis reveals 16.7% inclusion of kerosene in the sample while the performance test carried out with the ARGF used in an ignition test engine shows tendency for knocking which can cause serious damage to vehicle engines and reduce the life span by 30%, this circumstance portends an economic loss to vehicle owners.*

Keywords—Adulterated fuel, Flash point, Knocking, Octane number, Premium motor spirit and Reid vapour pressure.

1. Introduction

Gasoline fuel is a volatile, flammable liquid produced by refining petroleum (crude oil). It was once dumped as a waste product from the manufacture of kerosene, but due to its low-temperature vaporization, it became a useful fuel for many equipment. One of the byproducts of fractional distillation, which does not actually make gasoline from crude oil but just separates it from other compounds in the crude oil is gasoline. It is one of the products of distilling and refining petroleum and the quality of this fuel can be improved by additional refining procedures.

One of the most crucial steps in the refinement of oil is catalytic cracking. A catalyst, high temperature and enhanced pressure are used in this procedure to modify the chemical composition of petroleum. Petroleum is treated with catalysts like aluminum, platinum, processed clay and acids to break down bigger molecules and produce the necessary gasoline-related chemicals. Polymerization is a further refinement procedure which combines smaller molecules of lighter gases into bigger ones that can be used as liquid fuels; this works in opposition to cracking.

Chemicals are included after gasoline has been refined. Some of these substances work to stop "engine knock" by reacting with the components of gasoline that burn too quickly. Tetraethyl lead is the anti-knock component in leaded gasoline. Antioxidants and other compounds are included to stop gum buildup in the engine. Gum is a compound that forms in gasoline and can coat the engine's interior components, causing more wear.

Heptane and isooctane, two volatile liquids, make up the majority of gasoline. The octane rating quantifies the ratio of heptane to isooctane. Less knocking and a higher octane rating are associated with higher isooctane percentages. An octane rating of 87, for instance, is equivalent to a blend of 87 percent isooctane and 13 percent heptane.

Because it powers the bulk of the nation's automobiles and motorcycles as well as the small to medium-sized energy generators used by homes and small businesses, gasoline is in high demand throughout Nigeria.

Artisanal refining is an illegitimate small-scale or subsistent distillation of crude petroleum (using local technology, resources and skills) over a specific range of boiling points, to produce useable products such as gasoline, kerosene and diesel in locally constructed stills.

Heavy fractions like lubricating oil and bitumen cannot be processed by artisanal refinery facilities. As a result, they are typically dumped or stored in pits near the refinery. According to Attah (2012), the process is so inefficient that it is very possible that up to 80% of the crude oil's bottom fractions cannot be refined and are instead just released into the environment.

Gasoline became crucial to the car industry with Nikolaus Otto's invention of the four-stroke internal combustion engine in 1876. Today, practically all gasoline is used to fuel cars, with just a very small amount going to aviation and agricultural machinery.

Internal combustion engines produce a knocking sound when a portion of the compressed air-fuel combination in the cylinder burns off too quickly. Numerous factors, including carbon buildup in combustion chambers or on cylinder walls, worn lifters or connecting rods, an overheated engine, back pressure from the exhaust, vacuum leaks, poor fuel quality or octane and faulty spark plugs or knock sensors can cause an engine to knock or bang. A portion of the charge may spontaneously ignite and burn wildly before the flame front, producing powerful, high-frequency pressure waves. This depends on the makeup of the fuel. The engine parts vibrate as a result of these pressure waves, producing an audible knock. Knocking can cause the spark plug points to overheat, the combustion chamber surface to erode and rough, inefficient operation. The most common solution is to burn gasoline with a higher octane rating. It can be avoided by altering engine design and operation characteristics like compression ratio and burn time.

The antiknock rating, often known as the octane number, measures a fuel's resistance to knocking when ignited in the cylinder of an internal combustion engine with a mixture of air. To determine a fuel's octane rating, its knock intensity is compared to mixtures of two reference fuels: iso-octane, which doesn't knock as easily as heptane under controlled conditions The octane number is the volume percentage of iso-octane in the iso-octane-heptane mixture that corresponds to the fuel being tested in a typical test engine.

The aim of this paper is to carry out an evaluation of engine damage caused by ARGF produced in the Niger Delta Region of Nigeria. The objectives of this paper are as follows:

i) To collect samples of artisanal fuel from the production site.
ii) To determine the properties of the artisanal fuel.
iii) To analyze the effects on automotive engines.

The significance of this study is to highlight the dangers of using artisanal fuel and hence the need to avoid it and save money that could arise from repairing damaged engines if it is used.

Several studies have been done in the areas of the impact of artisanal fuel on the environment; comparative analysis of artisanal fuel and official fuel, etc. However little research work has been focused on the effect of artisanal fuel on automotive engines. The review of related literature is done in this section.

Sibe et al. (2019) looked at the physico-chemical characteristics of the interstitial water in the intertidal zone of Bon-Ngyia Creek in K-Dere, where artisanal refining activities are ongoing and bottom hydrocarbon fractions and unrefined crude oil are continuously disposed of. The findings reveal that temperature and pH fluctuates temporally between 6.0 – 8.2 and 27^{o} – 32^{o}C respectively. TDS (1845 – 7655*mgl*-1) falls within the US EPA range (3000 – 10,000*mgl*-1) for highly saline water. EC and TDS (238 - 7885µS/cm and 1845 – 7655*mgl*-1) also varied temporally and spatially between the study areas.

Igben (2021), conducted research on the occupational dynamics and artisanal petroleum refining in Nigeria's Niger Delta. As an indirect effect of artisanal refining in the experimental and controlled settlements, the study found significant dynamics (t = - 0.22, df = 12, p 0.05) in the number of respondents in the indicated occupational typologies. Therefore, the report suggests stepping up efforts to put existing regulations on environmental protection into practice and providing jobs for a growing population.

In 2020, Enakpoho et al. investigated the air pollutants from small-scale oil refineries in Nigeria's Niger Delta. The outcome showed that, as processing capacity grew, pollutants emission rose and varied greatly between unit operations. The emissions (CO, NOx, and SO_2) exceeded the daily limitations that were established by the Environmental Guidelines and Standard for Petroleum Industry in Nigeria (EGASPIN) 2002. Gwary et al (2021), investigated the fuel quality produced by the artisanal refineries operating illegally in the Niger Delta region. It was found that the Sulphur content of gasoline, kerosene and diesel, respectively fall in the ranges of 0.10-0.62 percent weight, 0.34-0.69 percent weight and 0.80-0.95 percent, which is above the permitted levels. Each site's Saybolt values for kerosene were below the minimum (+20) value established by the American Standard for Testing Materials (ASTM). The fact that the color of the diesel likewise falls short of the ASTM standard suggests that both the kerosene and diesel may have been contaminated or degraded while being stored or refined.

2. METHODOLOGY

The methodology employed in this study include the collection of fuel sample from artisanal refinery camp; analysis of data obtained from the study site; the production of artisanal fuel and its impact on automotive engine.

2.1 Study Site

In the Atlantic Ocean's Gulf of Guinea, the Niger Delta Region is located. There are nine states in all, including all six of Nigeria's South-South states (Bayelsa, Rivers, Delta, Edo, Cross-Rivers, and Akwa-Ibom state), as well as oil-producing states Abia, Ondo, and Imo. (NDDC, 2004; Kiikpoye, 2003). The region is in the Southern part of Nigeria and stretches within Latitude 40 12’ 30.892” N through Latitude 40 50’ 10.7” N and Longitude 40 56’ 15” E through longitude 90 40’ 2.654” E.

The study considered an illegal refinery sites located in Oluokobo community, Ahoda West in Ahoda LGA of Rivers State. It lies on latitude: 5.0391 North, longitude: 6.49372 East and altitude: 18.00 m/59.06 ft.

2.2 Sample collection and Preparation

The ARGF was collected from the study site in a 1.0 litre container and sent to a laboratory for analyses to determine its properties and also carry out a performance test with it in an ignition engine system. Similarly, conventionally refined petroleum products were collected from Mobil filling station to serve as a basis for comparison.

2.3 Artisanal Refinery Process

A typical artisanal refinery process goes through several stages as illustrated in Fig 2.1 and explained thus:

Stage 1: Crude oil illegally obtained from pipeline vandalisation is supplied to the refinery camp and fed into the refining oven which heat it up to a temperature of about 250^{o}C. This enables separation of the compounds into

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fractions according to their boiling points (distillation process). At this stage, vaporisation of petroleum gas, gasoline, kerosene and diesel fuel occurs.
Stage 2: Evaporating compounds of the crude oil are channelled out of the oven in succession by means of several pipes connected into the coolant tank where the vapour is cooled and condensed into liquid form.
Stage 3: A single pipe with a diameter of about 100 mm conveys the condensed product to the extraction tank where gasoline, kerosene and diesel fuel can be tapped in succession.
Stage 4: The receiver or fuel storage tank is used to collect and store fuel that are not tapped at stage 3.
Stage 5: Unvapourized portion i.e. low pour fuel oil (LPFO) of the crude oil that cannot be heated up to their boiling point remains in the oven and are channelled out through a pipe to a surrounding pit.
In contrast to the artisanal method of refining crude oil, a more advanced system of conventional (modern) refinery is shown in Figure 2.2 where the various components of the crude oil are evaporated and condensed in separate receiver (fractional distillation column) maintained at different temperatures.

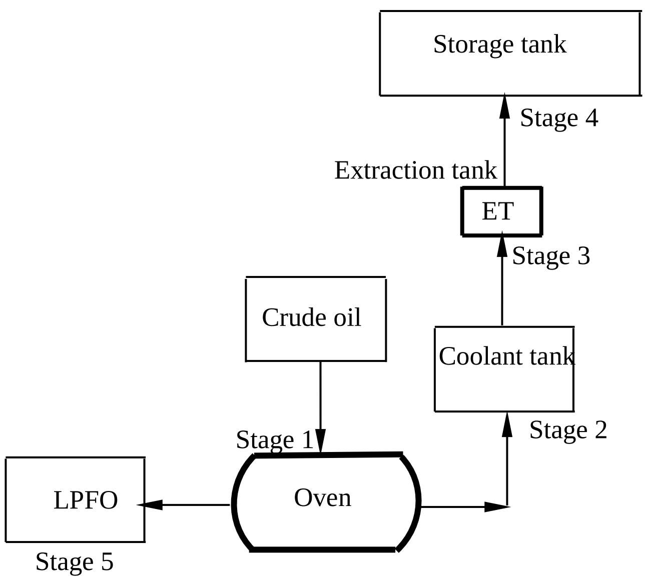

Fig. 2.1: Artisanal refinery process

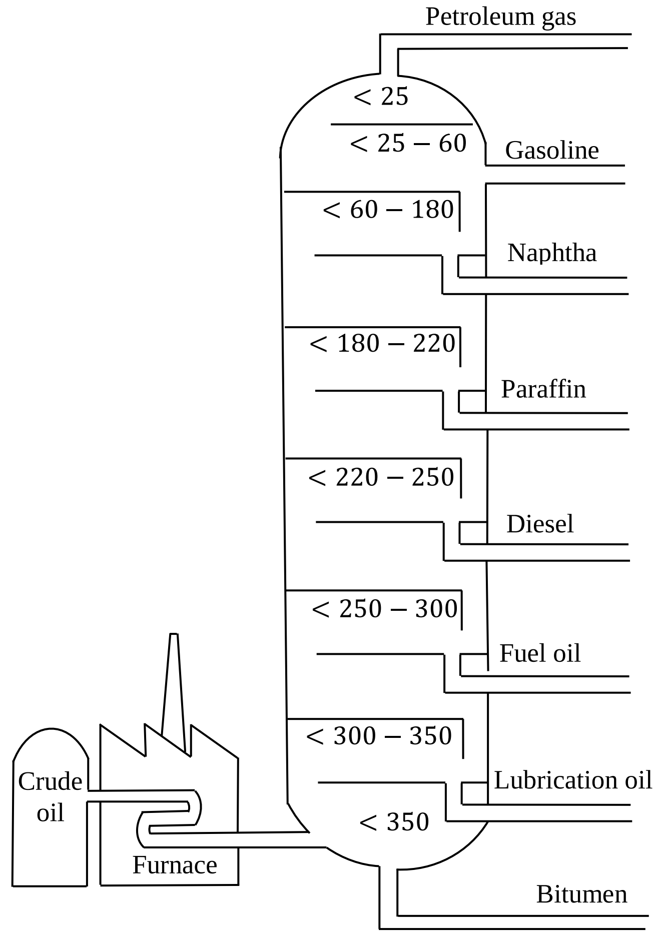

Fig. 2.2: Conventional refinery process

Table 2.1: Time Interval for Extraction of Fuel

S/N	Criteria	Artisanal	Conventional
1	Desalting of crude oil	Desalting undone	Desalting done
2	Instrumentations and control system	Uninstalled	Installed
3	Furnace temperature	≈250ºC	≈360º C
4	Processing	Incomplete processing (engine and bitumen oil remain in the oven)	Complete evaporation of all the components of the crude oil
5	Separation process	Single extraction tank	Distillation columns
6	Refinement process after distillation	Not carried out	Catalytic cracking and polymerization

Time (min)	Fuel
30 – 90	Petroleum gas (vented off)
90 – 120	Gasoline (PMS)
120 – 240	Kerosene
240 – 330	Russian diesel
330 – 540	Normal diesel
540 – 660	Engine oil mixed with bitumen

2.4 Method of Extraction of Artisanal Refined Fuel

The oven heats up the crude oil to vapour state which then condenses to liquid state and then extracted. The process of extraction of the various components is through the same point and it is based on the time interval from the period (shown in Table 2.1) of firing the oven.

2.5 Differences Between Artisanal and Conventional Processing of Crude Oil

The major differences between artisanal and conventional method of refining crude oil is shown in Table 2.2.

Table 2.2: Differences Between Artisanal and conventional Refinery

2.6 Determination of sample Octane Number

Using a knock meter model ZX101C, the experiment was carried out in accordance with ASTM-D2699 standard protocol. The selector valve was left running for a few minutes to reach balance after the carburettor had been filled with 240 mL of gasoline samples. The knock meter had also been turned on. The cylinder height of the knock meter reading was modified between 45 and 47, then to 50, after finding the fuel level for the maximum knocks. The research octane number indicated the maximum knock fuel ratio and average knock severity. It was also obtained by adjusting the assessed gasoline sample's compression ratio until a knock meter registered knocking. The engine was run on a mixture of 94.20:5.8 iso-octane and n-heptane till it banged once more. Next, the evaluated gasoline's research octane number (RON) was obtained. The result is presented in Table 3.1.

2.7 Determination of Flash Point

The samples' flash points were measured using a pour/cloud point tester (model PP-F3B4) for the lower temperature and a closed type K16270 flash point tester in accordance with ASTM-D86 standard procedure. A 120mL of the gasoline sample was added to an anti-bumping pellet-filled flask with a circular bottom. The temperature was set to 300°C and the distillation apparatus was turned on. As soon as the first drop of the sample reached the measuring cylinder, the temperature at the initial boiling point (IBP) was promptly taken note of.
The following calculation was used to determine the 10 percent ASTM D86 temperatures and to calculate the flash points.

$$\frac{1}{T_{EF}} = -0.014568 - \frac{2.8497}{T_1} - 1.903 \times 10^{-3} lnT_1$$

where T_{EF} = Flash point of gasoline
T_I = ASTM 10% temperature for the gasoline or normal boiling point (ºF)

2.8 Determination Reid Vapour Pressures (RVP)

Using the Reid vapour pressure analyser, the samples' Reid vapour pressure (RVP) was calculated in accordance with ASTM test method D323 (P-700-1.00model). The Reid vapour pressure machine and Reid vapour pressure water bath were both filled with 50mL gasoline sample. A temperature of 38ºC was set and the light fraction of the gasoline sample began to vaporize after 30 minutes, the pressure of the evaporating vapour was noted.

2.9 Determination of Specific Gravity (S.G)

A tiny amount of the test sample was spun in a measuring cylinder (100ml), which was then blown dry before 50ml of the test sample was added. The sample was submerged in a

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hydrometer with a calibration range of 0.50 to 0.85 and the specific gravity (S.G.) was noted. The sample's ultimate temperature was also documented and converted to Fahrenheit using a thermometer that was placed inside the measuring cylinder (F). This test was carried out using ASTM test method D1298 (ASTM, 2006a).

2.10 Gas Chromatography Determination of Kerosene Component

The sample was analyzed to quantify the percentage of kerosene inclusion in the gasoline sample using gas chromatography test.

2.11 Performance Test on Engine

A spark-ignition, four-stroke, water-cooled engine with a rated speed of 4600 rpm and brake power of 60 kW was employed. The test engine was fueled with fuel sample from the artisanal refinery (85.3 percent gasoline blended with 14.7 percent kerosene). The engine was run under "no load" conditions, and the fuel control valve was changed to bring the speed to 4500 rpm. After running the test engine until it reached a constant speed, it was gradually loaded.

3 RESULTS AND DISCUSSION

The results of the fuel analysis and the performance test carried out on the ignition engine are discussed in this section.

3.1 Gasoline Sample Analysis

The results obtained from the experimental analysis of the ARGF sample is presented in Table 3.1.

Table 3.1 AG Experimental Test Result

Test Parameter	Artisanal Gasoline	Conventional Gasoline	ASTM Standard
Octane number	72.3	92.3	≥ 90
Flash point (ºC)	– 35	– 34	– 43
RVP (kg/cm^2)	0.37	0.54	0.45 – 0.60
Specific gravity	0.69	0.77	0.75 – 0.85

i) Octane Number of ARGF

The gasoline's propensity to withstand pre-ignition during compression in an engine cylinder is determined by its octane rating (David et al., 2018). The ARGF sample's octane number, which was determined by experimentation, is 72.3, this is below the ASTM norm of 90. An engine's efficiency and performance may suffer as a result of this low octane number, which may be the result of a poor refining procedure. As a result, it may cause engine knock.

ii) Flash point of ARGF

The lowest temperature at which a liquid can ignite its vapour in the presence of an ignition source and have the flame spread across its surface is known as the flash point. Because the ARGF has a flash point that is lower (– 43ºC) than the ASTM norm (–45ºC), the gasoline samples under evaluation may readily catch fire and explode in the refinery camp.

iii) Reid Vapour Pressure of ARGF

At 100ºF, Reid vapour pressure (RVP) is used to estimate the vapour pressure of a gasoline blend (David et al., 2018). It serves as a gauge for gasoline volatility when used in car engines. When exposed to the atmosphere, some components of a gasoline blend with a high RVP volatilize (David et al., 2018). In comparison to the minimum ASTM requirement of 0.45 kg/cm^2, the RVP of the ARGF is 0.37 kg/cm^2. Because of the low RVP of ARGF sample, starting an automobile engine at low temperatures may be problematic (David et al., 2018). Extremely low RVP in cold regions prevents automobile engines from starting, whereas extreme volatility in hot weather causes what is known as vapour lock

iv) Specific Gravity of ARGF

The difference in density between two substances that is used as a benchmark is known as specific gravity. The standard for both liquids and solids is water. The ARGF had a specific gravity of 0.69, which was below the minimal ASTM requirement. Using this in an automobile engine could harm it. It might also cause the spark-ignition engine to completely detonate (Alang et al., 2018).

3.2 Gas Chromatography Analysis

An analytical method called gas chromatography (GC) is used to separate the chemical components of a sample mixture and then detect them to ascertain whether or not they are present and/or how much of them are. Typically, these chemical components are gases or organic compounds. The results of the test performed on the ARGS shows that 16.7% of the sample contained kerosene. Kerosene doesn't make a good fuel for spark ignition engines because it would detonate on compression and has an extremely low octane rating, at around 20. Because kerosene has a lower octane number than gasoline, kerosene-adulterated gasoline will generate engine banging (Fonseca et al., 2007).

3.3 Engine Performance Test

Since kerosene has a lower octane number than gasoline, it was difficult to start the engine when gasoline was doped with kerosene at the ratio of 85.3:14.7, and there was a chance of knock. The engine will knock when kerosene-adulterated gasoline is used; this was discovered when the engine was operated on a mixture of 50% kerosene and 50% gasoline.

4. CONCLUSIONS

In terms of octane number, Reid vapour pressure, specific gravity, and flash point, the quality and properties of the ARGS typically fall short of the suggested ASTM standard. These flaws have the potential to significantly enhance the tendency for knocking, which might ultimately result in catastrophic engine damage along with financial loss for car owners. In addition, a very severe environmental pollution is produced by the artisanal refining of crude oil which can increase the risk of respiratory infections, heart disease and lung cancer.

5. REFERENCES

[1] Akeredolu, F.A., Sonibare, J.A. (2015). Process Evaluation of Nigeria's Artisanal ("Illegal") Petroleum Refineries for Effective Air Pollution Control. In: Proceedings of the 45th Annual Conference of NSChE, 5th – 7th Nov. 2015, Warri, Nigeria, pp. 94–109.

[2] Alang, M. B., Ndi-kontar, M. K., Sani, Y.M., and Ndifon, P. T. (2018) Synthesis and Characterisation of a Biolubricant from Cameroon Palm Kernel Seed Oil Using a Locally Produced Base Catalyst from Plantain Peelings. Green Sustain. Chem. Vol. 8, PP. 275–287.

[3] Anthony, O., Bamidele, S. F. and Ademola, S. (2020). Investigation of Air Emissions from Artisanal Petroleum Refineries in the Niger-Delta of Nigeria. Article in Heliyon · November 2020.

[4] ASTM International (2004). Annual Book of ASTM Standards: Section 2, Nonferrous Metal Products. Volume 02.05, Metallic and Inorganic Coatings, Metal Powders, Sintered P/M Structural parts. American Society for Testing and Materials.

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

[6] Diya'Uddeen, B. H. (2019). Quality of Fuels Produced by the Illegal Artisanal Refineries in the Niger Delta Area of Nigerian, Journal of Scientific Research, Vol. 18, No. 1, pp. 43 – 47.

[7] Fonseca, M. M., Yoshida, M. I., Fortes, I. C., and Pasa, V. M. (2007). Thermogravimetric Study of Kerosene-Doped Gasoline, J. Therm. Anal. Calorim. Vol. 87, No. 2, pp. 499 – 503.

[8] Gwary, K. M., Abubakar-Zaria, U. 1., Galadima, M. S. and
Igben, J. L. (2021). Artisanal Petroleum Refining and Occupational Dynamics in the Niger Delta Region, Nigeria, J. Appl. Sci. Environ. Manage, Vol. 25, No. 3, pp. 341-345.

[9] Kiikpoye, K. (2003). Human Rights Violation and Petroleum Pipeline Vandalization in the Niger Delta Region. Nig. Soc. Sci. Vol. 6, No. 2, pp. 17-26.

[10] Murago, E. N. (2013). Assessment of gasoline adulteration in Nairobi, Kenya, Doctoral dissertation, Jomo Kenyatta University of Agriculture and Technology, Kenya.

[11] Nadkarnim, K. R. (2000). Guide to ASTM Test Methods for the Analysis of Petroleum Products and Lubricants. East Brunswick, NJ: Millennium Analytics Inc, 36–79.

[12] Obodeh, O. and Isaac, F. O. (2011). Investigation of Performance Characteristics of Diesel Engine Fueled with Diesel-Kerosene Blends. Journal of Emerging Trends in Engineering and Applied Sciences, Vol. 2, No. 2, pp. 318 – 322.

[13] Olorunnishola, A. A. and Olabisi, O. I. (2018). Effects of Vessel Pressure on Flame Temperature and Height of Adulterated Kerosene Fuel Samples in a Pressurized Cooking Stove. International Journal of Advances in Scientific Research and Engineering, Vol. 4, No. 4, pp. 26 – 35.

[14] Sibe, L., Osuji, L. C. and Hart, A. I. (2019). Physico-Chemical Alterations of Interstitial Water Quality by Artisanal Refining Operations at K-Dere Coastal Plain, South-Eastern Nigeria, International Journal of Scientific & Engineering Research, Vol. 10, Issue 12, pp. 194 – 205.

[15] Stauffer, E., Dolan, J. A. and Newman, R. (2008). Chapter 7. Flammable and Combustible Liquids. Fire Debris Analysis; pp. 199-233.

[16] Totten, G.E., (2006). Handbook of Lubrication and Tribology: Application and Maintenance. Vol. 1, CRC Press, Taylor and Francis Group, 6000 Broken Sound Parkway, New York, USA.