

The Use of Diesel Oil Treated with Inorganic Salt: An Alternative to Kerosene

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Abstract

This paper investigates the effect(s) of inorganic salts (potash and alum) on diesel oil and the suitability of the mixture as an alternative to kerosene. Samples of diesel oil were treated with different proportions of potash and alum. The resulting mixture was then subjected to different physicochemical property analysis. The properties tested for included: volatility, sulfur contents, aniline point, smoke point, flash point, density, kinematics viscosity and color. All the tests were carried out using the American Society for Testing and Materials (ASTM). The results obtained showed that the treatment of diesel oil with alum and potash alter measured physicochemical properties of diesel oil. Samples of diesel oil treated with potash showed a very little significant change from properties of diesel oil, while that treated with alum produced higher color and odor closer to that of kerosene. The overall analysis showed that the properties of the diesel oil treated with both potash and alum do not have close values compared to that of the kerosene, and it appeared to have serious technical limitations to their use in domestic stores and lamps. Therefore, diesel oil treated with inorganic salts is not suitable as an alternative to kerosene.

Keywords: *Inorganic salts, potash, alum, volatility, sulfur contents, aniline point, smoke point, flash point, density, kinematic viscosity, color.*

Introduction

Crude petroleum is a dark, brown and black viscous liquid, which is lighter than water. It is obtained as a product of natural physical and chemical changes of decayed organic material buried under the earth crust, for a very long period of time (Ababio 1993). Crude petroleum is found naturally in the earth in which physical composition and chemical composition varies and depends on the source of petroleum (Ababio 1993). Crude petroleum consists of a complex mixture of hydrocarbons varying in a chain length between C_1 and C_{40} .

Diesel fuel and kerosene are liquid fuel originated from crude oil. Hence, the lower boiling fraction, which composed of, saturate hydrocarbon, singly bonded together with general formula C_nH_{2n+2} is the group in which Diesel fuel and kerosene belong as fractions of product petroleum (Ababio 1993).

Diesel fuels are a broad class of petroleum products, which includes distillate or residual materials (or blend of these two). The properties of commercial fuel depend on the refining practice employed and the nature of the crude oil from that which is produced (Leffler 1987). Diesel fuel fraction follows the kerosene fraction during fractional distillation of petroleum, and it is classed as an intermediate distillate, which is a natural liquid fuel.

Diesel fuel is a mixture of hydrocarbon with about 12-25 hydrocarbon ($C_{12}H_{25}$) atoms per molecules and distillates over a temperature of 250° to $400^\circ C$ (Dyloff 1993). They are used as a source of power, heating of homes fuel for heavy engines and as raw materials for cracking processes to obtain motor gasoline (Dyloff 1993).

Kerosene is obtained as a fraction from crude petroleum, it is known as light gas oil used for domestic purpose (household cooking and heating) and also as fuel for modern jet

engines. It distillates over a temperature of about (200-300°C), and contain C₁₂ to C₁₈ per carbon molecule (Dyroff 1993). Most Nigerians use kerosene for domestic purposes, mostly for cooking in place of gas.

The demand for kerosene increased spontaneously due to the growing population of consumers, but supplies did not grow in the same direction, leading to a serious scarcity of this product. The major factor considered responsible for this is the low capacity at which our refineries operate, which were as a result of poor funding, poor maintenance, culture, etc.

However, the need for an alternative and environmental friendly source for kerosene became very necessary.

In the past years during the kerosene scarcity period, most Nigerians used products like diesel fuel pre-treated with inorganic salt, in place of kerosene for cooking, this exposed them to possible explosions, and emissions of thick carbon deposits that affect utensils and health (Innocent 1997). Due to the problems stated above, this paper is channeled towards the investigation of the effect(s) of inorganic salts on diesel oil. The introduction of inorganic salt, which is meant to act as a catalyst in the mixture, is expected to show a positive effect in the conversion of diesel oil to kerosene.

However, the major aim of this research is to establish the fact that, "diesel oil treated with common inorganic salts can be used as an alternative to kerosene". This became necessary because of the fraudulent practices of some marketers during the time of the kerosene storage.

Methodology

Samples

Samples of diesel fuel and Kerosene used for this analysis were collected from Kaduna Refining and Petrochemical Company (KRPC). While potassium aluminate [KAl(SO₄)₂], and potash (potassium chloride) were obtained in the market. All the tests carried out were based on the American Society for Testing and Materials (ASTM 1985).

Sample Preparation

Specified quantities of KAl(SO₄)₂ were grinded into a fine power form while potassium chloride, which was already in powdery form, was not subjected to this treatment. Each of the salts was dried in an oven to reduce the moisture content. Various percentages (5, 10, 20, 35, 55 and 80%) of each of the salts were introduced into a constant and volume of fresh diesel.

The mixture was allowed to react at room temperature after thorough stirring for a maximum of two days. The salt was then separated to obtain a clear filtrate on which further analysis were carried out. The bluish brown color of the diesel fuel then changed to a pale yellow color due to physical reactions. Samples of salts added to diesel were added in various percentages in which 100% of salt was equivalent to 100 g of salts.

Atmospherical Distillation -Test: ASTM (D-86)

100 ml of a pre-treated sample was placed in a distillation flask and distilled under prescribed conditions (100-370°C) in distillation column. A graduated cylinder of 100 ml was placed at the tip-end of delivery tube to collect distillate.

During the process the initial boiling point was recorded as the first drop of the distillate was observed. Also, systematic observations of thermometer readings and volumes of condensate were noticed and recorded in °C and ml, respectively, in 10-ml intervals until the end boiling point was noticed, i.e. maximum thermometer reading after the evaporation of all liquids from bottom of the flask.

The same procedure was followed for the entire samples, and results obtained were recorded in the table of results.

Sulfur Analysis-Test Type: ASTM (D1552)

Here, X-ray methods were performed using a sulfur analyzer. Disposable cells, where samples are to be placed and were firstly cleaned with samples. After which, the cleaned disposable cells were then firmly fitted in the

inner frame of cells known as male and female couple. The female couple refers to inner frame while male couple refers to outer frame. Samples of pre-treated diesel fuel were then poured into the frame cell up to the level marked on the inside of inner frame of the cell (holder A).

However, the cells were covered with a cell window, which consists of circular paper, and nylon in which circular paper centered the inner frame and with nylon. Then, the outer frame of the cell (holder B) was placed to cover holder A in such a way it fitted. Thereafter, the outer frame was pressed with the palm of the hand gently, in order to hold it firmly. After this, the sample was then placed on the cell tube of the X-ray sulfur analyzer from which the beam would be emitted from the X-ray source.

The sample was measured three times and the average was printed out as the measured value of sulfur in weight percentage. The same method was applied for the rest samples and results obtained were recorded in the table of results

Aniline Point - Test Type: ASTM (D611)

Specific volumes of aniline and sample were placed in a tube (100 ml) and mixed mechanically. Aniline was carefully introduced into the U-tube (part of apparatus) after pouring of the same volume of sample. The mixture was then heated at a controlled rate until the two phases became miscible. The mixture was then cooled at a controlled rate and the temperature at which the phases separated were recorded as the aniline point for all samples. Therefore, the results obtained were recorded in the table of results.

Smoke Point - Test Method (1P51)

Twenty ml of pre-treated diesel fuel sample was introduced into enclosed wick-fed lamp (dry oil container) that had been cleaned with the sample under test. The sample under test was then soaked with wick and placed on the wick holder. Then wick holder was placed on the container and screwed in firmly in order to prevent air into the fuel under test. The wick was trimmed horizontally at end in which

about 6 mm of wick was projected from the container.

After this, the wick was then inserted into the lamp and lighted, it was then adjusted to give off a flame of about 10 mm in height and was allowed to burn for about 5 minutes. The wick was allowed upright until a smoky flame was produced and then lowered until smoke tail disappeared and a measurement was taken in millimeters from the scale calibrated on the side of the central vertical white line.

Also, the time at which smoke disappeared was noted and recorded in seconds. Then, the oil container was removed from the lamp and cleaned with solvent and air dried, ready for another subsequent test. Also new wick was used for subsequent samples.

Gravity Measurement, Hydrometer: ASTM D1298

The temperature of the sample was adjusted to 15.4°C while hydrometer cylinder and thermometer was brought to the same temperature as the sample was transferred into a clean hydrometer cylinder without splashing. The cylinder containing the sample was then placed in a vertical position in a location free from air current. The hydrometer was then gently lowered into the sample in which care was taken to avoid wetting the stem above the level to which it was immersed in liquid.

The meniscus shape was observed when the hydrometer pressed below the point of equilibrium position. As the hydrometer came to rest (the reading was taken) to the nearest 0.0001 and this was observed as hydrometer floated away from the walls of the cylinder. The point on the hydrometer scale at which the principal surface of the liquid cut the scale then looked into and recorded as hydrometer reading for a given sample. This process was then repeated for subsequent tests and results obtained were recorded in the table of results.

Color (ASTM. D 1500): Procedure

A sample container filled to a depth of 50 mm with distilled water was placed in the compartment of the colorimeter through which the standard glasses were being observed. Then

another test sample container was placed in the other compartment. Both containers were covered to exclude all exterior light. The light source was switched on and the color of the sample was compared with that of the standard glasses, i.e. determine which glass matches the color of the sample; or if an exact match is not possible, then use that glass which possesses the next darker color. Record the color of the sample, the designation of the glass producing matching color, e.g. 7.5 ASTM color. If the color of the sample is intermediate between those of the two standard glasses, record the designation of the darker glass preceded by the letter 'L' for, e.g. 7.5 ASTM color.

Kinematic Viscosity (ASTM D445) Procedures (Cannon-Fenke Viscometer)

The viscometer was then washed thoroughly and cleaned with the aid of a pipette; an appropriate volume of solution to be tested was added to the reservoir. The oil sample was allowed to come to thermal equilibrium in a constant temperature bath. Suction was applied with a rubber tube to the upper part of the viscometer, using an aspirator.

The liquid was aspirated up into the tube with two bulbs to a level above the second bulb. The time needed for the level of the liquid under test to the signal markings was timed.

The time in seconds was multiplied by the calibration constant (0.03) of the viscometer to give the kinematics viscosity in CST:

- V= kinematics viscosity, CST
- C= calibration constant of the viscometer
- L= flow time in seconds

Flash Point: Test Type (ASTM D93) Test Method: Penskey-Martens Closed-Cup Method

The cup part of the Penskey-Martens closed cup apparatus and its accessories was firstly cleaned filled with sample to be tested to the level indicated by the filling mark. Then, the lid of the cup was placed on and the cup was properly set on the store and care was taken, making sure that all the locking devices were properly engaged.

A thermometer was then inserted and a test flame was lighted and adjusted up to 4mm in diameter. In which heat was supplied in such away that the temperature indicated by thermometer increases 5-6°C/mm. After introduction of heat, the sample then stirred in a downward direction and care was taken by making sure that sample was not stirred when applying the test flame. The sample was heated at a low constant rate with continual stirring at which a flame test normally directed into the cup at a regular interval with simultaneous interruption of stirring.

However, during the process, the lowest temperature at which the application of the test flame causes the vapor above the sample to ignite was recorded as flash point. This procedure was followed for the rest tests and the results obtained were recorded in the table of results.

Results

After various experimental analyses carried out on the sample of treated-diesel oil, results obtained are tabulated in Tables 1 to 9.

Table 1. Atmospheric distillation of alum (volatility)

Sample	Diesel (°C)	5 g (°C)	10 g (°C)	20 g (°C)	35 g (°C)	55 g (°C)	80 g (°C)	Kerosene (°C)
IBP	233	233	232	231	229	227	225	160
5 ml	257	256	250	255	256	255	254	180
10 ml	267	267	265	267	265	264	264	193
20 ml	275	272	270	273	272	271	270	210
30 ml	283	281	280	284	280	280	218	218
95 ml	361	361	359	357	351	354	355	271
EBP	368	362	361	359	356	356	357	280
Recovery	96	94	92	92	90	90	91	210

Table 2. Sulfur analysis of alum and potash sample

Sample	Average wt. (%)	
	Alum	Potash
Diesel	0.1452	0.1452
+ 5 g	0.1361	0.1366
+10 g	0.1338	0.1354
+20 g	0.1335	0.1355
+35 g	0.1152	0.1319
+55 g	0.1301	0.1331
+80 g	0.1224	0.1325
Kerosene	0.1400	0.1400

Table 3. Aniline point of alum and potash sample

Sample	Average °C	
	Alum	Potash
Diesel	71.00	71.00
+ 5 g	71.00	70.50
+10 g	71.50	70.00
+20 g	71.75	71.00
+35 g	72.50	71.00
+55 g	72.00	71.50
+80 g	72.50	71.50
Kerosene	62.00	62.00

Table 4. Smoke point of alum sample and potash sample

Diesel fuel plus alum

Diesel fuel plus KCl

Sample	Smoke point (mm)	Burning duration	Sample	Smoke point (mm)	Burning duration
Diesel	18 mm	147 sec.	Diesel	18 mm	147 sec.
+5 g	20 mm	153 sec.	+5 g	18 mm	150 sec.
+10 g	22 mm	163 sec.	+10 g	20 mm	155 sec.
+20 g	22 mm	163 sec.	+20 g	21 mm	160 sec.
+35 g.	23 mm	168 sec.	+35 g	21 mm	160 sec.
+55 g	23 mm	168 sec.	+55 g	22 mm	164 sec.
+80 g	23 mm	168 sec.	+80 g	22 mm	164 sec.
Kerosene	25 mm	200 sec.	Kerosene	25 mm	200 sec.

Table 5. Flash point of alum sample and potash sample

Diesel + alum

Diesel + potash

Sample	°C	Sample	°C
Diesel	65	Diesel	65
+5 g	62	+5 g	62
+10 g	60	+10 g	61
+20 g	57	+20 g	60
+35 g	52	+35 g	59
+55 g	52	+55 g	60
+80 g	55	+80 g	60
Kerosene	46	Kerosene	46

Table 6. Atm. distillation of potash sample

	Diesel °C	5 g A°C	10 g A°C	20 g A°C	35 g A°C	55 g A°C	80 g A°C	Kerosene °C
IBP	233	233	233	232	230	229	228	160
5 ml	257	257	256	256	255	255	254	180
10 ml	267	267	266	265	267	265	264	193
20 ml	275	270	271	270	270	269	270	210
30 ml	283	283	282	281	281	282	282	218
95 ml	361	361	360	359	360	358	359	271
EBP	368	365	364	363	361	359	360	280
Recovery	96	95	94	93	92	92	92	210

Table 7. Specific gravity of potash and alum sample

Sample	Density (g/cm ³)		T°C		SG		A.P.I gravity	
	Potash	Alum	Potash	Alum	Potash	Alum	Potash	Alum
Diesel	0.8615	0.8615	28.00	29.00	0.8634	0.8634	32.38	32.38
+5 g	0.8570	0.8549	29.50	30.00	0.8668	0.8647	31.74	32.14
+10 g	0.8494	0.8513	30.00	30.00	0.8596	0.8611	31.11	32.82
+20 g.	0.8538	0.8499	30.00	31.50	0.8636	0.8607	32.35	32.90
+35 g.	0.8518	0.8376	29.50	31.50	0.8613	0.8485	32.79	35.26
+55 g	0.8521	0.8450	30.00	31.50	0.8619	0.8558	32.67	33.84
+80 g	0.8517	0.8411	30.00	31.50	0.8615	0.8520	32.75	34.58
Kerosene	0.8267	0.8267	29.00	29.00	0.8267	0.8267	39.66	39.66

Table 8. Kinematic viscosity sample of alum and potash at 40°C

	Alum	Potash
Sample diesel	3.92	3.92
+5 g	3.70	3.90
+10 g	3.50	4.25
+20 g.	3.30	4.50
+35 g.	2.55	4.65
+55 g	2.30	4.82
+80 g	2.22	4.90
Kerosene	2.00	2.00

Table 9. Color of alum sample and potash

	Alum	Potash
Sample diesel	1.5 ASTM	1.5 ASTM
+5 g	2.0 ASTM	2.0 ASTM
+10 g	2.0 ASTM	2.0 ASTM
+20 g.	2.0 ASTM	2.0 ASTM
+35 g.	2.0 ASTM	2.0 ASTM
+55 g	2.0 ASTM	2.0 ASTM
+80 g	2.0 ASTM	2.0 ASTM
Kerosene	2.0 ASTM	2.0 ASTM

Discussion

The objective of this project work is to investigate and determine the effect of inorganic salts on diesel oil (automotive gas oil - AGO). It is important that the fuel oil used in a domestic store should be clean and carboniferous deposit free, in order to prevent environmental pollution, which affect lives and properties (Ababio 1993). In characterizing the pre-treated diesel oil with various percentages of salts, the distillation point, sulfur analysis, specific gravity, kinematical viscosity and color test were determined and presented in tables of results

From Tables 1 and 6 of result obtained it could be observed that when diesel fuel is treated with various concentrations of potash and Alum, the atmospheric distillation (volatility), which is the separation of liquid mixture into several components indicate the constant purity of product (Ababio 1993). The distillation recovery from result reveals that the temperature decreases as concentration of the salts increases. It could also be observed from table of results through extrapolation that the best concentration of Alum sample was at 45 g with end boiling point of 355.7°C and the percentage variation with desired product was 27%.

The sample of potash had its best concentration at 55 g with boiling point of 359°C. Analysis shows that the percentage variation of Alum and potash sample to that of kerosene was 27 and 28.2%, respectively, at their best concentration. Although the result did not give a close range compared to that of kerosene, but better results were obtained, when using Alum as shown in Tables 1 and 6.

Sulfur analysis results obtained with addition of salts showed a better result. Compared to actual kerosene, for instance, the ordinary diesel fuel has a sulfur content of 0.1452 wt% while that of kerosene is 0.1400 wt% with variation of 4.5%.

The sulfur analysis of alum and potash samples gives a sulfur content of 0.1152 wt% and 0.1319 wt% at concentration of 35 g. Potash gives a better reading closer to the value of kerosene when compared to alum that contains some percentage of sulfur that is

normally used for sulfur displacement with oxide to form active sulfate, whereas potash is not reactive (Table 2).

Aniline point is an important characteristic, which must be considered in assessing the amount of aromatic hydrocarbon contained in fuels. The aniline point of normal diesel is 71°C while that of kerosene is 62°C with variation of 14.5%. The addition of salts generally, brought about increase in aniline point instead of reducing it.

For instance the aniline point of alum and potash sample at their best concentration was 71°C at 5 g and 70°C at 10 g, while that of potash gave a better reading but has a very wide variation to that of kerosene. This shows that salt cannot be used to reduce aromaticity of diesel fuel, as shown in Table 3.

Smoke point is the maximum height of flame in millimeters at which a given fuel will burn without experiencing smoke (Ababio 1993). It is an essential characteristic, which must be considered in assessing the overall carboniferous deposit of fuel.

The variation that exists between diesel fuel and kerosene was 28%; and that of salts sample (Alum and potash) was 8 and 12%, respectively to that of kerosene. Kerosene has a smoke point of 25 mm but alum and potash samples obtained a result of 23 and 22 mm at its best concentration. These values were obtained using 35 g of alum and 55 g of potash, as shown in Table 4.

Density plays a very important role in determining the quality of kerosene (Innocent 1997). The specific gravity test was carried out in order to enhance the determination of the density of the treated diesel fuel. Sample treated with alum has its best value at 35 g with a density of 0.8376 g/cm³ and a specific gravity of 0.8485, while that of potash determined at 10 g gave the best reading with density value of 0.8494 g/cm³ and specific gravity of 0.8596 g/cm³. It is very obvious that the results obtained are not close or comparable to that of kerosene, which has a value of 0.8267 g/cm³ and a specific gravity of 0.8267, respectively (Table 7).

Flash point is the lowest temperature of a sample at which application of a test flame causes the vapor of the fuel to ignite (Joseph

2001). It is an important property, which must be considered in assessing the overall flammability hazard of the fuel. The flash point obtained from normal diesel fuel is 65°C and that of kerosene gave 46°C.

But the introduction of salts into diesel fuel reduces its flash point from 65° to 52°C for the case of alum and 59°C for that of potash at a concentration of 35 g. It could be observed from the results obtained, that there is a wide range to that of the normal kerosene, as in Table 5.

Kinematics viscosity of kerosene is 2.0 and that of diesel fuel is 3.92. The result obtained showed that in the sample treated with alum, as concentration increases the kinematics viscosity reduces from 3.70 to 2.22 cst and when potash was introduced the kinematics viscosity increases from 3.90 to 4.90 cst as its concentration increases (Table 8).

However, the treatment of diesel oil with Alum produced a lighter color and odor closer to that of kerosene than that of raw diesel oil, and that of potash showed a change in color from 1.5 ASTM of raw diesel at to L 2.0 ASTM for all the concentrations of the potash salt, as in Table 9.

Conclusions

The result of this research has shown that the two inorganic salts used for the treatment of diesel oil have effects on the physicochemical properties of the oil. Comparing the results obtained with that of kerosene, the most significant effect observed was in the sample of diesel oil treated with Potash, which produced a sulfur content of 0.1319 wt% at 35 g concentration as against that of kerosene, 0.1400 wt%. A lighter color change and odor closer to that of kerosene than raw diesel oil was observed. This may probably be the driving reason for the chemistry practiced during the fuel shortages or scarcities. It was observed that based on the result obtained, diesel oil treated with inorganic salts cannot be used as kerosene.

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