Physicochemical Analysis of Petroleum Products in Selected Depots in Calabar Metropolis Cross River State and The Effects on Motor Engine

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Abstract: The physicochemical properties of the premium motor Spirit (PMS) and Automotive Gas Oil (AGO) were determined to ascertain with each other and their compliance with American Society for Testing Materials (ASTM) standards and the Nigerian Midstream and Downstream petroleum Regulatory Authority (NMDPRA). The properties studied for NNPC and Zone 4 oil depots results obtained were respectively as follows: density 0.7445, 0.7425, Research octane number 91.8, 93.1, ethanol content was absent for both petroleum depots samples, distillation test at the initial boiling point is 34, 30, at the final boiling point were 181, 181 for both NNPC and zone 4 depots samples, benzene content were 1.0, 0.9, Sulfur content test 0.0275, 0.0215 and Reid Vapour pressure 49.5, 49.0, the study revealed that the PMS quality was within the ASTM and NMDPRA requirements for both NNPC and zone 4 depots and has positive effect on motor engines. AGO samples from two different depots (NNPC and Hudson) was analyzed. The parameters analyzed and the results obtained as follows; density test 0.8530 and 0.8404, flash point 69, 70, distillation at the initial boiling point 127, 80 for NNPC and Hudson oil depots, diesel Index 38.2, 42.8, cetane number 37.9, 46.2, kinematic viscosity 3.324, 3.144, sulfur content 0.0740, 0.0475, Acidity were all within the ASTM and NMDPRA specifications for PMS for both NNPC and Hudson depots. Hudson depot cetane number analyzed was in compliance with the regulatory authority standards while NNPC depot cetane number, and carbon residue were off specifications. There was deviation in the diesel index number and carbon residue, distillation test for both NNPC and Hudson oil depots for AGO samples will have adverse effect on motor engine. Based on the research studied, the AGO might have been poorly refined or adulterated and could constitute problems to automobile engines if utilized. It is imperative that regular quality tests be conducted randomly to check depots petroleum products compliance with the required standards.

Keywords: physicochemical analysis, petroleum products, Calabar metropolis, motor engine.

I. Introduction

Petroleum products are materials derived from crude oil (Petroleum) as it is processed in oil refineries. Unlike petrochemicals which are a collection of well-defined usually pure organic compounds, petroleum products are complex mixtures Nelson *et al.* (2016). Petroleum is formed when the remains of zooplankton, marine algae, and animals gradually settle on sea beds and over the years tend to be covered with mud, silt and other sediments under intense heat and pressure as the sediments are piled up, their mass exert a great pressure on the lower layers, changing them to hard sedimentary rocks but due to bacterial activity coupled with heat and pressure, it changes the plant and animal remains into crude oil or petroleum. From chemical standpoint, petroleum is an extremely complex mixture of hydrocarbon compounds usually with minor amounts of Nitrogen, Oxygen and sulfur containing compounds Speight *et al.*(2023). Consequently, it is not surprising that petroleum can vary in composition properties and produce wide variation in refining behavior as well as product properties in accordance with ASTM D- 4175(Speight, 2015). The oil industry classifies crude by the location of its origin and by its relative weight or viscosity as light, intermediate or heavy. According to the composition of the crude oil and depending on the demands of the market, refineries can produce different shares of petroleum products. These fuel products can be blended to give premium motor spirit (PMS) or gasoline, Dual purpose Kerosene (DPK) or Jet fuels or Aviation Turbine Kerosene (ATK), Automotive Gas oil (AGO) or diesel fuel, lubricating oil, asphalt etc. Walther*et.al.*(2005). Over the years, adulteration of petroleum products has been a common trend in the world today notwithstanding its hazardous effects. Adulteration of petroleum products is an act perpetrated daily by unscrupulous people in the developing countries like Nigeria with the intention of making profit in their business with total disregard to the hazardous effect their action could have on end users (Onojake*et al.* 2012).

According to Onojake, adulteration is the deliberate mixing of petroleum products with partially refined products or condensates (reservoir gases that condense to liquid hydrocarbon when produced) with products that are in high demand like PMS, DPK with the aim of maximizing more profit. PMS, AGO and DPK that are contaminated or whose quality has been weakened by adding inferior quality ones or products of lower grade are referred to as adulterated PMS, AGO and DPK. But this poses a serious problem that can be tackled if proper and regular analysis which involves the quality control tests is carried out on the PMS, AGO and DPK to ascertain its composition Onyinye *et al.*(2015).The physical and chemical parameters of petroleum products stored and sold in depots is of immense economic and social important, but the adulteration of this essential commodity (PMS and AGO) has pose a serious threat to end users and it has become a prevalent problem in the petroleum industries in regards to motor engines

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application due to low octane number, Cetane number, specific gravity, water content, carbon deposits, improper storage facilities, tank and engines calibrations and poor maintenance had been assumed to caused desired effect or adverse effect on motorable engines.

Hence, the purpose of this research is therefore to ascertain if the depots products understudy sold in Calabar metropolis is in compliance with Nigerian Midstream and Downstream petroleum Regulatory Authority (NMDPRA) required standards and other regulatory standards. The aim of this research was to analyze the physicochemical properties of petroleum products: Premium motor spirit (PMS), Automotive Gas Oil (AGO) samples from three different oil depots in Calabar metropolis, Cross River State, Nigeria.

II. Materials and Method

The materials and reagent used include: measuring cylinder, tiff can, amber bottle, flash machine, thermometer, distillation machine, cold water, refrigerator, syringe, lighter, viscometer, setavap 2 Tester, sample cup, X-ray fluorescence Sulfur-in-oil analyzer, Zeltex Octane & fuel analyzer, spectrocolorimeter, Vapour pressure Tester machine, 700 hydrometer, 750 hydrometer, 800 hydrometer, 850 hydrometer, 400 thermometer, 300 thermometer.

III. Methodology

Sample collection

The PMS and AGO petroleum products used for this work were gotten directly from Calabar industrial area in esuk utan community tanks farms storage facility from three randomly selected depots. The depots are NNPC, Hudson, Zone 4 Petroleum depots respectively. Samples were collected using amber bottles from three (3) different depots and were refrigerated at 4°c and analyzed within 24 hours of collection.

Temperature Measurement

The temperature of each sample was measured using thermometer. 500 ml of PMS was measured into 500 ml measuring cylinder, the thermometer was inserted into the product measuring cylinder for five minutes and the reading was recorded as indicated.

Test for color and odour

Color profile of each sample was measured by comparing the Petroleum products samples against a standard by setting it using the screw knob on the Spectro colorimeter machine to match the color on the color Comparator machine and it was recorded. Naturally, hydrocarbon is colourless; addictive like dye are added to distinguished Petroleum products from each other at the refinery. The odour was observed using sensory organs and it was seen marketable.

Density Determination

500 ml of the PMS product was measured into the measuring cylinder and the hydrometer was inserted into the liquid (PMS and AGO) and it was spined and allowed to be suspended and the reading was recorded and the observed density was used to determine the corrected density (specific gravity) using ASTMD1298 test method.

A sample was collected that will be up to 500 ml, Shake gently the representative sample and transferred to the clean measuring cylinder without splashing, Place the cylinder containing the test sample in a vertical and stable position. Lower the appropriate hydrometer into the liquid and release when in position of equilibrium. Allow time for the hydrometer to come to rest floating freely away from walls of the cylinder. Record the hydrometer scale and temperature reading. Remove the hydrometer from the liquid and insert a thermometer to take the temperature of the samples. Record the temperature on the thermometer, Correct to 60 using API.

Determination of Sulfur Content

The ASTMD2622 standard test method for Sulfur in Petroleum products by wavelength dispersive X-ray fluorescence spectrometry analyzer was used. The distillation process segregates Sulfur species in higher concentrations into higher boiling fractions and distillation residual, Syringe was used to collect sample from the sample bottle and it was dipped into the sample holder to be slightly above half of the sample holder, the sample holder was inserted into the X-ray fluorescence Sulfur-in-oil analyzer, the machine was covered after a few minutes the reading was recorded by the machine and the result was printed automatically.

Distillation

Using Standard Operating Procedures (SOPs) for Petroleum products distillation (PMS, AGO) (ASTMD86), Select the correct apparatus to be used e.g thermometer, flask support board, distillation flask, measuring cylinder etc, Prepare the test sample by: collecting the sample from the tank, vessel etc preferable morning, analyzed the samples in the laboratory adhering strictly to standards operating procedure(SOPs) to obtained the (Temperature and density) parameters of the sample firstly, take part of the sample into a sample bottle and cool it. e.g used ice block to cool, using a measuring cylinder, take 100 ml of the cold sample and discharge into the distillation flask, set up the glassware, Place the distillation flask into the distillation module and align the arm of the distillation flask to the end of the condense tube, Install the distillation thermometer and thermometer centering device into the top of the distillation flask. Place the specified receiver under the condenser tube outlet. Fill the cooling tank with an appropriate

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coolant e.g ice block. To proceed with the distillation, switch on the main supply and set the rocker switch to heat and set the heating rate, monitor the distillation process and record the appropriate temperatures and volume required for each product in use. Cool the machine and wash off the residues after use.

Determination of Flash point

Standard Operating procedures (SOPs) for flashing Petroleum products (AGO and DPK) using ASTMD93, the sample was collected and analyzed to obtain their parameters (Temperature, Density etc.), Prepare the instrument by checking that the correct **—0"** ring seal is fitted, and wipe the sample cup cleaned, ***ON*** and set the flash machine at a temperature of 60°c for AGO and 35°c for DPK using the setting knob. Use a 2 ml syringe to dish the sample. When the machine is ready for flashing, Dispense the sample (from the syringe) into the filler orifice, Switch the gas supply on through the gas valve and light on the pilot and test jet. Press the timer button and allow the equipment to ramp. As it beeps at every 1°c rise in temperature, fill and release the shutter handle over a period of 2.5 secs. Repeat the process continually until a flash is detected. Record the temperature and result. Switch the gas supply off and wait until the test and pilot flames are extinguished. Press then release the temperature button to reset the flash detector and temperature display. Unlock and open the lid, remove used sample and clean the sample cup, Switch the instrument off at the ***ON/Off*** power switch.

Determination of Reid Vapour pressure (RVP):

The Reid vapour pressure of the collected sample was determined using SETA KV – 6 viscometer Bath machine using laboratory method.

Procedure

Turn on the power of the vacuum pump, Turn on the power to the ***setavap 2 tester***, The top line of the display. Place the waste container under the drain show the instruction ***"Remove Septum*>,(5)** Unscrew the septum holder and remove the septum. Press ***the 'proceed' button (>) (4)*** The top line of the display will change to show the message **'*Draining 10'* and** will start to count down to zero. After 10 seconds the top line of the display will change to show the message ***'purging 120'*** and will start to count down to zero. After 120 seconds an audible warning ***(beep)*** will be heard and the top line of the display will change to show the instruction ***'Insert New Septum >'. (8)*** Fit a new septum into the septum holder by pressing a new septum into the recess on the end of the holder (see figure 4). Smear a minute amount of silicone grease onto the exposed surface of the septum. Screw the septum holder firmly into the setavap 2 tester to give a vacuum tight seal. Press the ***'proceed' button (>)*** the top line of the display will change to show the message evaluating '300' and will start to count down to zero. After 300 seconds an audible warning ***(beep)*** will be heard and the top line of the display will change to show the instruction prepare sample >. Check that the bottom line of the display shows a reading of ***0.0*** kappa 37.8°c. A tolerance of + 0.1 is allowed on both readings. If either reading is outside this limit, refer to section 8 FAULT FINDING.

Note: For crude Oil samples refer to appendix A.

To make sure that there is no contaminant in the syringe that might affect the test result, draw a small amount of sample into a previously cleaned and dried syringe, pull back the plunger fully and then expel the contents into the waste container.

Note: To prevent vaporization of the sample or dissolved air being drawn out of solution, the sample must be slowly drawn into the syringe. Draw approximately 3.5 ml of sample into the syringe. Hold the syringe vertically with the needle upwards and eject surplus sample into a paper cloth until exactly 3 ml remains.

remove

Press the **proceed button** (>). The top line of the display will change to show the instruction "**Inject sample >.** Push the needle into the septum holder until the syringe is felt to come into contact with the bottom of the septum holder. Inject the sample and remove the syringe (see figure 5).

Press the proceed button (>) the top line of the display will change to show the message 'Test in Progress ' The bottom line of the display will change to show the elapsed time (minutes/ seconds) and total vapor pressure (kpa). The **setavap 2 Tester** will automatically take readings at one-minute intervals. When three consecutive readings at one-minute intervals. When three consecutive readings are within **0.1 kpa** of each other, the test is terminated automatically an audible warning **(beep)** will be heard and the test result is displayed on the top line of the display will change to show the instruction 'Place container>'

Ptot: To obtain a test result which display ptot, turn the control knob until the top line of the display **shows ptot=kpa**.

DVPE: To obtain a test result which displays **a DVPE correlation**, turn the control knob until the top line of the display shows **'DVPE=kpa**.

Determination of the Research Octane Number

Using standard operating procedures (SOPs) as required by American Standard for Testing Materials (ASTM D2699) with the used of FOR Zx-101XL portable octane & fuel Analyzer.

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Operation:

Put sample in a bottle and put it in the refrigerator or chiller to chilled. Fill the sample cup to the ***MARK*** on the cup and firmly cover it and carefully clean the Spilled product on the cup. Switch power ***ON*** followed by a 15 second count down on the machine, after which ***CLEAN CHAMBER*** and press ***MEASURE*** will appear on the screen. Cover the ***CHAMBER*** with the light shield. Press ***MEASURE KEY*** on the equipment to standardize the instrument, after the reading take place, put in ***SAMPLE*** will appear on the display screen. Remove the ***LIGHT SHIELD*** over the ***SAMPLE CHAMBER***. place the filled ***SAMPLE*** in the ***SAMPLE CHAMBER***. Carefully align the alignment stripe in the ***SAMPLE CHAMBER*** with the left alignment stripe on the instrument. Carefully replace the ***LIGHTSHIELD*** over the ***SAMPLE*** holder, this ***SHIELD*** must always be used when measuring a fuel sample otherwise the result will be incorrect. Press ***MEASURE*** on the equipment, After the reading take place, ***REMOVE*** and ***REPLACE*** will be displayed on the screen. Remove the ***SAMPLE*** holder and rotate it to align the stripe on the sample holder with the ***RIGHT-***hand alignment stripe on the instrument. Carefully replace the *LIGHT SHIELD* over the sample holder. Press ***MEASURE*** after the reading take place, remove and press "M" will be displayed on the screen. Remove the ***SAMPLE*** holder and cover the empty ***CHAMBER*** with the ***LIGHT SHIELD*** and press ***MEASURE.*** After the measurement is complete, Result will be printed by the instrument.

Determination of Kinematic Viscosity for Automotive Gas Oil (AGO):

Kinematic viscosity was determined using the standard operating procedures (SOPs) of **ASTMD445; -**Syringe was used to measure the sample into the viscometer sample holder. A standard temperature at37.80°c was applied and the equipment was allow to boot and warm up until the required temperature was indicated on the viscometer readout before inserting the sample and air was compressed into the glass tube to aid the flow of the liquid into the orifice of the capillary under the force of gravity and a stop watch was used as a timer checker for the kinematic viscosity analysis and the instrument used is viscometer, As the liquid get to the first orifice mark of the kinematic viscometer tube we record the time and as it get to the second orifice mark we also record the timing using the stop watch and the figures were calculated according to the standard multiplier of **0.008**

IV. Results and Discussion

Results

The physicochemical parameters analyzed for premium motor Spirit for NNPC and Zone 4 depots is presented in Table 3.1

Table 3.1: Physicochemical Analysis for Premium Motor Spirit (PMS) Sample In G/L

S/N	PARAMETERS		TEST METHOD	NMDPR LIMITS	PETROLEUM PRODUCT NNPC	ZONE 4
1	Appearance		Visual ASTMD 4176	Clear and bright	Clear and Bright	Clear and Bright
2	Colour Before Distillation		Visual	Light Yellow	Light yellow	Light yellow
3	Temperature		APHA 2550	NILL	29	29
4	Observed	Density	ASTM D1298	0.720-	0.7445	0.7425
	(G/L)			0.780		
5	Corrected (Kg/M^3)	Density	ASTMD4052	NILL	744.5	742.5
6	Correction Factor		ASTM4052	NILL	0.9829	0.9828
7	Odour		Visual	NILL	Merchantable	Merchantable
8	Reid Vapour Pressure		NIS 116:2008 Appendix H	62.0 (9psi)	49.5	49.0
9	Distillate Evaporated		NIS 116:2008	NILL		
	at		Appendix C		34	30

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	Initial boiling point o^{c}		70	39	33
	10^{oc} % (v/v) max		125	78	77
	50^{oc} % (v/v) max		180	96	96
	90^{oc} % (v/v) max			181	181
	Final Boiling				
	point^{oc}max				
10	Residue% v/v (max)	NIS 116:2008 Appendix C	2	1.5	1.5
11	Free Water	ASTM D4176	NILL	NILL	NILL
12	Suspended Matter	ASTMD4176	NILL	NILL	NILL
13	Total Sulfur Content % m/m (max)	NIS 116:2008 Appendix E	0.015	0.0275	0.0215
14	Benzene% m/m (max)	ASTMD598	2.0	1.0	0.9
15	Ethanol	ASTMD6293		0.0	0.0
16	Research Octane Number RON (min)	ASTMD2699	91	91.8	93.1
17	Motor Octane Number MON (min)	ASTMD2700	81	81	83.0
18	Anti-Knock Index, AKI (min)	Calculated	86	86	88.0
18	Flash Point	NIS 149: 2006 Appendix F		Not Applicable	Not Applicable

Method Source: American Society for testing and materials (ASTM) 2007 NMDPRA – Nigerian Midstream and Downstream Petroleum Regulatory Authority

Table 3.1.2: Physicochemical Analysis for Automotive Gas Oil (AGO) (Diesel Fuel) Samples In G/L

S/N	PARAMETERS	NMDPRA REQUIREMENTS	TEST METHODS	PETROLEUM PRODUCTS	DEPOT
				NNPC	**HUDSON**
1	Appearance	Clear and Bright	Visual	Clear	Clear
2	Colour	3.0	NIS 149:2006 Appendix A	Brown (3.0)	Light Brown (2.0)
3	Observed Density G/L	0.820-0.870	NIS 149:2006	0.8530	0.8404

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			Appendix B		
4	Corrected Density	NIL		853.0	840.4
5	Correction Factor			0.9868	0.9873
6	Acidity (Inorganic Acid)	NIL	NIS 149:2006 Appendix C	NIL	NIL
7.	Temperature	NIL	APHA	31	30
8	Odour	NIL		Merchantable	Merchantable
9	Distillation		NIS 149: 2006		
	Initial Boiling Point (IBP)		Appendix E	127	80
	Percentage Recovery at 357^{oc} v/v (min)	90		NIL	NIL
	Final Boiling Point (FBP) o^c max	385		348	279
10	Flash Point o^c (min)	66	NIS 149: 2006 Appendix F	69	70
11	Kinematic Viscosity of	1.6-5.5	NIS 149:2006	3.324	3.144
	37.8 o^c (cst)	14	Appendix G		
12	Total Sulfur % vol (max)	0.3	ASTM 04294 or 0.129	0.0740	0.0475
13	Diesel Index (min)	47	NIS 149:2006 Appendix O	38.2	42.8
14	Cetane Number	45	NIS 149:2006 Appendix O	37.9	46.2
14	Carbon Residue % wt (max)	0.15		1	2
15	Cloud Point o^c (max)	4.4	NIS 149:2006 Appendix H	4	3.5

Method Source: American Society for testing and materials (ASTM) 2007 NMDPRA - Nigerian Midstream and Downstream Petroleum Regulatory Authority

Table 3.1.3: Distillation Profile of The Premium Motor Spirit (PMS) Samples

TEST	**UNIT**	**Method ASTM IP**	**Specification**	**Result for PMS Sample (NNPC)**	**Result for (PMS) Sample (ZONE 4)**
Distillation I.B.P	$^O C$				
				34^0C	

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			REPORT		30^0C
5% **10%** **20%** **30%** **40%** **50%** **60%** **70%** **80%** **90%** **95%**			REPORT 70 max REPORT REPORT REPORT 125max REPORT REPORT REPORT 180max REPORT	45^0C 50^0C 57^0C 64^0C 74^0C 84^0C 93^0C 114^0C 134^0C 156^0C 178^0C	44^0C 51^0C 60^0C 69^0C 75^0C 86^0C 97^0C 111^0C 130^0C 153^0C Nil
F.B.P			210max	181^0C	181%
Recovery			97%	97%	97%
Residue			2%	1.5%	1.5%
Loss			1%	1.5%	1.5%

TEST	**UNIT**	**Method ASTM IP**	**Specification**	**Result for AGO Sample (NNPC)**	**Result for (AGO) Sample (HUDSON)**
Distillation **I.B.P**	^{O}C				
				127^0C	
			REPORT		80^0C
5% **10%** **20%** **30%** **40%** **50%** **60%** **70%** **80%** **90%** **95%**			REPORT REPORT REPORT REPORT REPORT REPORT REPORT REPORT REPORT REPORT REPORT	172^0C 198^0C 232^0C 251^0C 265^0C 279^0C 290^0C 304^0C 320^0C 331^0C 346^0C	115^0C 154^0C 177^0C 200^0C 222^0C 238^0C 249^0C 258^0C 272^0C 278^0C Nil
F.B.P			385 max	348%	239%
Recovery			90	98%	96%
Residue			Nil	1%	2%
Loss			Nil	1%	2%

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Discussion

The physicochemical parameters of premium motor Spirit (PMS)

The appearance, colour, Odour, free water, suspended matter, specific gravity (density) was all analyzed and were all within the required standards as recommended by (Bendierad et.al, 2022) and Nigerian Midstream and Downstream petroleum Regulatory Authority (NMDPRA) for both NNPC and Zone 4 depots. The Sulfur content for NNPC depot is 0.0275 and zone 4 is 0.0215, the sulphur content was above the permissible maximum requirements set by NMDPRA for both depots for premium motor Spirit.

The Reid Vapour pressure (RVP) (kpa) for both depots products were obtained at

49.5 for NNPC depot and 49.0 for zone 4 depot, both result of the product were in agreement with the regulatory bodies standards.

Benzene result recorded is 1.0 for NNPC and 0.9 for zone 4 and both fall within the required range of permissible benzene content in premium motor Spirit (ASTMD598).

The Antiknocking properties of the liquid motor fuel of motor engine known as the Research Octane Number (RON) was obtained at 91.8 for NNPC depot and 93.1 for zone 4 petroleum depot, ethanol content was recorded Nill for both depots products.

The density obtained as shown in Table 3.1. showed the physicochemical characteristics of the two PMS depots samples based on its appearance, colour, Odour, Reid Vapour pressure, density, ethanol content, benzene content, Research Octane Number (RON) and the Sulphur content. The density obtained for NNPC and Zone 4 are 0.7445 and 0.7425 respectively were within the ASTM density range (0.720-0.780) indicating that the samples are either too light nor too heavy. The value of the RON which is the measure of the PMS ability to knock or ping in an engine is 91.8 for NNPC depot sample and 93.1 for zone 4 depot which is above the RON minimal value of 90%, this is not connected with adulteration which is a common practice and the premium motor spirit is acceptable for motor engine optimization.

The implication of the high RON is that it will enhance the efficiency of machine and promote it engine life span. Knocking is the metallic noise usually observed in spark ignited engine as a result of low octane rating of PMS. High octane rating of PMS is necessary for better performance of the internal combustion engine (Speight, 2023). Low octane rating of PMS could hinder engine power performance (Speight, 2023). Ethanol was found to be absent via the ethanol content test. The benzene test showed the concentration of substituted benzene in PMS samples for NNPC 1.0 and 0.9 for zone 4 which were within the range (2 max) by ASTM and NMDPRA since benzene is classed as a toxic material and knowledge of the concentration of the compound can be an aid in evaluating the possible health hazards to persons handling and using the PMS products. The Reid Vapor pressure (RVP) measure the volatility of the PMS which indicate how quickly the PMS products can evaporate, the result obtained were

49.5 for NNPC depot PMS sample and 49.0 for zone 4 depot PMS sample using ASTM test method & NIS 116: 2008 Appendix H which was within the maximum range of 62.0 (9psi) set by the regulatory authority. The quality many Petroleum product is related to the amount of Sulfur present. The knowledge of the Sulfur concentration is necessary for processing purposes. Here the value obtained is not in agreement with NMDPRA standards as it does not provide a means of compliance with specification or limits set by the regulatory authority for Sulfur content in PMS. The result of the distillation profile of the PMS samples are shown in the table 3.1.3, according to the American Society for Testing and Materials and Nigerian Industrial standards (NIS116:2008 appendix C NMDPRA) for PMS , the distillation profile is planned such that it shows the reported result in terms of Initial Boiling point which is the thermometer reading in the neck of the distillation flask when the first drop of distillate temperatures: usually observed when the level of distillate reaches each 10%mark on the graduated receiver with the temperatures for 5% and 95% marks often included, the final boiling point which is the highest thermometer reading observed during distillation, the recovery, the residue and finally the distillation loss. However, the Initial Boiling point (IBP) and Final Boiling Point (FBP) are mainly considered (Speight, 2023). The results obtained from NNPC and Zone 4 PMS samples in Table 3.1 based on the IBP and FBP are 34 and 181 for NNPC and 30 and 181 for zone 4 respectively which the result was slightly in variance when compared to the specification requirements set by ASTMD86 range for distillation.

The results of the physicochemical properties of the Automotive Gas Oil (AGO).

The physicochemical properties of Automotive Gas Oil (AGO) diesel fuel were obtained using ASTM and Nigerian Midstream and Downstream petroleum Regulatory Authority (NMDPRA). The determination of the density of Petroleum and its products (AGO) is necessary for the conversion of measured volume to weight standard temperature of 15°c and gives evidence of the quality of fuel (Osman., *et.al*, 2021). Density of fuel is an important quality characteristic, which is used for the description of Petroleum products and to calculate other physicochemical characteristics (Osman., *et.al*, 2021). The direct density of diesel has a direct effect on other physicochemical characteristics and it is used in the calculation of Cetane number that determines the quality of diesel fuel.

The density obtained were 0.8530 for NNPC and 0.8404 for Hudson depots indicating that the AGO density was within the range of ASTM1298 and NMDPRA specifications. The appearance of both depot samples were within the specification requirements of the regulatory body. The odour was merchantable for both depots samples indicated conformity with the regulatory authority as shown in table 3.1.2

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The flashpoint temperature is an assessment for the overall flammability hazard of materials (Aga., 2018) lowest temperature at which it will produce enough Vapour to produce a flammable mixture in the air. The lower the flash point temperature, the easier it is to ignite the air if an ignition source is present. The higher the flash point, the safer the material to handle, the result of flash point for both depots samples were obtained using ASTMD93, NNPC and Hudson was 69 and 70 respectively and results both fall within the specification of ASTM and NMDPRA standards requirements.

Cetane Number (CN) is a Measurement of performance or quality of petrol or biodiesels fuel. The higher the CN, the better the fuel burns within the engine of a vehicle. The difference between CN and octane number (ON) is that octane number rates(gasoline) PMS whereas Cetane number rate diesel (Chukwezie., *et.al*, 2017). The result obtained for cetane number for NNPC and Hudson depots were 37.9 and 46.2, the result for Hudson depot was in conformity with NMDPRA & ASTM while NNPC depot product was below the required specification set by the regulatory bodies, which may be due to refining processing method, poor storage facilities or adulteration of the product. Diesel Index results obtained from both depots using the ASTMD 976 or IP 380, for NNPC is 38.2 and 42.8 for Hudson depot were below the NMDPRA specifications required limits of 47. The implication of lower cetane number can cause issues like rough running, increased emissions and decreased fuel efficiency and pose serious adverse effect on motor engines upon application, on the other hand, A higher cetane number signifies better ignition quality, resulting in improved combustion and reduced ignition delay, understanding the influence of cetane number on diesel engines is essential for optimising engine performance and meeting emission standards (Wu, H., *et.al*, 2021).

Total Sulfur content analyzed using ASTMD 5453 or D2622 or IP 336 test method, result obtained for NNPC was 0.0740 and 0.0475 for Hudson depots sample were within the permissible required Sulfur content of AGO and therefore is adequately in conformity with the specification limits of (0.3 max) set by the regulatory body.

Kinematic viscosity is one of the important characteristics of diesel fuel, the fuel which is having higher viscosity can cause damage in the pump. Besides, the lowest fuel may lead to a lack of effective Lubrication in engines. It also influences the fuel delivery rate and the atomization of the fuel during injection. That is why the ASTM put a limit for diesel fuel (2.2-8.8) and NMDPRA limit is (2.2-5-5) mm^2/s (Mousavi *et.al*, 2021). Results obtained from the analysis of the Petroleum product kinematic viscosity were 3.324 for NNPC and 3.144 for Hudson sample respectively indicating both were within the required specification limits of ASTM and NMDPRA.

Cloud point results obtained were $4^{\circ c}$ for NNPC and $3.5^{\circ c}$ for Hudson, both are within the specification limit as shown in table 3.1.2 Carbon residue results obtained for NNPC and Hudson samples was analysed using ASTM D2500 or IP 219 were above the specification requirements set by the regulatory authority, it may due to inadequate refining and storage facilities of petroleum products of the depots understudy.

Table 3.1.3 Distillation, the Initial Boiling point IBP for NNPC and Hudson samples was obtained at $127^{\circ c}$ and $80^{\circ c}$ and the percentage discovered at $357^{\circ c}$ v/v as required by ASTM and NMDPRA was 90 minimum and the product sample never reach $357^{\circ c}$ and the Final Boiling point (FBI) $^{\circ c}$ max for the NNPC sample is $348^{\circ c}$ which was within the required standards but Hudson sample was having more residue above the required standards and behavior which seems adulterated.

The auto-mobility is an important factor in the socio-economic life of man. Automobile is thus a basic necessity. Adequate Lubrication allows smooth continuous operation of the engine and equipment with only mild wear and without excessive stresses or seizure of the motor oil at the bearing while the main functions of engine or motor oil is usually to lubricate moving parts, motor oil also cleans, inhibits corrosion, improves scaling by carrying heat away from moving parts (Cai et.al, 2020). This then calls for importance of the quality of automobile consumable oil especially for the engine, the gear box and brake system. These vehicles and machinery need lubricants, especially for proper functioning of engine parts and to reduce the wearing ().

V. Conclusion

The results of this study revealed that the research octane number (RON), motor Octane number (MON), specific gravity, free water content of regular premium motor Spirit (PMS) were within ASTM specifications while total sulfur content, Initial Boiling point, final boiling point deviated from the ASTM and NMDPRA required standards.

In the result obtained from the regular Automotive Gasoline (AGO) revealed that the specific gravity, Acidity, flash point, kinematic viscosity, carbon residue, Total Sulfur content, odor etc were in compliance with ASTM specifications standards while the diesel index , initial boiling point, Hudson product colour, carbon residue for both NNPC and Hudson Petroleum depot sample were not in agreement with the required standards set by Nigerian Midstream and Downstream petroleum Regulatory Authority (NMDPRA) and ASTM(American Society for Testing and Materials).

Therefore, conclusively from the analyzed results using NMDPRA, ASTM laboratory test methods and specifications requirements, the regular premium motor Spirit (PMS) or (petrol) for NNPC and Zone 4 depots samples are good for motor engines consumption and it will have positive effect upon it application on motor engines while the regular Automotive Gas Oil (AGO) (diesel) fuel Petroleum product for both NNPC and Hudson samples is not good for motor engines, it will have adverse effects on motor engine which will results in affecting the economic factor of users of the products, shorten motor engine lifespan, and increased environmental pollution. Based on the findings, the automotive gas oil (AGO) might have been poorly refined, inadequate storage maintenance system or adulterated and could constitute problems such as knocking of engines, delayed ignition, malfunctioning of components parts in Automotive Gasoline engines when used. The quality of the Automotive Gas Oil (AGO) can be enhanced through upgrading refineries operation conditions and the introduction of gasoline additives. Nigerian needs to develop local technology in order to attain self-sufficiency in the Petroleum sector.

The federal Government and the Nigerian Midstream and Downstream petroleum Regulatory Authority (NMDPRA) should legislate a legal framework to regulate the activities of Automotive Gas Oil (AGO) refineries. This will enhance the Petroleum sector, boost motor engines lifespan, socioeconomic and environmental sustainability. From the findings and conclusion drawn from this research, it is imperative that regular quality assurance tests should be conducted randomly on the PMS and AGO to check their up-to-date compliance of the products with ASTM and NMDPRA and adulteration.

Declarations

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Competing interests

All authors declare zero financial or inter-personal conflict of interest that could have influenced the research work or results reported in this research paper.

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Authors' Contributions

Fredrick C. Asogwa: Project conceptualization, design, and supervision. **Emmanuel**

E. Ojong: Writing, results extraction, analysis, and manuscript first draft. **Ivon E. Akpang:** Manuscript revision, review, and proofreading **Chinedu Achukee** Manuscript, review, and proofreading.

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