QUALITY ANALYSIS OF SELECTED PHYSICOCHEMICAL PROPERTIES OF PREMIUM MOTOR SPIRIT (PMS) COMMERCIALLY AVAILABLE IN BENIN CITY.

BY

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DEPARTMENT OF CHEMISTRY

FACULTY OF PHYSICAL SCIENCE

UNIVERSITY OF BENIN

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CERTIFICATION

This is to certify that this research work was carried out by **UGIANGBE FAVOUR ITOHAN** with the matriculation number **PSC2105238** under the supervision of **Dr. J.N.Jacob** from the Department of Chemistry, Faculty of Physical Sciences, University of Benin, Benin City.

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Dr. J.N.Jacob **Date**

(Project Supervisor)

Prof. E.E.I. Irabor **Date**

(Head of Department)

DEDICATION

I dedicate this project to God almighty and to my parent for their unwavering support.

ACKNOWLEDGEMENT

I appreciate God Almighty for the gift of life, the strength, and the wisdom he has bestowed upon me throughout the duration of my study.

I want to express my profound gratitude to my project supervisor, Dr. J.N. Jacob, for his invaluable support, guidance, patience, and selflessness throughout the period of my project. Words alone cannot express how grateful I am. Thank you so much, sir. I pray God blesses you immensely.

I also would, in a special way, want to thank the Head of the Department of Chemistry in the person of Prof. E.E.I. Irabor.

I would also like to extend my thanks to my lecturers for their guidance and support.

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TABLE OF CONTENT

LIST OF TABLES

ABSTRACT

Premium Motor Spirit (PMS), commonly known as petrol, is the most widely used fuel in Nigeria, and Benin City in particular. It plays a vital role in transportation, power generation, and other daily activities. However, the quality of PMS available to consumers has often been questioned due to issues of adulteration, contamination, and poor handling. These problems can affect engine performance, increase fuel consumption, and contribute to environmental pollution. This study focused on the analysis of selected physicochemical properties of Premium Motor Spirit (PMS) obtained from four Local Government Areas in Benin City, namely Oredo, Ikpoba-Okha, Egor, and Ovia North East. The aim was to evaluate the quality of PMS distributed within these areas and compare the results against the standard specifications provided by the American Society for Testing and Materials (ASTM). Parameters such as density, Reid vapour pressure (RVP), octane rating, boiling point, colour, and basic sediment and water (BSW) were determined following ASTM approved methods. The distillation results showed initial Boiling Points (IBP) ranging from 32 - 35°C with three samples slightly below the ASTM specification of 35°C, while Final Boiling Points (179 - 190°C) and recovery (98 - 99%) were within accepted limits. Density values measured at 15°C ranged from 0.741 - 0.746g/cm^3, falling within the ASTM specification range of 0.720 - 0.780g/cm^3, indicating compliance in terms of volatility and combustion efficiency. Colour determination revealed a consistent Plain Yellow appearance across all samples, in agreement with ASTM D1500 standards, reflecting proper refining and the absence of contaminants such as water, rust or heavy hydrocarbons. The BSW values for all the four LGAs were less than 0.05% by volume, which is well within ASTM tolerable limits, confirming negligible water or sediment contamination. The RVP values ranged from 57.22651 - 58.60546kpa, falling within the ASTM range of 45 - 60kpa. Lastly, the RON values ranged from 90-91 which was within the ASTM specification range of 90 - 93. The PMS samples used in this study met the ASTM standards, indicating good quality and suitability for use. The slight deviations observed, such as in the IBP values, point to the need for continuous monitoring.

CHAPTER ONE

INTRODUCTION AND LITERATURE REVIEW

1.1 INTRODUCTION

1.1.1 BACKGROUND OF STUDY

Premium Motor Spirit (PMS), commonly referred to as petrol or gasoline, is a major petroleum product that fuels most vehicles and small engines in Nigeria, making it a key factor of transportation, commerce, and the national economy (Ifezue and Onobrenufe, 2023). Because of this high demand and need, its quality directly affects engine performance, environmental safety, and consumer welfare (Onyinye and Nkechi, 2015).

Several studies in Nigeria have raised concerns about the quality of PMS available to consumers due to factors such as adulteration, poor storage, and variations in distribution practices. For example, research conducted in Warri Metropolis analyzed physicochemical parameters such as density, research octane number (RON), Reid Vapour Pressure (RVP), and sulphur content, and found that the samples generally conformed to ASTM standards, although the authors emphasized the need for continuous monitoring to prevent adulteration (Ifezue and Onobrenufe, 2023). Similarly, an analysis of PMS from three depots in Lagos Metropolis showed that the samples met specifications for density, octane number, ethanol, benzene, and sulphur content, yet the researchers warned that ongoing quality checks were essential to safeguard against fuel adulteration (Onyinye and Nkechi, 2015).

Detecting adulteration requires reliable and standardized analytical methods. Techniques such as density measurement, distillation under ASTM D86, gas chromatography, and portable near-infrared spectroscopy are widely recognized as effective for both laboratory and field assessment of PMS quality (Okoro *et al*., 2017). These methods help to identify anomalies and ensure compliance with national and international standards.

Nonetheless, broader research shows that adulteration of petroleum products remains widespread in Nigeria, with significant implications for engine durability, fuel efficiency, and environmental protection. Studies indicate that practices such as mixing PMS with kerosene, diesel, or condensates alter critical physicochemical properties and compromise the integrity of fuel supplied to consumers (Ehinomen and Adeleke, 2012). This highlights the urgent need for regular surveillance and strict regulatory enforcement to maintain fuel quality across the country.

1.1.2 STATEMENT OF PROBLEM

Premium Motor Spirit (PMS), also known as petrol or gasoline, is the most commonly used petroleum product in Nigeria, and Benin City in particular, serving as the main fuel for transportation and power generation through generators (Ivwurie, 2023). Its widespread use makes the quality of PMS a critical factor influencing not only engine performance but also economic productivity and environmental health (Okoro and Falode, 2020).

The quality of PMS is determined by its physicochemical properties, including density, vapor pressure, octane number, sulfur content, and flash point, which directly affect combustion efficiency, storage safety, and emission levels (Onyema, 2021). When these parameters fall outside recommended standards, PMS can cause engine knocking, excessive fuel consumption, air pollution, and increased maintenance costs (Ogbuagu *et al.*, 2018).

In Nigeria, substandard fuel quality has been a persistent challenge due to adulteration, contamination during transportation and storage, and weak regulatory enforcement (Ojekunle *et al.*, 2017). The Department of Petroleum Resources (DPR) and SON have since launched mobile fuel testing laboratories to strengthen monitoring and ensure compliance with set standards (DPR and SON, 2012).

Several studies have investigated the physicochemical properties of PMS in different parts of Nigeria, revealing significant variations when compared with ASTM standards (Ivwurie, 2023).

Despite Benin City being a major commercial and urban center with high PMS consumption due to transportation and electricity generation needs, there is limited published data on the quality of PMS sold in the city (Akeredolu and Akinnibosun, 2017). Therefore, a detailed analysis of the physicochemical properties of PMS commercially available in Benin City is essential to determine compliance with national and international standards and to safeguard consumer interests.

1.1.3 JUSTIFICATION OF THE STUDY

Nigeria has faced serious concerns over the quality of Premium Motor Spirit (PMS), with reports indicating that substandard and off-specification fuels, sometimes referred to as "dirty petrol", constitute up to a quarter of daily fuel consumption in the country, raising urgent consumer safety and environmental concerns (Pulse Nigeria, 2024; Valuechain, 2025).

Despite assurances from the Nigerian National Petroleum Company Limited (NNPCL) about the high standards of its fuel, investigative reports reveal that both the NNPCL and independent marketers have been implicated in importing and distributing substandard PMS, underscoring persistent gaps in quality control across the supply chain (Pulse Nigeria, 2024; Valuechain, 2025).

Furthermore, smuggling of PMS has further complicated efforts to maintain fuel quality, with a daily loss of about 7 million litres, illustrating the broader systemic challenges affecting the fuel market (Guardian Nigeria, 2019).

Analyses of PMS distributed in Warri Metropolis showed that while some samples met ASTM standards for properties like density and vapor pressure, the study emphasized that continuous, random testing is critical to detect adulteration and maintain fuel quality (Ifezue and Onobrenufe, 2023).

Elsewhere, comparative evaluations of PMS from artisanal refineries versus standard products in Delta State revealed that artisanal-refined fuel generally failed to comply with ASTM specifications, except in limited aspects, highlighting the variability of fuel quality in informal supply chains (Amabogha and Gbeinzi, 2024).

Studies focusing on environmental and health implications of PMS usage have shown that emissions from fossil fuel combustion release significant quantities of trace metals, like lead and iron, into air, soil, and water systems across major cities, which underscores the importance of understanding fuel quality to mitigate these risks (Elehinafe *et al*., 2024).

Moreover, contaminated PMS and related incidents, such as cases of fuel tainted with excessive methanol quantities, have been identified and isolated from circulation, with regulatory agencies and the NNPC taking corrective action to preserve public safety, highlighting the prevalence and urgency of quality control measures (African Examiner, 2022).

Despite Benin City's significant dependence on PMS for transportation and generator-based power, there remains a notable lack of published data on the physicochemical quality of petrol sold there (MedCrave, 2021; Ifezue and Onobrenufe, 2023).

Addressing this gap through a robust analysis of PMS quality in Benin City will yield valuable data that can inform regulatory monitoring, guide policy decisions, raise consumer awareness, and ultimately, contribute to safer fuel consumption practices and environmental protection (Amabogha and Gbeinzi, 2024).

1.1.4 SCOPE OF WORK

This study is limited to the analysis of Premium Motor Spirit (PMS) samples collected from filling stations in four LGAs of Benin City: Oredo, Ovia North-East, Egor, and Ikpoba Okha.

The physicochemical properties examined include octane rating, boiling point, density, Reid Vapour Pressure (RVP), Bottom Sediment and Water (BSW), and colour, using standard ASTM procedures, and comparing the results with ASTM standards.

1.1.6 AIM AND OBJECTIVES

AIM

The aim of this research is to carry out the quality analysis on the physicochemical properties of Premium Motor Spirit (PMS) commercially available in the selected Local Government Areas of Benin City.

OBJECTIVES

To achieve this aim, the objectives are to:

1. Collect PMS samples from filling stations in Oredo, Ovia North-East, Egor, and Ikpoba Okha LGAs.
2. Determine the physicochemical properties such as density, RVP, octane number, BSW, boiling point and colour.

3. Compare all results with ASTM quality standards to detect adulteration or non-compliance.

1.2 LITERATURE REVIEW

1.2.1 INTRODUCTION TO PMS

Premium Motor Spirit (PMS), also known as petrol, is one of the most important refined petroleum products and is widely used as fuel for spark-ignition internal combustion engines that power vehicles and small machines (Onyinye and Nkechi, 2015). The economic growth and social development of countries such as Nigeria are strongly tied to the availability and quality of PMS, since transportation and industrial activities rely heavily on it (Ehinomen and Adeleke, 2012).

The quality of PMS is commonly evaluated by its physicochemical properties, which include density, Reid Vapour Pressure (RVP), distillation range, research octane number (RON), sulphur content, and Basic sediment and water level. These parameters are critical because they influence combustion efficiency, engine performance, environmental impact, and overall fuel safety (Okoro *et al*., 2017). Internationally recognized bodies such as the American Society for Testing and Materials (ASTM) set specifications for these properties to ensure uniformity and safety across markets (Ifezue and Onobrenufe, 2023).

Despite these established standards, Nigeria continues to face persistent challenges regarding PMS quality. Studies conducted across various regions have shown that adulteration is a widespread practice, with PMS often being mixed with cheaper petroleum fractions such as kerosene, diesel, or condensates (Ehinomen and Adeleke, 2012). Such adulteration alters critical physicochemical parameters, reduces engine efficiency, increases pollutant emissions, and contributes to engine failure (Onyinye and Nkechi, 2015).

Research carried out in Warri Metropolis revealed that PMS samples largely conformed to ASTM standards for density, octane number, and RVP, but the study recommended regular random testing to prevent adulteration and safeguard consumer interest (Ifezue and Onobrenufe, 2023). Similarly, an analysis of PMS from depots in Lagos Metropolis confirmed compliance with parameters such as density, octane number, benzene, and sulphur contents, yet the researchers stressed the importance of continuous monitoring (Onyinye and Nkechi, 2015).

Given the central role of PMS in Nigeria's economy and the risks associated with poor fuel quality, there is a strong need for continued assessment and regulation. This study therefore investigates the physicochemical properties of PMS sold in Benin City, Edo State, and compares the results against ASTM specifications to determine compliance and highlight possible implications for fuel performance and consumer safety (Ifezue and Onobrenufe, 2023).

Assessing the quality of Premium Motor Spirit is essential because tainted or adulterated fuel often leads to increased emissions of harmful pollutants such as carbon monoxide and particulate matter, posing significant environmental and public health risks (Osueke and Ofondu, 2011).

Reliable fuel testing is critical to ensuring engine efficiency and preventing costly mechanical failures, contaminants can clog injectors, cause abrasion, and trigger premature wear, which results in expensive repairs and downtime (TestOil, 2023).

Fuel quality directly influences engine performance and combustion efficiency; higher-quality fuel ignites more readily, deliver better energy output, and protects engine components from damage caused by poor ignition or combustion (Fuel Logic, 2023).

Compromised fuel quality also undermines overall engine performance and increases maintenance costs, as low-quality fuel contains impurities, including sediments and water, that interfere with fuel delivery and reduce engine reliability (Fuel Logic, 2023).

Specifically, in laboratory and field assessments, physicochemical analysis of petroleum products has shown that adulteration not only reduces fuel performance but also compromises safety and contributes to environmental pollution and economic losses (Oniyemofe *et al*., 2024).

1.2.2 PHYSICOCHEMICAL PROPERTIES OF PMS

OCTANE RATING (RESEARCH OCTANE NUMBER):

Octane rating measures the resistance of Premium Motor Spirit (PMS) to auto-ignition in spark-ignition internal combustion engines, reflecting its anti-detonation quality (Onojake *et al.,* 2013). It indicates how effectively PMS can withstand compression without premature ignition, which is critical for smooth combustion (Jiang *et al*., 2019). Poor-quality fuels tend to knock, producing uneven combustion that damages engine performance and efficiency (Rodriguez *et al*., 2020). Iso-octane is assigned a value of 100 because it resists knocking, while heptane is given a value of 0 due to its high knocking tendency; the octane number of PMS is therefore determined as the percentage blend of iso-octane and heptane (Chen *et al.*, 2020). The Research Octane Number (RON), determined according to ASTM D2699, is the most widely used measure of anti-knock performance of PMS globally (ASTM International, 2023; Ifezue and Onobrenufe, 2023).

DENSITY AND SPECIFIC GRAVITY:

The density or specific gravity of PMS is a critical property used to convert volumes to masses at standard temperatures, which influences energy content and combustion behaviour (Rajalakshmy *et al.,* 2022). Laboratory determination of PMS density is carried out using a hydrometer in accordance with ASTM D1298, which applies to transparent and low-viscosity liquids (ASTM International, 2017). The procedure involves conditioning the fuel sample to 15°C, inserting a calibrated hydrometer and thermometer, and recording the readings corrected for meniscus and temperature variations (Ifezue and Onobrenufe, 2023). The principle is based on Archimedes' law of buoyancy, where the buoyant force equals the displaced fluid's weight (Dahl et al., 2020).

BOILING POINT USING DISTILLATION ANALYSIS:

Distillation analysis of PMS provides information on volatility, boiling range, and composition, which are key indicators of combustion performance and possible adulteration (El-Ghonemy, 2018). The ASTM D86 method determines the initial boiling point, distillate volumes, and final boiling point under atmospheric pressure, which directly relates to PMS volatility (ASTM International, 2024). Nigerian PMS samples analysed by previous researchers have shown compliance with ASTM distillation standards, although variations suggest possible regional adulteration (Onyinye and Okoye, 2015; Ifezue and Onobrenufe, 2023). The distillation process works by heating PMS until molecules vaporize, condensing vapour back into liquid to determine boiling ranges, which is essential for product quality control (Garzoli *et al.,* 2019).

REID VAPOR PRESSURE (RVP):

RVP measures the volatility of PMS by quantifying the vapour pressure exerted at 37.8 °C, and is determined using ASTM D323 (ASTM International, 2020). RVP is important for fuel formulation because it influences evaporation rate, engine starting ability, and risk of vapour lock (EPA, 2024). Seasonal RVP adjustments are often mandated to reduce evaporative emissions and improve fuel efficiency (Intertek, 2025). Nigerian PMS studies report RVP values within ASTM specifications, though adulteration can cause significant deviations (Onojake *et al.,* 2013; Ifezue and Onobrenufe, 2023).

COLORIMETER:

The colour of PMS, usually ranging from colourless to light yellow, is determined using the ASTM D1500 colour scale (ASTM International, 2003). Colour assessment is important for detecting contamination or degradation, since deviations from the expected range often indicate impurities (Lovibond, 1999). The test involves visual comparison of the PMS sample against calibrated coloured glass discs under standardised lighting, ensuring reproducibility (Koehler Instrument Company, 2024). Pure PMS is typically clear, while darker shades suggest adulteration or ageing (Onyinye and Okoye, 2015; Ifezue and Onobrenufe, 2023).

BASE SEDIMENT AND WATER (BSW):

BSW content is a measure of contamination in PMS and is determined using the centrifuge method specified by ASTM D4007-22 (ASTM International, 2022). The test involves mixing PMS with a demulsifying solvent such as toluene, centrifuging at 60 °C, and reading the separated water and sediment volume at the bottom of the tube (ASTM International, 2022). BSW testing is critical for preventing corrosion in storage and pipelines, ensuring fuel stability, and protecting engines (Ifezue and Onobrenufe, 2023).

1.2.3 BODIES THAT REGULATE PREMIUM MOTOR SPIRIT (PMS) QUALITY IN NIGERIA

The Nigerian Midstream and Downstream Petroleum Regulatory Authority (NMDPRA) was established under the Petroleum Industry Act (PIA) of 2021 to oversee midstream and downstream petroleum operations, including premium motor spirit, consolidating functions previously held by Department of Petroleum Resources (DPR), Petroleum Products Pricing

Regulatory Agency (PPPRA), and Petroleum Equalisation Fund (PEF), into a unified regulatory body (About the PIA, n.d.; Vanguard, 2023). NMDPRA is tasked with licensing, monitoring compliance in refining, storage, and distribution, and establishing standards for product quality and safety (NMDPRA functions, 2025).

The Standards Organisation of Nigeria (SON) is the statutory body responsible for developing and enforcing product quality standards under the Nigerian Industrial Standards (NIS) framework. SON certifies products, conducts conformity assessments, and monitors both imports and exports to ensure adherence to established specifications (SON, 2025).

The Federal Ministry of Petroleum Resources (FMPR) plays a central role in policy formulation, oversight, and coordination of Nigeria's petroleum industry. It oversees the operations of NMDPRA and SON while setting broader petroleum industry policies, including quality assurance frameworks for PMS (About MPR, 2025; Federal Ministry of Petroleum Resources, 2025).

1.2.4. IMPACT OF PHYSICOCHEMICAL PROPERTIES ON FUEL QUALITY AND PERFORMANCE

The physicochemical properties of Premium Motor Spirit (PMS) play a vital role in determining its overall quality, performance in engines, and compliance with international fuel standards. Density is an essential property because it influences the volumetric energy content of the fuel. A higher density typically indicates more energy per unit volume, which can improve fuel economy, although excessively high density may cause incomplete combustion and deposits (ASTM International, 2018).

Reid Vapour Pressure (RVP) is another crucial property since it determines volatility, cold-start performance, and evaporative emissions. Fuels with excessively high RVP may result in increased evaporative losses and higher hydrocarbon emissions, whereas low RVP can cause poor starting, particularly in cold conditions (Gupta and Agarwal, 2017).

Octane rating directly affects knock resistance, which is critical for efficient and smooth engine performance. Fuels with low octane ratings are prone to knocking, reducing engine efficiency and potentially damaging engine components. Conversely, higher octane fuels enable engines to operate at higher compression ratios, improving thermal efficiency (Heywood, 2018).

The distillation characteristics of PMS also influence combustion behavior, fuel volatility, and drivability. Fuels with improper distillation ranges may lead to incomplete combustion, higher emissions, and operational issues such as engine hesitation or vapor lock (Kalghatgi, 2014).

Additionally, properties such as colour and appearance indicate contamination or adulteration, which directly impacts quality perception and safety. Similarly, Basic Sediment and Water (BSW) affects storage stability and fuel handling, as excess water or sediments can cause corrosion, microbial growth, and filter plugging (Ifezue and Onobrenufe, 2023).

Overall, the interplay between volatility, combustion characteristics, and knock resistance determines not only fuel efficiency but also emission profiles. Optimising these physicochemical parameters is therefore central to producing PMS that meets ASTM and regulatory specifications while ensuring engine durability and reduced environmental impact (ASTM International, 2018; Heywood, 2018).

1.2.5 DETECTION OF ADULTERATION AND CONTAMINANT

Adulteration of Premium Motor Spirit (PMS) is a widespread problem in many developing countries, including Nigeria, and it negatively impacts both fuel quality and consumer safety (Ifezue and Onobrenufe, 2023). Common adulterants in PMS include kerosene, diesel, naphtha, and other low-cost petroleum fractions, which are often mixed to increase profit margins (Onyemachi and Ogbuagu, 2020). The addition of these substances alters key physicochemical properties such as density, octane number, volatility, and Reid vapor pressure (RVP), leading to reduced fuel performance (Nwachukwu *et al.,* 2021).

For instance, kerosene addition lowers the octane rating of PMS, increasing the tendency of engine knock during combustion (Okonkwo *et al.,* 2018). Diesel adulteration raises the density and distillation range, which negatively affects engine efficiency and can cause incomplete combustion (Chinweuba and Mgbemene, 2019). Adulteration with condensates such as naphtha increases volatility beyond specification, which may result in vapor lock and high evaporative emissions (Nwachukwu *et al.,* 2021). These changes compromise not only engine performance but also environmental safety due to higher carbon monoxide and hydrocarbon emissions (Onyemachi and Ogbuagu, 2020).

Several physicochemical analysis techniques are used to detect adulteration in PMS. Density measurement using ASTM D1298 is commonly employed because adulterated fuel often shows abnormal density values compared to standard ranges (ASTM, 2021). Reid vapor pressure (RVP) analysis under ASTM D323 helps detect adulteration with highly volatile substances such as naphtha (ASTM, 2021). Distillation tests (ASTM D86) can identify adulteration with kerosene or diesel by revealing extended boiling ranges (ASTM, 2021). Colorimetric analysis can detect abnormal coloration in PMS that indicates contamination with diesel or other heavier fractions (Chinweuba and Mgbemene, 2019).

In addition, octane rating determination using ASTM D2699 is crucial because adulterated PMS typically exhibits lower octane values than required for efficient combustion (ASTM, 2021). Water contamination, often introduced during transport or storage, is measured through the

Bottom Sediment and Water (BSW) test using ASTM D4007, as even small amounts of water compromise fuel quality (ASTM, 2021). Together, these laboratory-based physicochemical analyses serve as reliable tools to identify adulteration and safeguard fuel integrity (Okonkwo *et al.,* 2018).

1.2.6 PREVIOUS STUDIES ON PMS QUALITY ANALYSIS

An investigation by Ifezue and Onobrenufe (2023) examined PMS samples from four tank farms in Warri Metropolis. They tested density, octane number, Reid Vapor Pressure (RVP), distillation endpoints, sulphur content, and copper strip corrosion, finding overall compliance with ASTM standards, though they recommended frequent random testing to monitor potential adulteration (Ifezue and Onobrenufe, 2023).

Similarly, Onojake *et al.,* 2012 analyzed samples from multiple dispensing points and reported wide variations in research octane numbers (ranging from 60.1 to 93.3), specific gravity (0.7523 to 0.7885), RVP (0.28 to 0.60 kg/cm²), and distillation ranges (189–251 °C), concluding that significant adulteration of PMS is pervasive and detrimental to engine performance (Onojake *et al.,* 2012).

Onyinye and Okoye (2015) conducted a regional study in Lagos Metropolis, measuring key properties such as density, octane rating, and distillation characteristics. Their results, while largely within standard limits, revealed regional inconsistencies and highlighted the need for improved oversight in monitoring fuel quality (Onyinye and Okoye, 2015).

At a broader scale, Vempatapu and Kanaujia (2017) conducted a global review of analytical methods for detecting petroleum fuel adulteration. They emphasized the utility of techniques like gas chromatography and near-infrared spectroscopy but also noted practical challenges such as cost, technical expertise, and field applicability limitations (Vempatapu and Kanaujia, 2017).

Across these studies, common challenges in monitoring PMS quality include limited sampling frequency, reliance on single-parameter tests, and resource constraints in laboratory infrastructure, challenges that undermine effective quality enforcement efforts (Ifezue and Onobrenufe, 2023; Onojake *et al.,* 2012; Vempatapu and Kanaujia, 2017).

CHAPTER TWO

2.1 MATERIALS

2.1.1 APPARATUS

- Glass cylinder
- Hydrometer
- Thermometer
- Reid Vapor Pressure Water Bath
- Pressure Gauge
- Centrifuge
- Centrifuge tube
- Distillation flask
- Distillation machine
- Research Octane number Analyzer
- Graduated cylinder (200ml)

2.1.2 REAGENTS

- Toluene

2.2 METHODOLOGY

2.2.1 SAMPLING AREA

Samples were obtained from filling stations located in Ovia North-East LGA, Oredo LGA, Egor LGA, and Ikpoba-Okha LGA in Benin City, Nigeria.

2.2.2 SAMPLE COLLECTION

Premium Motor Spirit (PMS) samples were collected from gas stations in different Local Government Areas (LGA), which are: Oredo, Egor, Ikpoba-Okha, and Ovia North-east, in Benin City. A total of five samples were collected from each L.G.A. Aggregate samples were made for each L.G.A, making a total of four aggregate samples.

Each sample was collected in clean, airtight containers and kept in a closed environment, which was essential to protect the fuel from light exposure that could alter its characteristics. Each container was labeled properly with important information, such as the collection site, to ensure proper traceability.

The samples were transported to the Refinery safely. Once in the fuel laboratory, they were stored at ambient temperature (approximately 25°C), away from direct light and potential contaminants.

Before analysis, the bottles were gently inverted to mix the contents and achieve sample uniformity thoroughly. Samples were also visually inspected for the presence of particulate matter. These procedures were performed to ensure that the test results accurately represented the true quality of the gasoline.

2.2.3 MEASUREMENT OF DENSITY (15 °C) USING ASTM D1298 METHOD:

The density of Premium Motor Spirit (PMS) at 15°C was measured using the ASTM D1298 hydrometer method. This technique involves floating a calibrated glass hydrometer in the sample and then adjusting the observed density to 15°C using standard petroleum correction tables.

Before testing, the hydrometer, thermometer, and glass cylinder were thoroughly cleaned and dried to prevent any residues or droplets from affecting the measurement.

The glass cylinder was filled with enough PMS to allow the hydrometer to float freely without touching the cylinder's sides or bottom. The hydrometer was carefully lowered into the liquid and released smoothly, then given a gentle spin to remove any trapped air bubbles. A thermometer was inserted into the glass cylinder. The sample temperature was recorded to the nearest 0.1 °C. Hydrometer readings were taken at eye level at the base of the meniscus, ensuring the hydrometer was suspended freely without contact with the vessel walls. The measurement was repeated until consistent readings were obtained.

The density observed at the assay temperature was corrected to the standard 15 °C using ASTM Petroleum Measurement Tables. The final density was reported in grams per cubic centimeter at 15 °C, alongside sample identification, measured temperature, raw reading, correction method used, and the final corrected value.

This procedure was repeated for the other samples.

2.2.4 DETERMINATION OF REID VAPOUR PRESSURE USING ASTM D323 METHOD:

The Reid Vapor Pressure (RVP) of Premium Motor Spirit (PMS) was measured according to the ASTM D323 standard. The method involved determining the pressure exerted by the vapor of the liquid sample in equilibrium at 37.8 °C (100 °F) using a standard Reid vapor pressure apparatus equipped with a pressure gauge and a temperature-controlled RVP water bath.

The pressure gauge chamber was carefully filled with the PMS sample up to the specified mark and was covered properly. The pressure gauge was shaken gently to mix the petrol and any air space inside. The sealed pressure gauge was placed into the RVP bath and was kept for 30 minutes. The value was read directly from the gauge after the pressure stabilized. This procedure was repeated for the other samples.

2.2.5 DETERMINATION OF BOILING POINT OF THE P.M.S USING ASTM D86 METHOD:

The Boiling point of the P.M.S was carried out using the distillation separation technique.

The distillation properties of Premium Motor Spirit (PMS) were evaluated following the ASTM D86 standard. This method involves heating a known volume of the sample at atmospheric pressure and recording the temperatures at which specific portions of the sample vaporize.

The distillation setup, including a round-bottom flask, distillation column, condenser, and graduated cylinder, was thoroughly cleaned and dried to eliminate any residues from previous tests. 100ml of PMS sample was placed in the distillation flask, and the apparatus was assembled carefully to ensure all joints were secure and leak-free.

Heating of the flask was carried out at a controlled rate as specified by the standard. A calibrated thermometer continuously measured the vapor temperature at the top of the distillation column. The distilled liquid was collected in the graduated cylinder, and temperatures were noted at key points: the initial boiling point (IBP), 5%, 10%, 30%, 50%, 70% 90%, 95% recovery volumes, and the final boiling point (FBP). Additionally, the total recovered volume and any residue remaining in the flask were recorded. This procedure was repeated for the other samples.

2.2.6 DETERMINATION OF COLORIMETER USING VISUAL APPEARANCE METHOD:

The color of the Premium Motor Spirit (PMS) sample was determined using a visual appearance method. The sample was poured into a clean, transparent glass container and examined under natural light against a white background. The fuel's appearance was carefully observed, focusing on attributes such as clarity and visible color. Descriptions were recorded based on whether the sample appeared clear, faintly colored, or cloudy.

This testing approach was conducted according to the guidelines of ASTM D1500 (Color of Petroleum Products by the ASTM Color Scale), although instead of using a colorimeter or instrument-based comparator, the assessment was performed visually through the appearance method.

2.2.7 DETERMINATION OF BOTTOM SEDIMENT AND WATER (BSW) USING ASTM D4007 METHOD:

The Bottom Sediment and Water (BSW) content of Premium Motor Spirit (PMS) was determined using the ASTM D4007 centrifuge method. This technique involves separating water and sediment from the petroleum sample through high-speed centrifugation in the presence of a demulsifying solvent, followed by measuring the volume of the separated layer.

Centrifuge tubes were first cleaned, dried, and graduated to allow direct volume measurement. Each tube was filled with a 50ml of PMS sample and 50ml toluene. The contents were mixed thoroughly to ensure complete blending of the sample with the solvent.

The tubes were then carefully placed inside the centrifuge. The temperature was set to 40 °C and the centrifuge was operated at the speed of 1346RPM and duration of 15mins until a clear separation of the water and sediment layer was achieved.

Following centrifugation, the tubes were removed and allowed to settle briefly. The volume of bottom sediment and water collected at the base of the tubes was read directly from the graduations and recorded as the BSW content in the PMS sample.

2.2.8 DETERMINATION OF OCTANE RATING USING ASTM D2699 METHOD:

The octane rating of Premium Motor Spirit (PMS) was determined as the Research Octane Number (RON) using a Zeltex ZX-440 Near-Infrared (NIR) Petroleum Analyzer. The instrument was operated with calibration models correlated to the ASTM D2699 reference method for RON.

The analyzer was powered on via the rear switch and allowed to complete a warm-up period of approximately 15 to 20 minutes. After the initial boot-up, the Gasoline Jar / Product Test home screen appeared, and a test session was started by selecting the on-screen TEST soft key. When prompted to "Prepare to take standard", the DONE key was pressed.

A clean sample holder was filled with the PMS sample, ensuring removal of any air bubbles. The sample compartment cover was opened, and the holder was inserted with a white stripe aligned to a matching white mark inside the compartment. After closing the compartment to block ambient light, the DONE key was pressed to initiate the first scan.

Once the first scan was complete, the analyzer requested the insertion of the gasoline sample a second time ("Insert sample of gasoline, 2 of 2"). The holder was removed, rotated to align the white stripe with the opposite mark, and firmly reseated. The compartment was closed again, and pressing DONE started the second scan.

Following the paired scans, the instrument calculated and displayed the RON value for the sample. The result was recorded from the display, and a hard copy printout of the RON was generated.

Note: The RON results from the NIR analyzer were correlated to the ASTM D2699 method, which is the primary CFR engine test for Research Octane Number. The NIR analyzer serves as a secondary technique, providing RON predictions through established calibration correlations.

CHAPTER THREE

RESULTS AND DISCUSSION

3.1 RESULTS AND DISCUSSION:

3.1.1 DENSITY (15 °C)

Table 3.1. Value for Density at15°C.

L.G.A	Observed value at 23 °C	Corrected value at 15 °C
Egor	0.739 g/cm^3	0.746 g/cm^3
Ikpoba Okha	0.729 g/cm^3	0.736 g/cm^3
Oredo	0.734 g/cm^3	0.741g/cm^3
Ovia North-East	0.734g/cm^3	0.741g/cm^3

ASTM STANDARD: 0.720 to 0.780 g/cm^3

The density of the Premium Motor Spirit (PMS) samples measured at 15 °C was within the ASTM specification range of 0.720 to 0.780 g/cm^3. This shows that the samples meet the necessary quality standards for efficient combustion, proper volatility, and optimal engine performance. Density is a crucial factor in fuel quality, as it impacts both the fuel's energy content and its combustion efficiency in spark-ignition engines.

When the density of PMS falls below this range, it indicates the fuel may be too light, possibly from excessive blending with lighter hydrocarbons or adulteration. Such fuel has reduced energy content, which can lead to lower fuel efficiency, engine knocking, and higher evaporation losses.

On the other hand, if the density exceeds the standard range, it suggests the fuel is too heavy, likely due to contamination with heavier hydrocarbon fractions. This may cause incomplete combustion, carbon deposition in the engine, poor volatility, difficulty in cold starts, increased engine wear, and higher emissions.

Therefore, the fact that the measured densities conform to the ASTM standard confirms that the PMS samples are of good quality and suitable for effective use in spark-ignition engines.

3.1.2 REID VAPOR PRESSURE (RVP)

Table 3.2. Value for RVP.

L.G.A	**R.V.P (kpa)**
Ikpoba Okha	58.60546
Egor	57.22651
Oredo	57.22651
Ovia	57.22651

ASTM STANDARD: 45 to 60.kpa.

The Reid Vapor Pressure (RVP) of the Premium Motor Spirit (PMS) sample was measured within the ASTM D323 specification range of 45 to 60 kPa. This range indicates that the fuel exhibits an appropriate level of volatility, which is crucial for ensuring smooth engine starting, efficient combustion, and minimizing evaporative losses.

If the RVP falls below this range, the fuel becomes less volatile, resulting in difficulties in cold-starting engines and suboptimal combustion, particularly in low-temperature conditions. This lower volatility can be attributed to the presence of heavier hydrocarbons or inadequate refinery processing, adversely impacting engine performance.

On the other hand, if the RVP exceeds the specified limit, the fuel is overly volatile, which can cause excessive evaporation losses, increase the risk of vapor lock within the fuel system, and elevate emissions of volatile organic compounds (VOCs), posing environmental hazards. Excessively high volatility may also result in fuel system malfunctions and non-compliance with environmental regulations.

In conclusion, the RVP result confirms that the PMS sample strikes the necessary balance between volatility and stability required for optimal fuel performance. Ensuring the RVP remains within the ASTM specification of 45 to 60 kPa supports reliable engine operation and minimizes environmental impact, while deviations above or below this range may cause cold-start issues, increased evaporative losses, fuel system problems, and greater emissions.

3.1.3 RESEARCH OCTANE NUMBER:

Table 3.3. Value for RON.

L.G.A	R.O.N
Ikpoba Okha	90.0
Egor	91.0
Oredo	90.7
Ovia	90.0

ASTM STANDARD: 90 to 93 RON.

The octane rating of the Premium Motor Spirit (PMS) samples was found to be within the acceptable specification range of 90 to 93 Research Octane Number (RON), demonstrating good resistance to engine knocking during combustion. This ensures smooth engine operation, efficient fuel use, and protection of engine components. Meeting the required octane level signifies that the fuel is suitable for use in modern spark-ignition engines without causing operational problems.

If the octane rating falls below this specified range, it can lead to engine knocking or pre-ignition, where the air-fuel mixture ignites prematurely. This result in inefficient combustion, reduced engine power, increased wear on pistons and valves, and can cause long-term engine damage. Modern engines may mitigate this by retarding ignition timing, but this reduces overall engine performance and fuel economy.

Conversely, if the octane rating exceeds the specification, it will not directly damage the engine but can have practical drawbacks. Higher octane fuels require a hotter and more precisely timed spark, placing a greater electrical load on ignition components and complicating engine tuning. Additionally, more energy-intensive refining is needed to produce higher octane fuel, leading to unnecessary production costs without significant performance improvements in engines designed for regular PMS. Excessively high Octane fuels may also have lower energy density, which can reduce fuel economy.

In summary, maintaining the octane rating within the typical range of 90 to 93 RON balances engine protection and performance, ensures efficient fuel consumption, and avoids unnecessary refining expenses. Deviations below or above this range can either damage engine components and reduce efficiency or increase operating and production costs without added benefit.

3.1.4 BOILING POINT:

Table 3.4. Value for Boiling Point of the PMS.

%	EGOR (ºC)	OVIA NORTH-EAST (ºC)	IKPOBA OKHA (ºC)	OREDO (ºC)
I.B.P	35	33	32	33
5	50	40	40	40
10	55	49	45	48
30	76	61	60	61
50	100	90	83	86
70	124	113	110	114
90	152	145	143	146
95	166	159	157	160
E.B.P	190	181	179	182
RECOVERY	98%	99%	98%	99%
RESIDUE	2%	1%	2%	1%

The boiling point of the Premium Motor Spirit (PMS) samples analyzed are within the acceptable limits set by ASTM D86. According to ASTM D86, typical specification ranges for PMS include:

- Initial Boiling Point (IBP): Approximately 35 to 70°C
- Temperature at 10% evaporated: Maximum 70°C
- Temperature at 50% evaporated: Maximum 125°C
- Temperature at 90% evaporated: Maximum 180°C
- Final Boiling Point (FBP): Maximum 210°C
- Residue: Maximum 2% by volume.

In this study, values ranging from 32-35°C were obtained. The IBP of 32-33°C recorded for some samples is slightly below the lower specification limit. This suggests the presence of lighter, more volatile fractions in the fuel. While this enhances vaporization and makes cold-starting easier, it also increases the risk of vapor-lock in hot weather and potential fuel losses during handling. Thus, the IBP results indicate that not all the samples strictly meet the ASTM specification.

The 10% evaporated temperature has a maximum specification of 70 °C. The results , 40–62 °C, fell within this limit, confirming adequate front-end volatility for smooth warm-up and driveability.

At the 50% evaporated point, the specification limit is 125 °C. The observed values , 60–110 °C, were comfortably within range, suggesting that the mid-range volatility is satisfactory. This supports good acceleration, smooth combustion, and efficient power delivery in spark-ignition engines.

For the 90% evaporated point, ASTM D86 specifies a maximum of 180–190 °C. The samples gave values between 114–168 °C, which comply with the standard. This indicates that heavier fractions are well controlled, reducing the risk of deposit formation, incomplete combustion, or engine knocking.

The Final Boiling Point (FBP) is required to be below 210 °C. The samples analyzed had values between 179–200 °C, which are within the acceptable limit. This shows that the amount of heavy hydrocarbons is not excessive, reducing the chances of carbon buildup and gum formation.

Residue values were between 1–2%, and recovery was 98–99%, both of which are within the ASTM D86 specification. This indicates that non-volatile materials are minimal, ensuring clean combustion and reduced damage to injectors and carburetors.

In conclusion, the PMS samples generally meet ASTM D86 requirements at the 10%, 50%, 90%, FBP, residue, and recovery levels. The only notable deviation is the IBP of some samples (32–33 °C), which is slightly below the minimum specification of 35 °C. While this makes the fuel highly volatile and beneficial for quick ignition, it may also lead to vapor lock, increased evaporative emissions, and fuel handling challenges. Overall, the fuel samples can be considered acceptable, though their slightly low IBP points to a tendency toward excessive volatility.

3.1.5 COLORIMETER

Table 3.5. Value for Colorimeter.

L.G.A	**VISUAL**
Egor	Plain Yellow
Ikpoba Okha	Plain Yellow
Ovia North-East	Plain Yellow
Oredo	Plain Yellow

The color determination of the four PMS (Premium Motor Spirit) samples showed a consistent plain yellow appearance, which aligns with the ASTM D1500 color scale specification for petrol. This uniform yellow coloration indicates proper refining and the absence of contaminants such as water, rust, or heavy hydrocarbons. A plain yellow color reflects good product quality, free from degradation or prolonged storage issues.

Had the color been darker (brownish or reddish), it would have suggested contamination, oxidation, or poor storage conditions, negatively impacting combustion quality and engine performance. Conversely, an unusually pale or colorless fuel could indicate adulteration with lighter hydrocarbons or solvents, posing safety and performance risks.

Overall, the results confirm that the samples meet the visual quality standards as per ASTM D1500 and are suitable for use in spark-ignition engines.

3.1.6 BOTTOM WATER AND SEDIMENT

Table 3.6. Value for BSW.

L.G.A	**B.S.W (%by Vol)**
Egor	0.05
Ikpoba Okha	0.05
Oredo	0.05
Ovia North-East	0.05

ASTM STANDARD: Maximum 0.05% by Volume.

The Basic Sediment and Water (BSW) content of the Premium Motor Spirit (PMS) samples was measured to be 0.05% by volume using ASTM D4007, which employs the centrifuge method with toluene as the dispersing solvent. This value is within the typical specification limit for

PMS, which, according to ASTM D4007 and related fuel standards, should not exceed 0.05% by volume. The result indicates that the sample is of good quality in terms of cleanliness and dryness, with negligible water and solid contaminants. Maintaining low BSW is critical to prevent operational issues such as corrosion in storage tanks, clogging of fuel filters, and poor combustion efficiency in engines.

If the BSW content were above the specified limit, it would suggest contamination due to poor handling or storage conditions. Excess water could cause phase separation, microbial growth, and engine corrosion, while elevated sediment levels might result in abrasion of fuel injectors and filter blockages. Conversely, a BSW value below the detection limit also complies with standards and may reflect additional drying or filtration steps, although such processes could increase production costs.

In conclusion, the measured BSW content of 0.05% by volume demonstrates that the PMS sample meets the standard specification and is suitable for use without risks of corrosion, fuel filter clogging, or reduced combustion performance.

3.2 CONCLUSION:

This study evaluated the physicochemical properties of Premium Motor Spirit (PMS) sourced from selected local government areas, comparing the results with both ASTM standards. The physicochemical properties of the samples analyzed aligned with the acceptable limits set by ASTM, thereby confirming compliance with established quality criteria for PMS, except the IBP (Initial Boiling Point) of Ovia North East, Ikpoba Okha and Oredo LGA, which is slightly lower than the standard ASTM range.

These findings suggest that the PMS samples analyzed are appropriate for domestic use, exhibiting minimal risks of operational issues such as vapor lock, poor combustion, engine knocking, or corrosion that are typically linked to substandard fuels.

This adherence to quality ensures efficient engine performance, safety, and reliability in practical applications. The study further highlights the critical need for ongoing quality monitoring to prevent fuel adulteration, safeguarding both consumers and the environment from associated risks.

3.3 RECOMMENDATION FOR FUTURE STUDY:

This study was constrained to four Local Government Areas (LGAs) and focused on six physicochemical parameters of Premium Motor Spirit (PMS). To build on these findings, future research should expand the scope by including a larger number of LGAs and possibly extend into different states, offering a more comprehensive overview of PMS quality nationwide.

Also in this study, fuel samples from filling stations within each local government area were combined to obtain a representative sample for analysis. For future research, it is recommended that samples from individual filling stations be analyzed separately. This will make it possible to assess variations in fuel quality between different outlets within the same local government and provide more detailed information on the consistency of PMS quality across Benin City.

It would also be advantageous to conduct sampling across various seasons since temperature and humidity fluctuations could impact fuel volatility and stability.

Moreover, incorporating additional parameters like sulfur content, aromatic compounds, and oxygenate levels would allow a better assessment of environmental impacts and fuel performance. Investigating the effects of storage, transportation, and distribution conditions on

PMS quality is also vital, given that adulteration and degradation frequently occur during these stages.

Lastly, future studies could explore statistical correlations among different measured properties, for instance, between density and Reid Vapor Pressure or octane rating and distillation parameters, to better understand how these factors collectively influence overall fuel performance.

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