DETERMINATION OF THE PHYSIOCHEMICAL PROPERTIES OF DIESEL OIL COMMERCIALLY AVAILABLE IN BENIN CITY

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CERTIFICATION

This is to certify that this research project was carried out by CYNTHIA UYINMWEN-IYABO ASIHA-ARASE with the matriculation number PSC2105247 under the supervision of Dr. J.N. JACOB in the Department of Chemistry, Faculty of Physical sciences, University of Benin, Benin City, Edo State.

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DEDICATION

This project research is dedicated to the Almighty God who in His infinite mercy saw me through my journey in the University of Benin.

ACKNOWLEGEMENT

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ABSTRACT

This study assessed the physicochemical quality of diesel oil sold in Benin City, Edo State, Nigeria, using aggregate samples collected from four local government areas (Egor, Oredo, Ikpoba-Okha, and Ovia North-East). The scope covered five key parameters—flash point, distillation characteristics, density, basic sediment and water (BSW), and colour selected for their direct impact on safety, efficiency, and compliance with standards. Diesel samples were collected in sealed one-liter containers, combined into four aggregates, and analyzed using ASTM methods (D93 for flash point, D86 for distillation, D1298 for density, D1796 for BSW, and D1500 for color). Results showed distillation ranges within specification, with initial boiling points of 160–165 °C and final boiling points of 355–356 °C, and final recovered volumes of 97–98 mL, indicating uniform volatility. Density corrected to 15 °C ranged from 0.834 g/mL (Oredo) to 0.847 g/mL (Ovia North-East), aligning with the acceptable 0.82–0.85 g/mL range. BSW content was consistently low at 0.05%, while ASTM colour values ranged from 1.0 to 1.5, all within standards. However, flash points were below 52 °C across all LGAs, failing to meet the ASTM D975 minimum, suggesting contamination or blending with lighter fractions. The findings highlight generally consistent diesel quality but raise safety concerns requiring regulatory oversight.

CHAPTER ONE

INTRODUCTION

1.1.1 Background of the Study

Diesel fuel is one of the most widely used petroleum products in Nigeria. It powers cars, trucks, buses, and generators that provide electricity in both homes and industries. In cities like Benin City, where electricity supply is not reliable, diesel has become a key source of energy for businesses and households. Because of this high dependence, the quality of diesel directly affects daily economic activities, industrial productivity, and the cost of living (Eboh, 2024).

Despite its importance, diesel quality in Nigeria has long been questioned. Adulteration, poor refining, and weak regulatory enforcement have allowed substandard products to dominate the market. Adulteration often involves mixing diesel with cheaper products such as kerosene or water, which reduces efficiency and damages engines. Studies in different parts of Nigeria, such as Onitsha and Sapele, have shown that many diesel samples fail to meet expected standards for flash point, density, and calorific value (Broni-Bediako, 2020). Such poor-quality fuels not only increase maintenance costs for vehicle owners but also reduce fuel economy, placing financial pressure on consumers.

The environmental and health consequences of poor diesel quality are also significant. High sulphur levels and incomplete combustion produce harmful gases and particulate matter, which contribute to air pollution and respiratory diseases (Bello, 2018). Research in West Africa has highlighted similar concerns, with fuel sold in Ghana and

Nigeria often containing higher sulphur and contaminants than allowed by international standards (Eboh, 2024). This creates serious health and environmental risks in urban areas where diesel-powered transport and generators are heavily used.

In response to these problems, regional bodies like the Economic Community of West African States (ECOWAS) have introduced fuel quality regulations. Nigeria has committed to gradually lowering the sulphur content in diesel from 650 ppm to 50 ppm and eventually 10 ppm to align with international best practices (Zhang *et al.,* 2023). However, recent reports suggest that enforcement is inconsistent, and many products in circulation still do not meet these standards (Bello, 2018). This gap between policy and practice makes local studies necessary to understand the true quality of diesel being sold in Nigerian cities.

Benin City presents a suitable case study because it is a commercial hub where transportation, industry, and domestic users rely heavily on diesel. Understanding the physicochemical properties of diesel sold across its local government areas will provide valuable evidence for regulators, policymakers, and consumers (BroniBediako, 2020). It will also help identify the level of compliance with international standards and highlight risks of adulteration. This research therefore seeks to evaluate diesel quality in Benin City by testing parameters such as flash point, distillation, basic sediment and water (BSW), density, and colour, which are key indicators of performance, efficiency, and safety.

1.1.2 Statement of Problem

Diesel fuel is essential for transportation, industrial activities, and power generation in Nigeria. In Benin City, many households and businesses rely on diesel-powered generators due to unstable electricity supply. However, the quality of diesel available in the market has become a major concern. Reports show that adulteration, contamination, and poor refining practices are common, leading to the circulation of fuels that do not meet expected standards for flash point, density, or calorific value (Zhang *et al.,* 2023). These practices reduce fuel efficiency, increase engine wear, and impose higher maintenance costs on consumers.

The environmental and health effects of substandard diesel are equally troubling. Fuels with high sulphur content and impurities release excessive emissions during combustion, contributing to air pollution and climate change. Studies in West Africa have found that diesel samples from Ghana and Nigeria often contain contaminants above acceptable limits, making them unsafe for both public health and the environment (Eboh, 2024). Poor fuel quality has been linked to respiratory diseases, reduced air quality, and increased greenhouse gas emissions in urban areas.

Although ECOWAS and Nigeria have introduced stricter fuel standards, including the gradual reduction of sulphur levels, enforcement remains weak. Reports indicate that many diesel products sold locally still fail to comply with these standards, partly due to inadequate testing infrastructure and regulatory lapses (Broni-Bediako, 2020). The lack of localized studies in Benin City further limits understanding of the scale of the problem. This creates an urgent need for research to assess the physicochemical properties of diesel sold in Benin City and to provide evidence that can guide regulation, consumer awareness, and policy enforcement.

1.1.3 Justification of the Study

This study is important because diesel plays a central role in the economic life of Benin City. It powers transport vehicles, industrial equipment, and generators that supply electricity to homes and businesses. Poor quality diesel reduces fuel efficiency, damages engines, and increases the financial burden on consumers. Previous studies in Nigeria have shown that adulterated diesel often fails to meet standard requirements for parameters like flash point, density, and calorific value, which are critical to fuel performance (Giwa *et al.,* 2019). By testing these parameters in local samples, this study provides data that can help consumers and businesses make better fuel choices and reduce costs linked to maintenance and fuel wastage.

From an environmental and public health perspective, the study also has strong relevance. Diesel with high sulphur or water content increases emissions, leading to air pollution and related health issues such as asthma and other respiratory conditions (Giwa *et al.,* 2019). Evidence from West Africa has shown that fuels sold in countries like Ghana and Nigeria often exceed recommended contamination and sulphur limits, exposing urban populations to harmful pollutants (Eboh, 2024). By quantifying contamination in Benin City samples, this research can highlight health risks and support calls for cleaner fuels that meet international standards.

Finally, the study carries policy and regulatory significance. Although Nigeria has adopted ECOWAS standards and committed to reducing sulphur levels in diesel, poor enforcement and limited testing facilities have weakened compliance (Zhang *et al.,* 2023). Findings from this research can provide baseline evidence for regulators to strengthen enforcement, improve supply chain monitoring, and push for stricter adherence to international fuel standards. It can also inform local policymakers and serve as a reference for future research on petroleum product quality in Nigeria.

1.1.4 Scope of Work

This study focuses on assessing the quality of diesel fuel sold in Benin City, Edo State, Nigeria, using samples collected from four local government areas: Egor, Oredo, Ikpoba-Okha, and Ovia North-East. A total of five samples from each LGA. An aggregate sample were made for each LGAs, making a total of four aggregate samples, were collected in a sealed containers to avoid contamination and analyzed for five key physicochemical parameters that directly influence fuel performance, safety, and efficiency. The parameters considered were flash point, to determine the safety and volatility of the fuel; distillation characteristics, to evaluate the boiling range; basic sediment and water (BSW), to check for contamination by solids and water; density, to assess mass per unit volume and its effect on injection and combustion efficiency; and color, measured using a ASTM colorimeter, was used to assess the quality and condition of the fuel. The study was limited to these parameters due to constraints in laboratory facilities, cost, and time. Nonetheless, the results provide a practical assessment of diesel quality in Benin City and offer a baseline for regulatory monitoring and further studies.

1.1.5 Aim and Objectives

The aim of this study is to assess the physicochemical properties of diesel oil commercially available in Benin City by analyzing key parameters that influence its performance, safety, and compliance with established fuel standards. The specific objectives of this research were to:

- collect diesel fuel samples from four local government areas in Benin City (Egor, Oredo, Ikpoba-Okha, and Ovia North-East) to provide a representative assessment of local supply.
- determine the physicochemical parameters such as flash point, boiling range, basic sediment and water, density, and colour of the diesel oil.

1.1.6 Limitations of the Study

This study was limited by several factors that may have influenced its outcomes. First, only four diesel samples were collected, one from each selected local government area in Benin City. While this provides useful insights, a larger sample size across more stations would give a broader representation of fuel quality. Secondly, the research analyzed only five parameters; flash point, distillation characteristics, basic sediment and water (BSW), density, and color due to constraints in laboratory equipment, cost, and time. Other important properties such as sulphur content, cetane number, and Reid vapor pressure were not included. In addition, the availability and reliability of local testing facilities posed challenges, and findings cannot fully capture seasonal or batch variations in diesel supply.

1.2 LITERATURE REVIEW

1.2.1 Concept of Diesel Fuel

Diesel quality shapes how your engine starts, runs, and lasts (Giwa *et al.,* 2019). Diesel is a middle-distillate fuel for compression-ignition engines: air is compressed until hot, then fuel is injected and auto-ignites. That ignition behavior depends on measurable properties; cetane index/number, density, flash point, and the distillation curve (Broni-Bediako, 2020). Each one controls a part of engine performance: ignition delay, spray atomization, handling safety, and how cleanly the fuel burns (Eboh, 2024). In practice, standards specify acceptable ranges for these properties, and routine tests like flash point, distillation (ASTM D86), basic sediment and water (BSW), density, and calorific value can tell you if a diesel sample is likely to perform as intended. When these numbers drift, engines smoke, filters clog, pumps wear, and costs rise. That simple chain from property to performance is why a local quality check matters for Benin City.

1.2.1.1 Origin and Composition of Diesel Fuel

Refining sets diesel's baseline. Crude oil enters an atmospheric distillation column; the diesel cut typically comes off in the ~180–360 °C boiling range. Refineries then hydrotreat the stream to cut sulphur and stabilize it, and they blend components to hit target properties. The result is a mix of paraffins (good for ignition), naphthenes, and aromatics (raise density but tend to smoke). Additives come later: detergents to keep injectors clean, lubricity improvers to protect pumps, antioxidants to slow gum formation, and cold-flow improvers for colder climates. From refinery to retail, handling can add defects: water ingress from breathing tanks, rust and dust from logistics, and cross-mixing with lighter products (Giwa *et al.,* 2019). Each shows up in routine tests—BSW flags water and solids; density and flash point reveal mixing with kerosene; the distillation curve shows volatility shifts. Composition explains why two clear samples can behave very differently in an engine, and why simple field tests still catch most problems.

1.2.1.2 Uses in Transportation, Power Generation, and Industry

Diesel does heavy work because it pairs high torque with good fuel economy. On the road, trucks, intercity buses, and many minibuses run almost entirely on diesel. Freight is the anchor: road freight alone accounts for about half of global diesel demand, so any change in diesel supply or quality shows up first in logistics costs (Giwa *et al.,* 2019). In power, diesel generators start quickly, take step loads, and scale from a few kilowatts to many megawatts—handy for standby and off-grid needs. In industry, construction equipment, mining trucks, drilling rigs, and farm machinery depend on reliable fuel to keep uptime high (Giwa *et al.,* 2019). Across these uses, the same core properties matter: flash point for safe handling, distillation profile for combustion behavior, density for metering and energy per litre, BSW for cleanliness, and calorific value for output. Keep them in range and engines run cooler and cleaner; let them slip and you pay in smoke, downtime, and spares.

1.2.1.3 Global and Nigerian Dependence on Diesel

Worldwide, diesel underpins freight, agriculture, construction, and a lot of distributed power. Alternatives are growing, but for many hard-to-electrify tasks, diesel remains the practical choice because it is energy-dense, easy to store, and widely available (Dibia *et al.,* 2025). In West Africa, policy has moved to tighten fuel quality; ministers adopted low-sulphur (50 ppm) fuels for imports starting 2021 and set a timeline for local refineries to upgrade, linking cleaner fuels to air-quality gains (Giwa *et al.,* 2019). Nigeria's regulator has since clarified alignment with these regional standards, which frames why sulphur and related parameters matter in local testing and enforcement (Eboh, 2024).

Nigeria's dependence is sharper because the grid is unreliable and businesses need predictable power. Best estimates point to more than 22 million petrol and diesel generators in use, serving about 26% of households and 30% of MSMEs; taken together, their net capacity is several times the effective grid output (Broni-Bediako, 2020). That reliance filters into daily life in cities like Benin City, where transport fleets, small industries, hospitals, and shops all buy diesel regularly. When fuel arrives off-spec—too much water or sediment, a light-end skew that drags down flash point, or heavy material that raises smoke—the costs show up as clogged filters, scored injectors, and higher fuel burn per task (Giwa *et al.,* 2019). Local evidencegathering is therefore practical: by sampling across LGAs and measuring flash point, distillation, BSW, density, and calorific value, you can map quality, flag hotspots, and give regulators and buyers data they can use.

Recent policy and finance headlines reinforce the context. Nigeria continues to seek support to improve the electricity sector, and reporting highlights how limited grid output leaves households and firms leaning on costly generators. Until reliability improves, the city-level exposure to diesel quality stays high. That is why a careful, parameter-based assessment in Benin City is more than a lab exercise, it is a decision tool for maintenance planning, procurement, and public health.

1.2.2 Physicochemical Properties of Diesel

When you think about the physicochemical properties of diesel, think about how each number translates into engine behavior. Flash point tells you how safely you can store and handle the fuel. The distillation curve hints at how it will vaporize and burn inside the cylinder. Density affects how much energy you meter per injection. Calorific value speaks to the work you can get per litre. Basic Sediment and Water (BSW) alerts you to dirt and water that wreck injectors and pumps (Dadson *et al.,* 2024). These properties are not abstract; they forecast smoke, starting ease, fuel economy, and maintenance bills. In applied work across Nigerian cities, these parameters explain most real-life complaints about black exhaust, clogged filters, and hard starts (Bello, 2018).

1.2.2.1 Flash Point and Its Safety Relevance

Flash point is the lowest temperature at which fuel vapour ignites over the liquid. For diesel, a higher flash point supports safe storage, transport, and refuelling, especially in hot climates. If light fractions sneak in—say, by mixing with kerosene—the flash point drops. You may notice stronger fumes at the pump and a higher handling risk. In engines, an abnormally low flash point can raise vapor lock risk in hot lines and can hint at adulteration. In the lab, you read flash point alongside the first part of the distillation curve to judge light-end content. In field studies in southern Nigeria, samples with low flash point often came from sites with poor product turnover or cross-contamination in tanks (Dadson *et al.,* 2024). Policy moves toward cleaner, better-controlled fuels also depend on meeting defined flash point limits (Eboh, 2024).

1.2.2.2 Distillation Characteristics and Combustion Behavior

Distillation testing heats a fuel sample and records temperature points as defined volume percents evaporate (e.g., T10, T50, T90, final boiling point). Inside your engine, atomized droplets must vaporize fast enough to mix with hot air before ignition. Too many light ends can lead to roughness and increased vapor formation; too many heavy ends can slow vaporization and raise smoke, deposits, and aftertreatment load. The shape of the curve matters: a smooth rise with appropriate T50 and T90 supports stable combustion across loads (Dadson *et al.,* 2024). West African assessments report that off-spec curves often track with blending errors or storage problems, which then show up as visible smoke and fouling in service (Eboh, 2024). When you pair the curve with flash point and density, you get a clear read on volatility balance and likely combustion quality.

1.2.2.3 Density and Its Effect on Fuel Efficiency

Meters and ECUs dose diesel by volume, but engines ―feel‖ energy by mass. Density links the two. Higher density usually means more energy per litre, but also thicker sprays and, depending on composition, more aromatics that can raise soot. If density is lower than expected, range drops, and you chase fuel economy with no obvious fault. If density is higher, you may see smoke and carbon build-up under load. Technicians use density as a quick screen for adulteration: mixing with kerosene or solvents lowers density; contamination with heavier streams raises it. Nigerian case studies show density drifting outside recommended bands in retail samples tied to poor logistics and blending control (Dadson *et al.,* 2024). Read density together with the cetane index and the distillation curve to judge spray quality, ignition delay, and likely emissions (Bello, 2018).

1.2.2.4 Colour as an Indicator of Diesel Quality

The colour of diesel is a quick visual cue for its condition and handling history. Fresh diesel typically appears light on the ASTM colour scale, while darker shades may suggest contamination, oxidation, or aging during storage. A shift toward higher color values often signals the presence of impurities, poor blending, or fuel degradation that can affect combustion efficiency and engine cleanliness. The ASTM D1500 method provides a standardized way to assign a numerical color value, making results comparable across batches and regions. Studies have shown that abnormal color readings often align with other quality issues such as elevated sediment, low flash point, or unusual distillation behavior, highlighting its role as an early warning parameter (Eboh, 2024). For operators and managers, tracking fuel colour alongside other laboratory metrics offers a simple but effective check on fuel quality before use.

1.2.2.5 Basic Sediment and Water (BSW) and Contamination Issues

BSW measures the ―dirt and wet‖ in your diesel—rust, dust, microbial sludge, and free or emulsified water. Even small amounts change everything. Water pits injector tips, strips lubricity from pumps, and feeds microbes that grow mats and acids inside tanks. Solids plug filters and erode precision parts. In the field, you often meet BSW problems after rainy periods or when tanks breathe in humid air. Mixed product lines and poorly maintained forecourt tanks add to the burden. Nigerian station surveys have linked high BSW with frequent filter changes, power trips in generator rooms, and rising smoke under load (Dadson *et al.,* 2024). Standards and recent policy pushes in the region aim to control contamination along with sulphur and volatility targets—because clean, dry fuel is a safety and reliability issue as much as a performance one (IVWURIE, 2023).

1.2.3 International Standards (ASTM D975, ISO, EN590)

International standards translate technical properties into a common language that labs, refiners, and buyers can use to judge diesel. ASTM D975, for example, groups diesel into grades and lists the battery of tests and limits a fuel must meet at delivery — it is not a single test but a specification that ties together density, flash point, distillation endpoints, and other parameters into pass/fail criteria for on-road and offroad fuels (Fasasi, 2024). EN 590 plays a similar role in Europe: it defines the physical and chemical properties required for automotive diesel (including limits that have progressively reduced allowable sulphur), and it also defines compatibility with biodiesel blends where applicable. For ships and certain industrial uses, ISO standards (such as ISO 8217 for marine fuels) set related specifications suited to engines and handling at sea. Together, these international documents create reference points for product quality, testing methods, and trading contracts — so a lab anywhere can measure a sample and compare it to a commonly accepted performance target.

1.2.3.1 ECOWAS Sulphur Limits and Regional Fuel Policies

West Africa’s push for cleaner fuels began as a public-health and trade decision. Regional ministers agreed to align imports to low-sulphur specifications (a 50 ppm cap for petrol and diesel for imported fuels in the ECOWAS directive) to reduce urban pollution and to harmonize markets across borders. That policy created a timeline for imported product controls and a transition window for local refineries to upgrade equipment (Fasasi, 2024). The idea was practical: harmonised limits reduce cross-border distortions and raise the quality floor for consumers in multiple countries. Implementation has used staggered deadlines and waivers in recognition of limited refinery capacity, but the direction is clear lower sulphur, tighter product control, and stronger import checks. The regional roadmap also ties fuel quality limits to vehicle emission standards, reflecting the link between fuel chemistry and air quality outcomes.

1.2.3.2 Nigerian Regulatory Framework (SON, DPR/NMDPRA, NNPC)

Nigeria’s formal standards and institutions mirror the complexity of the market. The Standards Organisation of Nigeria (SON) published updated Nigerian Industrial Standards for petroleum products (e.g., NIS 948 series for diesel) that align many product tests and limits with global practice. The downstream regulator (now NMDPRA) manages licensing, distribution oversight, and rule changes; it periodically issues guidance on acceptable sulphur limits and related compliance measures. Policy moves since 2017 have included tighter national standards and staged implementation for refineries, while regulators have used waivers to avoid sudden supply shocks. At the same time, press and industry reporting in 2023–2024 document a mix of actions — tightening limits in some directives, temporary higher caps for local refining competitiveness in others — highlighting the balancing act regulators face between cleaner fuel goals and practical supply realities. These national rules set the legal test thresholds for fuels sold in Nigerian states and therefore frame what a local quality study must compare against.

1.2.3.3 Compliance Challenges In Developing Economies

Standards matter only if they are enforced and supported by reliable testing and logistics. In many developing markets, enforcement faces three linked constraints: limited laboratory capacity and field testing, weak inspection and reporting systems, and supply-chain points where contamination and adulteration occur. Analytical reviews and field surveys show that adulteration — mixing diesel with kerosene, used oils, or lighter streams — can shift flash point, density, and calorific value in ways that standard laboratory tests will detect, but only if samples are taken and tested regularly (Fasasi, 2024). Storage and retail conditions add another layer of risk: water ingress, tank corrosion, and cross-contamination in shared pipes or aging distribution equipment all change product quality after it leaves the refinery. Governance shortfalls and resource limits mean that even when national standards align with international best practice, compliance gaps persist because enforcement action, frequent sampling, and public reporting require sustained funding and institutional will.

1.2.3.4 Implications for City-Level Testing and Policy

That regulatory landscape explains why a focused, city-level quality assessment is useful. International and regional standards create the benchmark; national rules define the legal target; but local realities determine what users actually receive at the pump. A practical testing program — measuring flash point, distillation points, basic sediment and water, density, and calorific value — delivers direct evidence of product condition at the point of sale. Such evidence can flag systemic supply-chain failures (tank problems, blending errors, or deliberate adulteration), guide targeted inspections, and inform maintenance and procurement choices for major diesel users. In short, standards provide the map; local testing shows whether the route is being followed (Fasasi, 2024). For a commercial city reliant on diesel, that combination turns abstract policy into actionable intelligence.

1.2.4 Diesel Adulteration Practices

Adulteration of diesel is a practical story of incentives meeting weak controls: sellers gain margin by adding cheaper liquids; users pay the price in broken parts and higher fuel bills. Across West Africa and Nigeria, research and field reports show that adulteration is widespread enough to be a routine operational concern for fleet managers, generators, and regulators (Wekalao *et al.,* 2024). Adulterants change measurable properties — flash point, density, viscosity, and calorific value — and those shifts predict the kinds of failures operators see on the ground: fouled injectors, increased smoke, shorter filter life, and more frequent overhauls. Systematic studies demonstrate that when adulterant fractions rise above about 15–20% by volume, many common laboratory tests will show off-spec results; below that level, changes can be subtle and harder to spot with simple field checks (Udeagbara *et al.,* 2014). That threshold matters because it determines whether a sample looked at with basic tools will pass or fail, even when the fuel is mixing in economically important but technically damaging amounts.

1.2.4.1 Common Adulterants (Kerosene, Water, Waste Oil).

Kerosene is the most frequent and obvious adulterant in diesel markets where price spreads make blending profitable. Kerosene lowers flash point and reduces cetane quality; blended fuel lights more easily as a vapor and loses the ignition reliability that diesel engines depend on. Water either free or emulsified commonly enters retail tanks through poorly sealed vents, leaking tanker hoses, storm infiltration, or from contaminated storage (Wekalao *et al.,* 2024). Water corrodes metal, fosters microbial growth that creates sludge, and causes immediate injector and pump damage. Used engine oil and waste lubricants are also reported in several regional studies; these add metals and ash, increase viscosity, and leave carbonaceous deposits after combustion (Mourched et al., 2024)

(Mourched *et al.,* 2024). Less conventional adulterants have been recorded too: solvents, essential oils, and lighter refinery streams are used to mask odour or apparent volatility, and sometimes vegetable or frying oils appear in clandestine mixtures. Each adulterant leaves a fingerprint in the fuel's physicochemical profile but not all fingerprints are easy to read at low concentrations.

1.2.4.2 Methods of Adulteration In Nigeria.

The how is as revealing as the what: adulteration happens at many points in the supply chain. At terminals and depots, product diversion and unauthorised blending can occur when oversight is lax or meters are bypassed. During transport, crosscontamination in tankers and the deliberate mixing of cheaper products into bulk loads are common (Mourched *et al.,* 2024). At retail, forecourt tanks with poor turnover, damaged floating suction pipes, or shared lines between products create opportunities for accidental and intentional mixing. Informal markets amplify the problem: jerrycans and local distributors may mix locally to meet demand or increase margin; clandestine ―reconditioning‖ of used oil is another facet (Nrior *et al.,* 2018). There are technical tricks too adding low levels of solvents to adjust viscosity or masking odour that can hide adulteration from casual inspection. Several field reviews and industry studies map these vulnerabilities and show that governance, logistics, and local market structure shape the specific methods used.

1.2.4.3 Detection Challenges in Local Markets.

Detecting adulteration reliably at the point of sale is difficult for three linked reasons: the sensitivity limits of simple tests, the intermittent nature of sampling, and the scarcity of advanced laboratory capacity. Common on-site checks — density, flash point, and basic distillation cuts — are useful for gross adulteration but can miss lowlevel blends that still harm engines over time (Wekalao *et al.,* 2024). Recent controlled studies found that many physicochemical parameters remain inside specification until adulterant content passes roughly the 15–20% mark, meaning lowlevel fraud can persist undetected by routine checks. Advanced tools (GC-MS, FTIR, NMR, or portable micro-GC devices) can detect and quantify adulterants at much lower levels and identify their chemical class, but they are more expensive and require trained operators and a laboratory chain of custody (Nrior *et al.,* 2018). Sensor arrays, rapid µGC devices, and supervised machine-learning classifiers show promise for field deployment, yet wide adoption is limited by cost, maintenance needs, and the institutional capacity to act on results. In short, the tests exist; scaling them into routine enforcement and into the hands of forecourt inspectors is the bottleneck.

1.2.4.4 Case Studies of Adulteration and Consequences.

Concrete local studies put numbers and human stories behind the technical claims. Field surveys in Nigerian towns and comparative studies in Ghana repeatedly document off-spec samples at retail points and link them to operational failures (Udeagbara *et al.,* 2014). In one regional assessment, samples with apparent kerosene blends produced lower cetane indices and reduced calorific values, coinciding with reports from fleet operators of increased fuel consumption and black smoke. In coastal and mining areas, researchers found that poor storage and distribution practices plus deliberate blending produced higher levels of basic sediment and water and greater particulate emissions when used in diesel engines (Nrior *et al.,* 2018). The operational consequences are immediate and measurable: higher fuel consumption to perform the same work, increased maintenance intervals, more frequent replacement of fuel filters and injectors, and higher emissions of particulates and hydrocarbons that harm local air quality and health (Wekalao *et al.,* 2024). Economically, these translate to added costs for households and firms, lost productivity from downtime, and wider public-health burdens when pollution rises. Case reports argue the point bluntly: the market can look functioning at the pump while, under the bonnet, machines are being gradually degraded (Udeagbara *et al.,* 2014).

1.2.5 Environmental and Health Implications of Poor Diesel Quality

Poor diesel quality changes a technical problem into a human one: what starts as altered chemistry at the refinery or in a tank becomes dirt in filters, smoke from tailpipes, and coughs in classrooms. Low-quality diesel whether from high water content, light-end dilution, or excessive sulphur reduces combustion efficiency and increases emissions of harmful gases and particles (Lucky, 2022). Those emissions do local damage (indoor and outdoor air pollution), and they add to regional greenhousegas totals that drive climate change. Global health authorities link ambient air pollution to millions of premature deaths each year, with fine particulate matter

(PM2.5) and combustion-related pollutants responsible for a large share of that burden (Nrior *et al.,* 2018). In places where generator use and diesel fleets are widespread, even modest declines in fuel quality raise population exposure in homes, workplaces, and along busy roads, which is why city-level fuel testing connects directly to public health assessments.

1.2.5.1 Emission of Sulphur Oxides, Particulates, and Greenhouse Gases

When diesel with high sulphur burns, it forms sulphur dioxide (SO_2) and downstream sulfates that contribute to particulate matter; these gases also irritate airways and aggravate asthma. Combustion of contaminated or poorly balanced diesel increases incomplete combustion products—soot and black carbon (primary particles) and secondary particles formed from gaseous precursors—so emissions of PM2.5 and PM10 rise compared with clean, well-specified fuel (Dibia *et al.,* 2025). Diesel combustion also produces nitrogen oxides (NOx) and carbon dioxide (CO_2); while CO_2 is a long-lived greenhouse gas from the carbon content of fuel, NOx participates in ozone formation and contributes to secondary particulate formation. The net climate effect is twofold: CO_2 adds to long-term warming, and black carbon acts as a short-lived climate forcer with strong regional impacts (Our Reporter, 2024). Measurement work shows that improvements in fuel quality, especially lowering sulphur and removing light-end diluents cut both particulate emissions and some toxic gases at the stack.

1.2.5.2 Links to Air Pollution and Climate Change

Diesel-related emissions sit at the intersection of immediate air quality and longerterm climate risk. Transport and distributed generation together make a significant share of national greenhouse-gas inventories; for the transport sector, CO_2 emissions represent a major slice of energy-related emissions worldwide. Local increases in soot and PM2.5 from poor diesel raise background pollution that interacts with other urban sources (industry, dust, domestic cooking) to push city concentrations above health benchmarks. At the same time, black carbon and some volatile organic compounds from diesel have climate effects on timescales that differ from CO_2 but are important for near-term warming and regional weather patterns (Lucky, 2022). In policy terms, reducing diesel sulphur and cutting adulteration not only improves local air quality but also strengthens short-term climate co-benefits by lowering black-carbon emissions, an attractive win for cities that need fast air-quality gains while working on longer-term CO_2 reductions.

1.2.5.3 Respiratory and Cardiovascular Health Risks

The health evidence linking diesel emissions to disease is robust and multifaceted. Fine particles from diesel penetrate deep into the lungs and enter the bloodstream, triggering inflammation, plaque instability, arrhythmias, and higher risks of ischemic heart disease, stroke, heart failure, and sudden death. Chronic exposure also increases the risk of chronic obstructive pulmonary disease (COPD) and is associated with worsened asthma control, especially in children. International agencies have classified diesel exhaust as carcinogenic to humans, based on consistent findings for lung cancer and suggestive links to bladder cancer, so long-term exposure to diesel particulates and associated organics carries cancer risk beyond acute respiratory and cardiac effects (IVWURIE, 2023). In urban communities where generators run close to homes or traffic corridors concentrate diesel exhaust, the combined burden appears as more hospital visits, lost school days, and productivity losses, effects that accumulate year after year.

1.2.5.4 Urban Air Quality Challenges in African Cities

African cities face amplified vulnerability: rapid urban growth, constrained public transport, unreliable grids, and high reliance on diesel generators and older vehicles mean that emissions per capital can be high even when absolute economic output is low. Local measurements in Nigerian cities, including Benin City, document elevated indoor and outdoor particulate levels and links to asthma and other respiratory problems, with generator exhaust often implicated in indoor exposures when units run near living or working spaces (Dibia *et al.,* 2025). Weak inspection systems, limited laboratory capacity, and informal fuel markets make widespread, routine checks rare; adulteration and storage problems (water ingress, rust, cross-contamination) further degrade fuel after it leaves refineries (Fasasi, 2024). The result is an uneven patchwork: national standards may exist on paper and regional limits may be set by ECOWAS or similar bodies, but what citizens breathe at the pump or in their generator room depends on local supply-chain integrity. Targeted city-level testing of fuel parameters (flash point, distillation, BSW, density, calorific value) therefore provides actionable data to identify hotspots, prioritize inspections, and reduce immediate exposure in high-risk neighborhoods.

1.2.5.5 What this Means for Policy and Practice

The science makes a practical prescription: reduce the pollutants at the point of fuel supply and you cut exposures at the point of human contact. That requires combining better fuel specifications and tighter enforcement with pragmatic local measures regular sampling, forecourt tank maintenance, safe generator siting, and communication to buyers about visible signs of poor fuel. Regional moves to lower allowable sulphur and to harmonize standards create an enabling framework, but enforcement and supply-chain integrity determine outcomes on the ground. For busy, generator-dependent cities like Benin City, linking laboratory testing of diesel quality to health surveillance and targeted inspections offers a short, direct route to lowering disease risk while broader energy transitions evolve. In practical terms, fuel quality checks are not only technical exercises but preventive public-health actions: they reveal hazards early and give regulators, businesses, and citizens the evidence they need to act.

CHAPTER TWO

MATERIALS AND METHODS

2.1 MATERIALS

2.1.1 Apparatus

- Clean, airtight, amber-colored glass bottles (3 L capacity)
- Pensky–Martens closed cup tester
- Stanhope-seta Distillation unit
- Test cup with tightly closed lid, thermometer, and ignition device
- Heating chamber with regulated heating rate
- Round-bottom flask (100 mL sample capacity)
- Condenser
- Thermometer
- Regulated heating source
- Calibrated centrifuge tubes (100 mL capacity)
- Koehler Laboratory centrifuge (capable of 1,500 rpm)
- Balancing accessories for centrifuge tubes
- 500 mL glass cylinder
- Hydrometer (appropriate range for diesel density)
- Lovibond Comparator

2.1.2 Reagents

- Consumer-grade diesel fuel (collected samples)
- Toluene (analytical grade)

- Isopropyl alcohol (analytical grade)

2.2 METHODOLOGY

2.2.1 Study Area

This research was conducted in Benin City, the capital of Edo State, Nigeria, situated between latitude 6°20′N and longitude 5°37′E. The city is a major administrative and commercial hub in southern Nigeria, with a high dependence on diesel for transportation, power generation, and industrial activities. Four local government areas (LGAs) were selected for diesel sampling to ensure coverage of different parts of the city. Oredo LGA, located at the heart of Benin City, lies approximately between latitude 6°20′N and longitude 5°37′E, and serves as the political and commercial core of the state. Egor LGA, positioned northwest of Oredo, falls within latitude 6°23′N and longitude 5°35′E, and is characterized by dense residential areas and small businesses heavily reliant on generators. Ikpoba-Okha LGA, situated on the eastern side of the city, lies around latitude 6°21′N and longitude 5°40′E, and is notable for its mix of residential, industrial, and agricultural activities. Ovia NorthEast LGA, covering the western and peri-urban outskirts of Benin City, is geographically located at latitude 6°25′N and longitude 5°25′E and is strategically important as a link between the city and surrounding rural communities. Together, these four LGAs reflect the urban, peri-urban, and industrial diversity of Benin City, making them suitable for assessing diesel fuel quality across different consumption environments.

2.2.2 Sample Collection

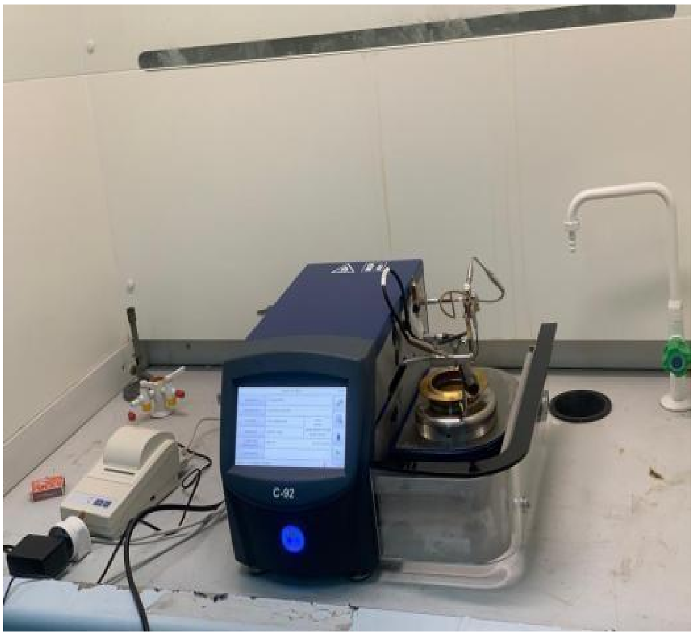
Diesel samples were collected from four selected local government areas (LGAs) within Benin City, namely Oredo, Egor, Ikpoba-Okha, and Ovia North-East, to provide a representative assessment of the quality of diesel sold across the city. A total of five samples from each LGA. An aggregate sample was made for each LGAs, making a total of four aggregate samples. Each sample was collected in a volume of one litre, using clean, airtight, amber-colored

2.2.3 Physicochemical Analysis

2.2.3.1 Flash Point Determination (ASTM D93)

The flash point of the diesel samples was determined using the Pensky-Martens closed cup tester in accordance with ASTM D93. Each test cup was filled with the sample to the marked level, and the lid assembly containing the ignition source and thermometer was secured. The sample was stirred continuously and heated at a controlled rate of 5–6 °C per minute. At set temperature intervals, the ignition source was applied above the liquid surface until a distinct flash was observed, which was recorded as the flash point. The procedure was carried out in triplicate, and the average flash point values obtained were compared with the minimum standard of 66

°C for diesel fuel.



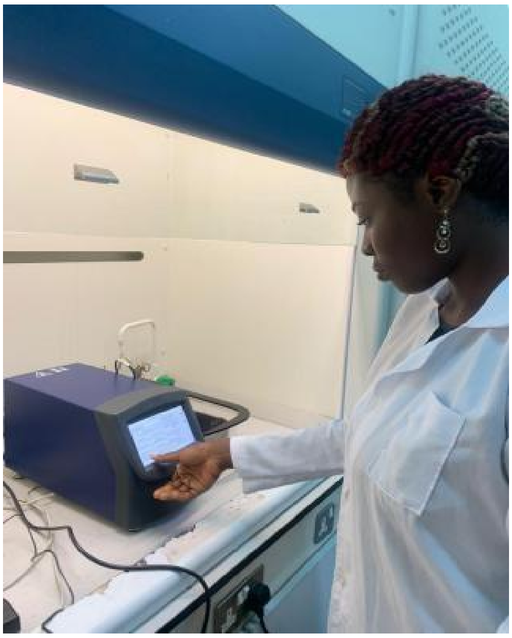


Figure 2.1: (a) Pensky-Martens closed cup tester for flash point determination (b) a view of when I was carrying out the determination

2.2.3.2 Distillation Characteristics (ASTM D86)

The distillation characteristics of the diesel samples were determined using the ASTM D86 method. A 100 mL portion of each sample was transferred into a clean roundbottom flask fitted with a calibrated thermometer and connected to a standard distillation apparatus. The sample was heated gradually under controlled conditions, and the vapors formed were condensed and collected in a graduated receiver. Temperatures were recorded at specific collected volumes of 5 mL, 10 mL, 30 mL, 50 mL, 70 mL, 90 mL, and 95 mL, along with the initial boiling point, the final boiling point, and the temperatures corresponding to 10%, 50%, and 90% recovery. The process was continued until only a small residue remained in the flask, and the recorded data were used to establish the distillation profile of the diesel fuel.

Figure 2.2: (a) Stanhope-seta Distillation unit for determination of distillation characteristics (b) a view of when I was carrying out the determination

2.2.3.3 Basic Sediment and Water (BSW) (ASTM D1796)

The Basic Sediment and Water (BSW) content of the diesel samples was determined using the ASTM D4007 centrifuge method. A 50 mL portion of each sample was measured into a clean centrifuge tube, and an equal volume of toluene reagent was added. The tubes were capped, shaken vigorously to achieve proper mixing, and then placed in a centrifuge operated at about 3000 rpm for 15 minutes. After centrifugation, three layers were observed, with clear diesel at the top, water in the middle, and sediment at the bottom. The combined volume of water and sediment at the bottom of the tube was read directly and expressed as a percentage of the total sample volume. The procedure was repeated in duplicate, and the mean BSW values were compared with the acceptable limits for diesel fuel quality.

Figure 2.3: (a) koehler Laboratory Centrifuge for determination of BSW (b) a view of when I was carrying out the determination

2.2.3.4 Density Measurement (ASTM D1298)

The density of the diesel samples was determined following ASTM D1298 using the hydrometer method. Each sample was poured into a clean 500 mL glass cylinder and placed in a water bath until the temperature stabilized at 15 °C. A clean, dry hydrometer of the appropriate range was gently lowered into the sample, ensuring it floated freely without touching the cylinder walls. The density reading was taken at the meniscus level, and the sample temperature was recorded simultaneously using a thermometer. The observed density values were corrected to the reference temperature of 15 °C with the ASTM D1250 conversion tables. Each measurement was performed in triplicate, and the average density was calculated and reported.

Figure 2.3: Set-up for Density determination using an hydrometer method

2.2.3.5 Colour Determination (ASTM D1500)

The colour of the diesel samples was determined using the ASTM D1500 method. A clean ASTM colorimeter was calibrated according to the manufacturer's instructions, and a matched glass cell filled with distilled water was placed in the reference slot to establish the zero baselines. Each diesel sample was then poured into a clean, matched glass cell and placed in the test chamber of the colorimeter. Light was passed through the sample, and the colour was visually compared with the ASTM colour scale ranging from 0.5 to 8.0. The corresponding ASTM colour values were recorded and compared with standard diesel specifications to assess the quality of the fuel.

Figure 2.3: Set-up for colour determination using a Lovibond Comparator

CHAPTER THREE

RESULTS AND DISCUSSION

Table 3.1: Distillation Characteristics of Diesel Samples from Selected LGAs in Benin City

Sample	IBP (°C)	5 mL	10 mL	30 mL	50 mL	70 mL	90 mL	95 mL	FBP (°C)	Final Volume (mL)
Egor	160	200	210	254	278	303	330	355	356	98
Ovia North-East	165	205	215	260	280	306	338	355	356	98
Oredo	160	203	210	255	276	300	330	354	355	97
Ikpoba-Okha	160	205	212	250	275	300	325	350	355	98

ASTM permissible limit = (160–370 °C),

Table 3.1 presents the distillation characteristics of the diesel samples collected from the four LGAs in Benin City. The initial boiling point (IBP) of the samples ranged from 160 °C to 165 °C, while the final boiling point (FBP) was between 355 °C and 356 °C. The distillation profile of the samples closely aligns with the typical distillation range of automotive diesel (160–370 °C), indicating that the samples are generally within specification. The progressive increase in temperature with higher volume fractions shows a uniform volatility distribution, which is essential for balanced ignition quality, combustion efficiency, and emission control. However, Ovia North-East showed slightly higher mid-range distillation temperatures (215 °C at 10 mL and 260 °C at 30 mL) compared to the other locations, suggesting a slightly heavier fraction in its composition. The similarity of the final boiling points across all samples indicates that the samples share a common upper distillation limit, reflecting consistency in refining or blending practices. A final recovered volume of 97–98 mL further supports the completeness of the distillation process with minimal losses. These findings confirm that the diesel supplied across the study area exhibits consistent distillation behavior, with minor variations that could be linked to regional supply chains or blending differences.

Table 3.2: Density of Diesel Samples at 24 °C and Corrected to 15 °C

Sample	**Density at 24 °C (g/mL)**	**Corrected Density at 15 °C (g/mL)**
Egor	0.839	0.845
Ovia North-East	0.841	0.847
Oredo	0.828	0.834
Ikpoba-Okha	0.834	0.840

ASTM permissible limit = 0.82-0.85g/mL at 15°C

The density results (Table 3.2) provide further insight into the quality of the diesel samples. At 24 °C, densities ranged between 0.828 g/mL (Oredo) and 0.841 g/mL (Ovia North-East), with corrected values at 15 °C falling between 0.834 and 0.847 g/mL. These values fall within the acceptable density range for diesel fuel (0.82–0.85 g/mL at 15 °C), which is specified by ASTM and EN standards. Density is an important indicator of energy content per unit volume, as higher density fuels generally provide more energy per liter, while lower density fuels may reduce engine efficiency. The slightly lower density recorded for Oredo (0.834 g/mL at 15 °C) suggests the presence of lighter fractions, which could improve volatility but might compromise energy yield and storage stability. Conversely, the higher density observed in Ovia North-East (0.847 g/mL at 15 °C) suggests a heavier blend that could increase power output per unit volume but may also produce more particulates during combustion. The narrow spread of density values across the samples indicates a relatively consistent supply, but the small variations may influence performance characteristics in different localities.

Table 3.3: ASTM Color Values of Diesel Samples

Sample	**ASTM Color Value**
Egor	1.5
Ovia North-East	1.0
Oredo	1.0
Ikpoba-Okha	1.5

Color, determined using the ASTM color scale (Table 3.3), ranged from 1.0 to 1.5 across the samples. These values fall within the acceptable limits for automotive diesel, which typically range from water-white (0.5) to light yellow (3.0). Color is not a direct indicator of fuel performance, but it is widely used as a quality check for contamination, degradation, or blending inconsistencies. Lighter colors, such as the 1.0 values observed for Ovia North-East and Oredo, often suggest fresher fuel with fewer heavy fractions, whereas the slightly darker values of 1.5 in Egor and IkpobaOkha may indicate minor aging effects, trace impurities, or blending with heavier stock. Since all values remain well within acceptable standards, the results suggest that the fuels are visually clean and free from significant contamination. Nevertheless, the slight variation in color supports the findings from density and distillation that some local differences exist in supply or storage practices.

Table 3.4: Basic Sediment and Water (BSW) Content of Diesel Samples

Sample	**BSW (%)**
Egor	0.05
Ovia North-East	0.05
Oredo	0.05
Ikpoba-Okha	0.05

ASTM permissible limit = 0.1%

The basic sediment and water (BSW) content (Table 3.4) was uniform across all four locations at 0.05%. This low level of BSW is well below the typical threshold of 0.1% set by international standards and indicates that the diesel samples were free from significant amounts of particulate matter or water contamination. The presence of sediment or water in diesel fuel can cause filter plugging, injector fouling, and corrosion, leading to reduced engine performance and increased maintenance costs. The consistently low BSW values across the samples suggest good handling and storage practices by suppliers in the study area. It also confirms that the observed variations in distillation, density, or color are unlikely to be caused by contamination during storage, but rather reflect intrinsic differences in the fuel blends supplied to different LGAs.

Table 3.5: Flash Point of Diesel Samples from Selected LGAs in Benin City

Sample	**Flash Point (°C)**
Egor	< 52
Ovia North-East	< 52
Oredo	< 52
Ikpoba-Okha	< 52

ASTM permissible limit = 52 °C

Flash point measurements (Table 3.5) showed that all the diesel samples ignited at temperatures below 52 °C. This result is significant because the standard minimum flash point for automotive diesel is typically set at 52 °C by ASTM D975 and EN 590 specifications. A flash point below this threshold indicates the presence of excessive light fractions, such as gasoline-range hydrocarbons, which reduce storage safety by increasing volatility and fire hazards. While the samples still exhibited normal distillation ranges, their substandard flash points suggest possible contamination during distribution or deliberate blending practices aimed at improving ignition quality. However, such blending compromises safety and regulatory compliance. The consistently low flash point across all four LGAs indicates that the issue is systemic rather than isolated, raising concerns about the quality control of diesel supplied to Benin City. This observation underscores the need for stricter monitoring of local fuel supply chains to prevent safety risks and ensure compliance with established standards.

CONCLUSION

The analysis of diesel samples from four LGAs in Benin City revealed generally consistent physicochemical properties, but with notable deviations that affect quality and compliance with international standards. Distillation results confirmed that all samples fall within the expected boiling range for automotive diesel, reflecting proper refining and blending practices. Density values also aligned with ASTM and EN limits, though slight differences across locations suggest variations in energy content and combustion performance. Color values, measured on the ASTM scale, remained within acceptable limits, indicating fuels that were visually clean and relatively free from degradation or contamination, while the consistently low sediment and water content (0.05%) confirmed proper handling and storage. However, the flash point results, which showed ignition below 52 °C for all samples, raise a significant safety concern, as they fall short of the minimum standard required for automotive diesel. This suggests the presence of lighter fractions, likely due to contamination or blending, which compromises storage safety and increases the risk of fire hazards. Overall, while the diesel supplied in Benin City generally meets performance-related parameters, the consistently low flash point highlights a systemic quality control issue that requires regulatory enforcement and improved monitoring of local supply chains.

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