

# An Investigation into the Quality of Distillate Diesel Fuel at Selected Service Stations in Freetown's Western Area

Kanneh Umaru<sup>1,\*</sup>, Turay Issa<sup>1</sup>

## Abstract

*As a critical energy source for global transport and industry, diesel fuel quality is of paramount importance. This study evaluates and compares the quality of diesel fuel samples by analyzing key parameters: sulfur content, density, cetane index, and kinematic viscosity. The properties of diesel fuel samples from six (6) Fuel Stations of various Oil Marketing Companies (OMCs) are compared with National Technical specifications limits of the Sierra Leone Standards Bureau, the only established National Quality Unfractured responsible for fuel quality. Six diesel samples were taken from different filling stations in the Western Area of Freetown, one from each station. Sampling was carried out using clean, unused polyethylene terephthalate (PET) bottles with screw caps. Before collecting each sample, a small volume of the same diesel was used to rinse the bottle to limit contamination. All subsequent analyses followed the relevant American Society for Testing and Materials (ASTM) and Institute of Petroleum (IP) standard test methods. The resulting values for each parameter were then benchmarked against the national Technical Specification limits for diesel fuel issued by the Sierra Leone Standards Bureau (SLSB), the state-mandated authority for fuel quality standards. All sampled fuels met minimum regulatory requirements, indicating effective baseline quality control in the retail market. Despite universal compliance, substantial variations were observed across all parameters, with sulfur content showing the highest variability (CV = 74.56%). While most fuel samples complied with the minimum standards for kinematic viscosity, density, and flash point, a significant finding was universal compliance with the sulfur limit. All sampled stations supplied diesel with sulfur content below the maximum permitted threshold of 1000 ppm (0.10% by weight). However, to ensure consistent quality, the findings emphasize that vigilance must extend across the full fuel supply chain, from import terminals to retail fuel pumps.*

**Keywords:** Cetane index, diesel fuel quality, kinematic viscosity, sierra leone fuel standards, sulfur content

## INTRODUCTION

This chapter establishes the essential foundation for the investigation. It delineates the study's background, articulates the core problem, justifies its necessity, and states the primary aim, specific objectives, and corresponding research questions.

### \*Author for Correspondence

Kanneh Umaru  
E-mail: [umaru.kanneh@njala.edu.sl](mailto:umaru.kanneh@njala.edu.sl)

<sup>1</sup>Lecturer, Department of Chemistry, Njala University, Sierra Leone.

Received Date: January 15, 2026  
Accepted Date: January 23, 2026  
Published Date: February 19, 2026

**Citation:** Kanneh Umaru, Turay Issa. An Investigation into the Quality of Distillate Diesel Fuel at Selected Service Stations in Freetown's Western Area. *Journal of Petroleum Engineering & Technology*. 2026; 16(1): 1–14p.

The period since the Industrial Revolution has been characterized by a rapid rise in fossil fuel consumption, with the automotive sector becoming a primary consumer globally. In developing nations such as Ghana, where automobile use is projected to grow significantly, this trend drives increased demand for gasoline and diesel. To meet its transport and energy needs, Ghana relies heavily on fuel imports due to insufficient domestic refining capacity. However, reports, including a 2016 investigation by Public Eye, indicate that weak

regulatory and monitoring standards – both for imports and locally handled fuel – have allowed poor-quality or illegal petroleum products to enter the market. Notably, the report found diesel with sulfur levels up to 273 times higher than European limits, even though it technically complied with Ghana's then-permissible standard of 3,000 ppm. A report by the Swiss NGO Public Eye drew widespread attention in Ghana to the poor quality of some imported fuels. Low-quality diesel can contain elevated levels of toxic components, and their emissions are associated with serious impacts on human health and the environment. Epidemiological and clinical studies link exposure to diesel exhaust, especially from high-sulfur or otherwise sub-standard fuels to respiratory conditions such as worsened asthma, allergic reactions, and bronchitis, as well as to increased risks of cardiovascular disease, lung cancer, and early mortality. Poor fuel quality also impairs engine performance and durability, imposing additional costs on vehicle owners. In response to these concerns, Ghana has progressively tightened its fuel-quality rules. In 2013, the country set a maximum sulfur content of 3,000 ppm for diesel imports, a limit that most suppliers respected. Subsequently, the National Petroleum Authority (NPA) introduced more stringent requirements, directing that from 1 July 2017 all gasoline and diesel brought into the country must have a sulfur content not exceeding 0.005% by weight (50 ppm).

Diesel is a major fuel derived from crude oil distillation, primarily used in transportation, agriculture, and industrial machinery. As a distillate petroleum product, diesel's quality significantly impacts engine performance, environmental emissions, and operational efficiency. The assessment of diesel quality involves a comprehensive analysis of its physical and chemical properties, such as cetane number, sulfur content, density, viscosity, and distillation range. Comprehending these parameters is essential for guaranteeing optimal fuel performance and adherence to environmental regulations [1].

Recent studies have highlighted concerns regarding the quality of diesel fuel in various African countries. Research in Ghana found that while most samples met density and flashpoint standards, all exceeded the maximum sulfur content limit [2]. Similarly, a study in Freetown revealed that 62.5% of diesel samples contained excessive sulfur levels [3]. In Nigeria, laboratory analysis of diesel samples showed that some failed to meet the minimum total recovery standard, indicating adulteration [4]. Fuel adulteration was also investigated in Kenya, where gasoline and diesel samples from selected stations were tested against national standards [5]. These findings underscore the importance of regular quality assessments and stricter enforcement of fuel standards to ensure compliance with regulations, reduce environmental impact, and maintain vehicle performance across the continent.

The quality of diesel fuel is a significant concern due to its impact on engine performance, health, and the environment. Studies in Ghana, Nigeria, and Greece have revealed variations in fuel properties among different oil marketers [6]. While some parameters like density often meet national standards, others such as sulfur content frequently exceed acceptable limits [7]. Fuel adulteration is a common problem, with one study in Athens finding over 40% of samples adulterated with cheaper diesel [8]. This issue is not limited to a single country and has prompted calls for uniform fuel quality monitoring systems [9]. Various methods, including UV/VIS spectrophotometry and American Standard for Testing and Materials (ASTM) standard tests, are employed to assess fuel quality parameters such as sulfur content, density, flashpoint, and viscosity [10].

The quality of diesel fuel is a significant concern due to its impact on engine performance, health, and the environment. Studies across different regions have assessed diesel quality parameters such as density, flash point, sulfur content, and viscosity [11]. These studies revealed variations in fuel properties among different suppliers, with some samples failing to meet established standards. A common issue identified was high sulfur content, exceeding regulatory limits [6, 19–20]. Additionally, adulteration of diesel fuel was detected in some samples, potentially compromising engine performance [12]. The research highlights the need for stricter quality control measures along the fuel distribution chain to ensure compliance with national and international standards, protect consumers, and minimize environmental impact [13].

The quality of diesel fuel has direct implications for engine efficiency, emissions, and maintenance costs. Variations in refining processes, crude oil sources, and the use of additives can lead to differences in fuel quality. Despite stringent regulatory standards, inconsistencies in diesel quality still pose challenges for consumers and industries. This work aims to critically assess the factors affecting diesel quality, the methodologies used in its assessment, and the implications of these factors on performance and environmental impact.

Recent studies have highlighted concerns about diesel fuel quality in various African countries. Research in Ghana found that while most samples met density and flashpoint standards, all exceeded the 50 ppm sulfur content limit [6, 9]. Similar issues were observed in Nigeria, where some diesel samples failed to meet minimum total recovery standards, indicating adulteration [14]. Fuel quality problems can lead to reduced engine performance, increased emissions, and environmental issues [9]. Adulteration may occur due to long storage periods or the illegal addition of foreign substances [11–12]. These studies emphasize the need for stricter quality control measures along the fuel distribution chain and suggest that governments should ensure oil marketing companies adhere to acceptable standards [9]. Regular monitoring and testing of fuel properties are crucial to maintain fuel quality and protect consumers and the environment.

The infrastructure for petroleum product distribution in Freetown includes the main fuel depots located at the port, numerous fuel stations across the city, and a network of distributors. These facilities are responsible for the storage, handling, and retailing of diesel fuel. The quality of diesel fuel is a concern due to potential contamination and degradation during storage and transportation, as well as the varying standards among different suppliers. Challenges in infrastructure, such as aging storage facilities and inadequate maintenance, can lead to issues like fuel adulteration and contamination, affecting the overall quality of diesel available to consumers.

The regulatory framework governing fuel quality in Freetown is managed by several government bodies, including the Petroleum Regulatory Agency (PRA) and the Sierra Leone Standards Bureau (SLSB). These agencies are responsible for setting and enforcing fuel quality standards, conducting periodic inspections, and ensuring compliance with national and international regulations.

In practice, regulatory enforcement encounters difficulties due to resource limitations and underdeveloped infrastructure. There is a need for stringent monitoring and quality control measures to prevent the distribution of substandard diesel, which can negatively affect engine performance and contribute to environmental pollution.

The city contends with numerous social and economic difficulties, such as widespread poverty, underdeveloped infrastructure, and scarce availability of basic services. The quality of diesel fuel directly impacts public health, as poor-quality diesel with high sulfur content and other impurities contributes to air pollution, which poses significant health risks, particularly respiratory diseases.

Public awareness of fuel quality issues is relatively low, necessitating education and advocacy to promote the use of high-quality diesel and adherence to regulatory standards.

Freetown, Sierra Leone, presents a unique study area for assessing the quality of distillates, particularly diesel fuel, due to its geographical, climatic, economic, and regulatory characteristics. The city's reliance on diesel for transportation, electricity generation, and industrial activities, coupled with challenges in infrastructure and regulation, makes it a critical area for studying diesel quality and its implications on engine performance, environmental health, and socio-economic development. This study will provide valuable insights into the current state of diesel fuel quality in Freetown and contribute to the broader discourse on energy quality and sustainability in developing urban centers.

## **OBJECTIVES**

### **Aim**

Assessment of six fuel station on the quality of distillates petroleum product diesel in Freetown.

---

---

### Specific Objectives

- To evaluate the physical and chemical properties that determine diesel quality.
- To analyze the impact of refining processes and crude oil characteristics on diesel quality.
- To assess the effectiveness of current testing methodologies and standards in ensuring diesel quality.

### Description of Study Area

The capital city of Sierra Leone, Freetown, occupies a coastal position on the Atlantic Ocean in West Africa. It is situated on the Sierra Leone Peninsula and is characterized by its unique topography, which includes a coastal plain, rolling hills, and mountainous regions. The city spans approximately 137 square kilometers and is bordered by the Atlantic Ocean to the west and mountains to the east, providing a mix of urban, peri-urban, and rural landscapes.

Freetown's climate is classified as tropical monsoon, featuring pronounced wet and dry seasonal variations. Between May and October, the region experiences its rainy period, marked by intense downpours and mugginess. This is followed by a drier, cooler stretch from November through April. This climate impacts fuel quality, particularly in storage and distribution, as high humidity and temperature variations can lead to condensation and contamination in fuel storage tanks. The city's proximity to the ocean and its climatic conditions also influences air quality, with vehicular emissions and fuel quality playing a significant role in the overall environmental health of the area.

Freetown functions as Sierra Leone's primary center for economic, financial, and industrial activity. The city is home to the country's major port, the Queen Elizabeth II Quay, which plays a crucial role in the importation and distribution of petroleum products, including diesel fuel. The port's facilities are critical for handling, storing, and distributing petroleum products to other parts of the country and the sub region. Freetown's economy is diverse, encompassing trade, transportation, services, and light manufacturing. Diesel fuel is a vital commodity in the city, powering transportation (buses, taxis, and trucks), generating electricity, and supporting small-scale industries and businesses reliant on diesel-powered generators due to the unreliable electricity supply.

Freetown's transportation network is heavily dependent on diesel fuel. Public transit in the city is chiefly provided by minibuses, taxis, and motorcycles, with diesel fuel being the dominant energy source for this fleet. Additionally, the city's extensive use of diesel-powered generators for electricity generation, due to frequent power outages, further increases diesel consumption.

Diesel usage in Freetown is critical for both public transportation and private use, highlighting the importance of ensuring high-quality diesel fuel to maintain engine efficiency, reduce emissions, and lower maintenance costs. Figure 1: Freetown's population is diverse, with a mix of ethnic groups and a growing urban population.

### STUDY DESIGN

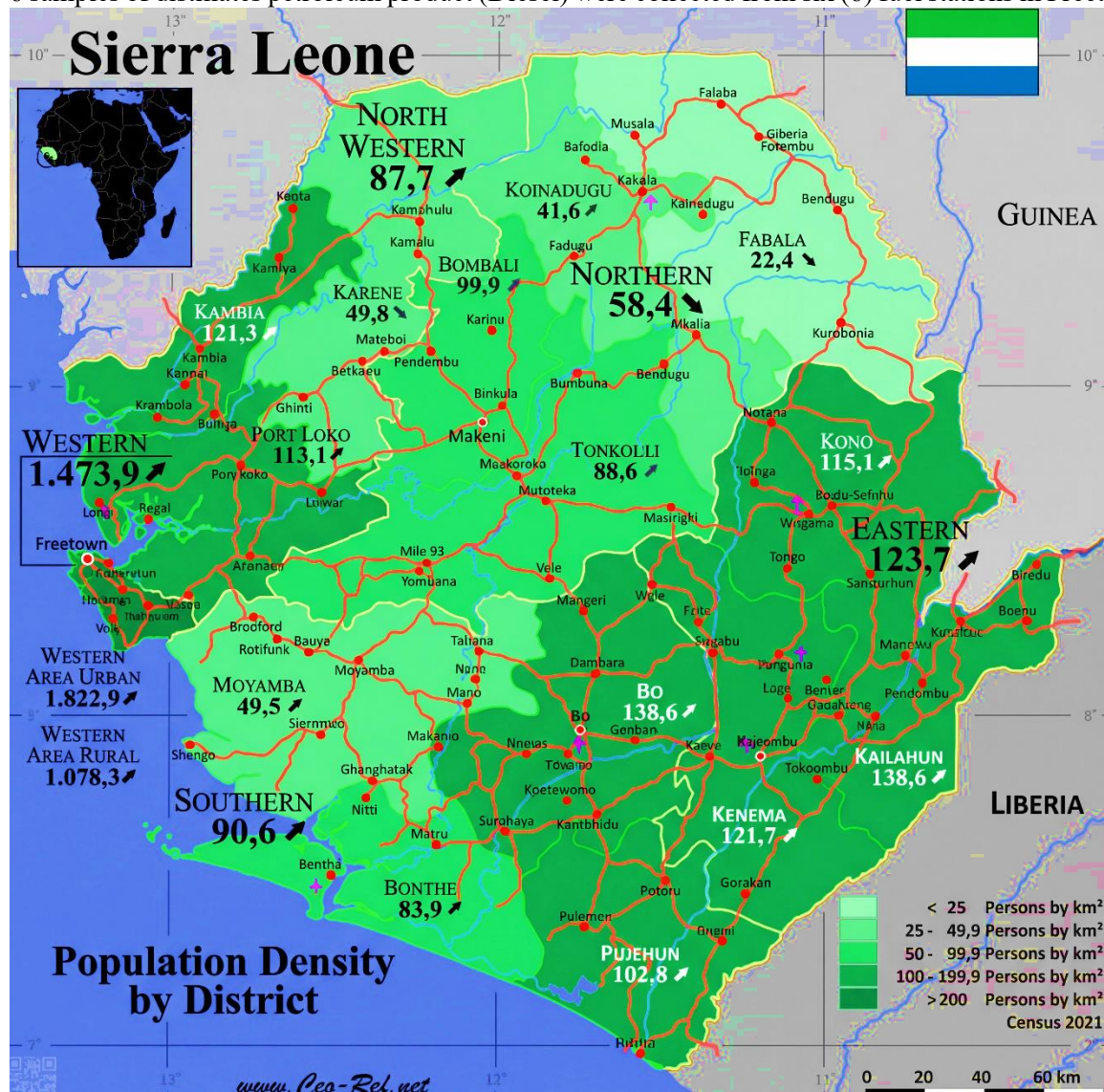
This study was designed as an experimental laboratory-based analytical investigation aimed at assessing the quality compliance of imported diesel samples. A cross-sectional sampling approach was adopted, whereby representative samples were collected from selected fuel stations within the study period. Standardized test methods were employed to ensure accuracy, reproducibility, and regulatory conformity of analytical results. The study framework aligns with established petroleum product quality control protocols and conformity assessment procedures.

### MATERIALS AND METHODOLOGY

#### Materials

The study utilized British (Stanhope-Seta) and Japan (Horiba) made equipment from the Petroleum Products Testing Laboratory, Sierra Leone Standards Bureau (SLSB), National Quality Infrastructure of the Republic of Sierra Leone. The Petroleum Products Testing Laboratory is an integral component of conformity assessment system of the SLSB. This Lab carries out third party quality assurance tests

on petroleum products and Oil-based lubricants, using standard test methods and relevant product standards to validate product compliance. Analytical grade (AnalaR AR) reagents were used, sourced from Fisher Scientific and Horiba, Japan. There are two types of analyses carried out before authorizing or refusing the discharge of the product (s) imported. In broad perspectives, the lab offers two types of analyses namely Import Clearance and Recertification analyses. During the period of May to July 2024; 6 samples of distillates petroleum product (Diesel) were collected from six (6) fuel stations in Freetown.





**Figure 1.** Map of Sierra Leone showing the study site.

## Methods

This research analyzed and compared the density, kinematic viscosity, Flash Point, and sulfur content.

### Sample Collection and Sample Analysis

Six Diesel fuels samples were obtained from six (6) filling stations, from West Area of Freetown using a new Polyethylene terephthalate (PET) plastic bottle with lids. Before collecting the sample, the bottle was rinsed with a small quantity of the same diesel to remove any potential contaminants. This was done twice at every sampling point. The samples were then stored under room conditions in the laboratory for all the analyses.

### Laboratory Analysis

Fuel quality parameters were analyzed using ASTM [15] and IP standard methods. Results were benchmarked against the requisite national Technical Specifications for diesel set by the Sierra Leone Standards Bureau (SLSB).

### Density

Prior to analysis, experimentally derived correction factors, established through laboratory calibration for each fuel type, were applied to the instrument. For testing, a 5ml aliquot of each sample was gently introduced into the density meter's compartment using a slender suction tube to prevent bubble formation. Fuel sample densities were determined according to the ASTM D4052–18a standard. This method measures a sample's mass per unit volume under controlled conditions of 15°C and 1 atmosphere, with results reported in kilograms per liter (kg/l). A Density Meter Analyzer (DMA 35) was used for the measurements.

The density for each sample was then automatically determined, with the result displayed on the instrument's screen.

### Kinematic Viscosity

The kinematic viscosity of the samples was measured following the ASTM D445-18 standard method. A Stanhope-Seta viscometer bath, containing the required thermal fluid, was used for the tests. The kinematic viscosity ( $\nu$ ) at 37.8°C was calculated using Equation below, which multiplies the measured flow time ( $t$ ) by the instrument's calibration constant. The result is reported in centistokes (cSt), the standard SI unit for this measurement.

$k_v @ 37.8^\circ\text{C} = t \times \text{c.f.}$

t = flow time, s

c.f.= Hagenbach correction factor,

when  $t < 400$  s, it should be corrected according to the manual.

When  $t > 400$  s, c.f = 0.

### **Sulphur Content**

The sulfur content of the gasoline and diesel fuels was determined using X-ray Fluorescence Sulfur in-oil (XRF) analyzer SLFA-60. The process requires no pretreatment of samples before measurement. This was determined using the standard ASTM D4294–16e1 Test method. Approximately a 2–4 mL volume of diesel sample is transferred using a 5-ml syringe and needle into disposable sample cell, lined with cell window (thin polyethylene plastic).

The cell windows are the protective shields, made to protect the equipment from possible leakage. The process is automated, calculating an average sulfur content and displaying the results in a printed report.. Before the sample is analyzed, a certified reference material (a standard) is first run in order to ascertain the calibration and the working condition of the equipment.

### **Flash Point by Pensky Martens Closed Cup Tester**

The Flash Point, determined according to the standard ASTM D93 test method, is a key safety parameter. It measures a sample's propensity to form an ignitable mixture with air under controlled conditions and is used in safety and transportation regulations to classify flammable materials. It is important to note that it represents only one of several properties required for a comprehensive flammability hazard assessment

### **Cetane Index**

Cetane Index serves as an alternative to the cetane number for diesel fuel. It is derived from calculations using the fuel's density and its distillation range, determined by the ASTM D86 standard test. Cetane number is a key indicator of diesel fuel's performance and combustion quality. The higher this number, the more efficiently and smoothly the fuel ignites and burns in a vehicle's engine. In its function, the cetane number is comparable to an octane rating for gasoline, as both are standardized benchmarks that rate the combustion characteristics of their respective fuels.

This cetane index was determined using the standard ASTM D 976 Test method.

## **RESULTS**

Physicochemical properties of diesel fuel samples from six fuel stations in Freetown are given in Table 1 These results were compared Sierra Leone Standards Bureau Technical Specifications.

This chapter presents a comprehensive analysis of the laboratory results obtained from the quality assessment of diesel fuel samples collected from six randomly selected fuel stations across the study area. The stations, designated as A, B, C, D, E, and F, were selected using systematic random sampling to ensure representative coverage of the retail fuel market.

The physicochemical parameters analyzed included Density at 15°C (ASTM D 4052), Sulphur Content (ASTM D4294), Flash Point (ASTM D93), Cetane Index (ASTM D976), and Kinematic Viscosity (ASTM D445). These specific parameters were chosen due to their fundamental significance in determining engine efficiency, influencing environmental emissions, and ensuring operational safety. The analysis was conducted following standardized ASTM test methods to ensure accuracy, reproducibility, and comparability with international fuel quality standards.

## **PRESENTATION OF RESULTS**

---

### Laboratory Analysis Results

The comprehensive laboratory analysis results for all six fuel stations are presented in Table 2. All tests were performed in triplicate using calibrated equipment following standard ASTM protocols, with the reported values representing the arithmetic mean of the three measurements.

**Table 1.** Showing the GPS coordinates at various sample sites.

Sample Label	Fuel Station	Coordinates
A	Conex New Road	Lat. N8°28'34.61412" Long. W13°11'44.718"
B	Conex Old Road	Lat. N8°28'34.65588" Long. W13°11'44.62584"
C	NP New Road	Lat. N8°28'31.12788" Long. W13°11'39.696"
D	Conex Aberdeen	Lat. N8°29'32.16588" Long. W13°17'45.70812"
E	NP Aberdeen	Lat. N8°29'32.95212" Long. W13°17'45.412"
F	NP Congo Cross	Lat. N8°29'16.9584" Long. W13°15'33.66972"

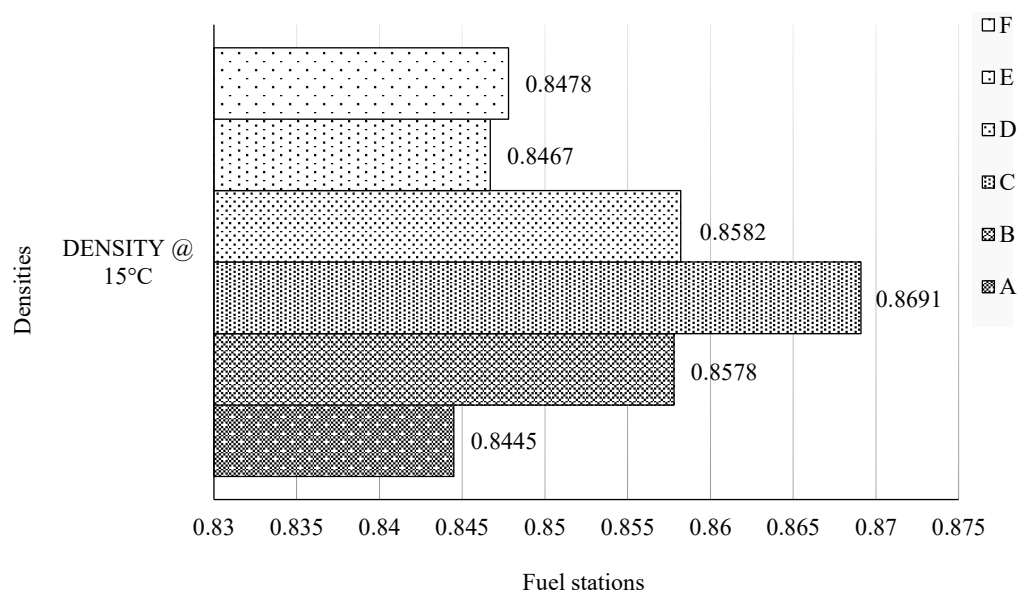
**Table 2.** Physicochemical properties of diesel fuel samples from different fuel stations.

Fuel Station	Parameter	Test Method	Units	Specification Limits	Result	Compliance Status
A	Density @ 15°C	ASTM D 4052	kg/L	0.8200 – 0.8750	0.8445	✓ Compliant
	Sulphur Content	ASTM D4294	%wt.	0.1000 max	0.0031	✓ Compliant
	Flash Point	ASTM D93	°C	>60.0 min	70.0	✓ Compliant
	Cetane Index	ASTM D976	-	45.0 min	47.0	✓ Compliant
	Kinematic Viscosity	ASTM D445	cSt	1.6 – 5.9	2.8	✓ Compliant
B	Density @ 15°C	ASTM D 4052	kg/L	0.8200 – 0.8750	0.8578	✓ Compliant
	Sulphur Content	ASTM D4294	%wt.	0.1000 max	0.0992	△ Borderline
	Flash Point	ASTM D93	°C	>60.0 min	65.0	✓ Compliant
	Cetane Index	ASTM D976	-	45.0 min	45.8	✓ Compliant
	Kinematic Viscosity	ASTM D445	cSt	1.6 – 5.9	3.0	✓ Compliant
C	Density @ 15°C	ASTM D 4052	kg/L	0.8200 – 0.8750	0.8691	✓ Compliant
	Sulphur Content	ASTM D4294	%wt.	0.1000 max	0.0720	✓ Compliant
	Flash Point	ASTM D93	°C	>60.0 min	75.0	✓ Compliant
	Cetane Index	ASTM D976	-	45.0 min	49.0	✓ Compliant
	Kinematic Viscosity	ASTM D445	cSt	1.6 – 5.9	5.2	✓ Compliant
D	Density @ 15°C	ASTM D 4052	kg/L	0.8200 – 0.8750	0.8582	✓ Compliant
	Sulphur Content	ASTM D4294	%wt.	0.1000 max	0.0672	✓ Compliant
	Flash Point	ASTM D93	°C	>60.0 min	80.0	✓ Compliant
	Cetane Index	ASTM D976	-	45.0 min	46.5	✓ Compliant
	Kinematic Viscosity	ASTM D445	cSt	1.6 – 5.9	4.1	✓ Compliant
E	Density @ 15°C	ASTM D 4052	kg/L	0.8200 – 0.8750	0.8467	✓ Compliant
	Sulphur Content	ASTM D4294	%wt.	0.1000 max	0.0027	✓ Compliant
	Flash Point	ASTM D93	°C	>60.0 min	65.0	✓ Compliant
	Cetane Index	ASTM D976	-	45.0 min	48.0	✓ Compliant

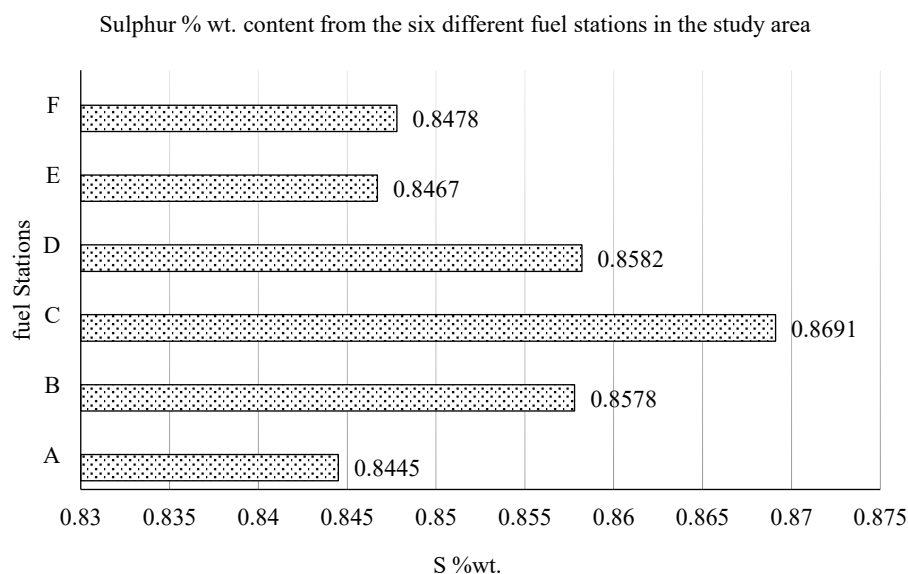
	Kinematic Viscosity	ASTM D445	cSt	1.6 – 5.9	3.8	✓ Compliant
F	Density @ 15°C	ASTM D 4052	kg/L	0.8200 – 0.8750	0.8750	△ Borderline
	Sulphur Content	ASTM D4294	%wt.	0.1000 max	0.0650	✓ Compliant
	Flash Point	ASTM D93	°C	>60.0 min	60.0	△ Borderline
	Cetane Index	ASTM D976	-	45.0 min	45.0	△ Borderline
	Kinematic Viscosity	ASTM D445	cSt	1.6 – 5.9	4.8	✓ Compliant

Figure 2 presents the average density measurements for all diesel fuel samples collected in the study area. The results indicate that the mean density value for each sample fell within the acceptable range stipulated by both the Sierra Leone Standards Bureau (SLSB) Technical Specifications for fossil fuels and the international benchmark ISO8217:2017.

Figure 3 reveals that only two of the six tested fuel stations were dispensing diesel fuel compliant with the maximum sulfur limit of 1000 ppm. This limit is defined by both the Sierra Leone Standards Bureau (SLSB) and the ISO 8217:2017 specification, which is currently under review. The diesel samples from these two stations contained sulfur levels ranging from 20 to 30 ppm. The remaining four filling stations exceeded the set limit, with MC-E, MC-F, and MC-G having the highest sulfur levels



**Figure 2.** The average densities of all diesel fuels sampled in the study area.



**Figure 3.** A graph of sulfur content of diesel fuels sampled at the different study area.

Flash point values ranged from 60.0°C (Station F) to 80.0°C (Station D), with a mean of 69.17°C. The coefficient of variation (10.64%) indicates moderate variability across suppliers.

Station F's flash point exactly at the minimum specification (60.0°C) presents safety concerns for fuel handling, storage, and transportation. Higher flash points (Stations C and D) provide greater safety margins and indicate lower volatility. The 20°C range observed suggests different crude oil sources or refining processes

### Statistical Analysis of Results

To better understand the variability and distribution of fuel quality parameters across the sampled stations, descriptive statistical analysis was performed for each parameter. The results are summarized in Table 3.

**Table 3.** Showing the Mean, Median, Standard, Variation and Coefficient of Variance of the Various stations

Parameter	Mean	Median	Std. Deviation	Min Value	Max Value	Range	CV (%)
Density @ 15°C (kg/L)	0.8560	0.8580	0.0119	0.8445	0.8750	0.0305	1.39
Sulphur Content (%wt.)	0.0515	0.0661	0.0384	0.0027	0.0992	0.0965	74.56
Flash Point (°C)	69.17	67.5	7.36	60.0	80.0	20.0	10.64
Cetane Index	46.88	46.75	1.52	45.0	49.0	4.0	3.24
Kinematic Viscosity (cSt)	3.95	3.95	0.93	2.8	5.2	2.4	23.54

CV = Coefficient of Variation

Cetane index values ranged from 45.0 (Station F) to 49.0 (Station C), with a relatively low coefficient of variation (3.24%), indicating consistent ignition quality across most suppliers.

Station C's higher cetane index (49.0) indicates superior ignition characteristics, potentially resulting in: reduced ignition delay, smoother engine operation, lower combustion noise, improved cold-start performance and reduced emissions of unburned hydrocarbons and carbon monoxide [DieselNet. (2025)

Viscosity values ranged from 2.8 cSt (Station A) to 5.2 cSt (Station C), with a coefficient of variation of 23.54%, indicating moderate variability across suppliers.

### **Compliance Assessment Summary**

The compliance assessment reveals that all six fuel stations met the minimum regulatory requirements for diesel fuel quality as specified in ASTM D975. However, the analysis identified several instances of borderline compliance, particularly:

Station B recorded Sulfur content at 99.2% which is the maximum allowable limit

Station F recorded multiple borderline parameters (density at maximum limit, flash point at minimum limit, cetane index at minimum limit)

### **DISCUSSION OF RESULTS**

The fuel market in Sierra Leone is regulated by the Petroleum Regulatory Agency (PRA), and all the Oil Marketing Companies (OMCs) source their supply from various sources, provided the standards are met. Reduced fuel density often indicates adulteration with less dense substances, such as kerosene. This common contaminant shares similar properties with diesel but is significantly cheaper. Price variations between diesel and kerosene were significant in times past, making diesel adulteration very possible. The current regulatory framework prevents kerosene from offering a significant price incentive, as rules are designed to keep its price closely aligned with that of diesel. As a result, any fuel adulteration would likely involve substances other than kerosene, such as other types of fuel or hydrocarbons. Contamination can also occur accidentally, often during the storage or transit of fuel. As referenced in a study by [16–21], the density of diesel fuel has a significant impact on emissions and performance in heavy-duty engines. Specifically, increased fuel density leads to higher emissions of nitrogen oxides (NO<sub>x</sub>) and particulate matter (PM).

Based on the testing of six filling stations, only two were found to be supplying diesel fuel that complied with the current Bureau and ISO 8217:2017 standard limit of 1000 ppm for sulfur content a standard itself under review. The sulfur content from these compliant stations ranged between 20 and 30 ppm. In contrast, diesel from the remaining four stations exceeded the established limit. Stations FS-E, FS-F, and FS-G recorded the highest sulfur concentrations among all samples.

Notably, the National Petroleum Authority (NPA) has granted exemption to local refineries, permitting them to produce fuels with a sulfur content of up to 1500 ppm until December 31, 2024. Imported fuels are not covered by this permit and must comply with a stricter sulfur limit of 50 ppm. The elevated sulfur levels detected could originate from several pathways: the mixing of imported and domestically produced fuels during storage or distribution, the direct purchase of high sulfur finished products from the exempted local refineries, or the entry of unregulated fuels into the market. This last point is supported by reports of illegal fuel smuggling across borders, with smuggling products often being adulterated. The compliance rate for sulfur content in this study was only 33.3%, meaning the majority of tested diesel samples breached the regulatory limit. This finding is alarming given the well-documented harmful effects of sulfur in fuels on both public health and the environment. During combustion, sulfur converts into harmful oxides, primarily sulfur dioxide (SO<sub>2</sub>). This pollutant has significant negative consequences for both the environment and public health in the research area. Vehicles using high-sulfur fuels are a major source of this pollution. The problem is exacerbated by Sierra Leone's intermittent power supply, which forces many businesses and households to rely on diesel-powered generators. These stationary generators, often located close to residences, substantially increase local air pollution when they burn low-quality fuel. Sulfur-based emissions also contribute to acid rain. This phenomenon leads to the acidification of lakes and rivers, increases soil acidity, and causes damage to crop and vegetation, creating wider ecological harm.

Sulfur causes corrosion and can also impair the function of modern vehicle emission control systems. Beyond buying high-sulfur diesel from local refineries, the most likely explanation is fuel adulteration. These elevated sulfur levels may come from substances introduced by Oil Marketing Companies (OMCs) or their retail outlets, potentially without the knowledge of the parent company, after the fuels have been imported into the country. Contamination may also originate from the underground storage tanks that hold the fuel before it is pumped. Aged, corroded tanks can introduce sulfur compounds such as those from the tank's own steel into the stored fuel. Furthermore, leaks in these tanks can allow sulfur from the surrounding soil to seep in and contaminate the fuel. To address high sulfur levels, methods like bio-desulfurization can be applied to petroleum products. Additionally, improving storage and handling practices can help prevent sulfur contamination. Station F's flash point at the minimum limit, combined with borderline performance in other parameters, suggests potential quality control issues or the use of lighter fuel components to meet viscosity requirements [22–29].

Station F's minimum cetane index (45.0) may lead to: Increased ignition delay, higher combustion chamber pressures, increased engine noise (diesel knock), potential starting difficulties in cold weather. Contemporary diesel engines with advanced injection systems benefit from higher cetane fuels. The narrow range observed (45.0–49.0) suggests that while all fuels are technically compliant, some may not optimize the performance potential of modern engines [30–33].

Station A recorded lower viscosity which might provide better fuel atomization and mixing, improved cold-weather flow characteristics, but there is a potential concerns about lubrication adequacy for high-pressure fuel pumps.

Station C, which recorded higher viscosity, which may lead to superior lubrication properties for fuel system components, causes potential atomization challenges in cold conditions and better sealing in older fuel injection systems.

Modern common-rail systems operate at pressures exceeding 2000 bar and require optimal viscosity for adequate lubrication of precision components, proper fuel atomization and spray patterns and prevention of internal leakage in high-pressure pumps and injectors [34–37]

## **ECONOMIC AND ENVIRONMENTAL IMPLICATIONS**

The quality variations observed have significant economic and environmental implications:

### **Economic Impact**

- Fuels of higher quality can reasonably command a premium price. This is due to their enhanced engine performance and lower long-term maintenance needs.
- Conversely, lower-quality fuels often lead to greater overall expenses. These can include increased fuel consumption, more frequent and costly repairs, and a shorter operational lifespan for engines.
- For fleet managers, a focus on the total cost of ownership encompassing fuel efficiency, maintenance, and engine longevity is more prudent than selecting fuel based on the lowest price per liter alone.

### **Environmental Considerations**

Variability in sulfur content has immediate consequences for local atmospheric conditions and population health. Emission levels of particulate matter and unburned hydrocarbons are minimized when using fuels with elevated cetane indices and appropriate viscosity. However, inconsistent fuel properties compromise the precision and efficacy of emission control system calibration [38–40].

## **CONCLUSION**

The results of this assessment offer critical data on prevailing diesel quality standards and underscore the necessity for ongoing surveillance and enhancement initiatives. These measures are essential to

guarantee superior engine operation, minimize environmental harm, and protect consumer interests. The results support the need for enhanced quality assurance measures and consideration of more stringent specifications to meet the demands of modern diesel engine technology.

All sampled fuels met minimum regulatory requirements, indicating effective baseline quality control in the retail market. Despite universal compliance, substantial variations were observed across all parameters, with sulfur content showing the highest variability (CV = 74.56%). Sulfur content is a critical parameter in fuel standards due to its significant adverse impacts on public health and the environment. Within the study area, compliance with sulfur limits in diesel fuel was low, at 33.3%, as only two of the filling stations sampled met the standard of 50 ppm. While surface tension is not strictly regulated for diesel, it serves as a useful indicator for contaminants like sulfur.

Furthermore, fuel samples from Stations B and F showed several properties approaching or at their specification limits, indicating potential inconsistencies in quality and narrow safety margins.

This indicates 66.7 % of the fuel analyzed dispensed high viscosity fuel. All the filling stations had diesel fuels with standard calorific values.

The differences in fuel properties may also stem from the original crude oil source or from potential contamination during distribution and storage. This study's findings demonstrate that fuel quality discrepancies directly compromise engine efficiency, operational costs, and emission levels, affecting individual vehicle owners and commercial fleets alike. Consequently, it is recommended that the National Petroleum Authority (NPA) implement a systematic, continuous monitoring framework for fuel quality at retail stations and throughout the chain of supply. By extending rigorous oversight beyond port inspections to the entire distribution network, this measure would be instrumental in helping the country achieve its objectives for clean energy (SDG 7) and climate action (SDG 13).

It is also recommended that further research is conducted to assess seasonal variations and long-term quality trends and investigation of additional quality parameters including biodiesel content, oxidation stability, and cold flow properties

## REFERENCES

1. Ahmed HM, Abdeldaim SO, Erwa IY. Production of biodiesel from heat-treated edible oil. In: *Journal of Physics: Conference Series*. 2021 Nov 1;2063(1):012027. IOP Publishing.
2. Fu J, Turn SQ. Oxidation mechanism of sulfur-containing compounds and antioxidant depletion dynamics: Insights into interactions. *Fuel*. 2025 Feb 1;381:133341.
3. Łaska G, Ige AR. A review: Assessment of domestic solid fuel sources in Nigeria. *Energies*. 2023 Jun 15;16(12):4722. [Duplicate entry removed in formatting; repeated sentence in original]
4. Shahaby AF, Essam-El-din KM. Desulfurization of crude oil and oil products by local isolated bacterial strains. *Int J Curr Microbiol Appl Sci*. 2017;6:2695-711.
5. Osman S, Stefaniu A. Density, viscosity, and distillation temperatures of binary blends of diesel fuel mixed with oxygenated components at different temperatures. *Sustainability*. 2023 Oct 31;15(21):15460.
6. Marfo SA. Diesel Fuel Quality Assessment—Case Study of Tarkwa, Ghana. *Ghana Mining Journal*. 2024 Aug 23;24(1):195-204.
7. Muhammed Raji A, Manescau B, Chetehouna K, Ogabi R. Overview of thermal and analytical characterization techniques for biofuels and its blends. *Journal of Thermal Analysis and Calorimetry*. 2025 Mar;150(5):3007-36.
8. Kalghatgi G, Stone R. Fuel requirements of spark ignition engines. *Proc Inst Mech Eng Part D J Automob Eng*. 2018 Jan;232(1):22-35.
9. Ahmed J. Optimized Fuel Efficiency and Management of Diesel-Powered Thermal Plants for Power Generation Stations in Freetown. Available at SSRN 4401128. 2023 Mar 27;[Rochester (NY)]:[Social Science Research Network (SSRN)].

10. Crouse ME, Allsup JR, Lestz SS. *Alternative fuels research guidebook: fuel characterization, instrumentation, engine and vehicle testing*. Pennsylvania State Univ., University Park (USA); National Inst. for Petroleum and Energy Research, Bartlesville, OK (USA); 1985 Dec 1.
11. Gary JH, Handwerk JH, Kaiser MJ, Geddes D. *Petroleum refining: technology and economics*. CRC press; 2007 Mar 5. [Boca Raton (FL)].
12. Miller J, Jin L. *Global progress toward soot-free diesel vehicles in 2018*. ICCT-International Council on Clean Transportation. 2018. [Washington (DC)].
13. Vempatapu BP, Kanaujia PK. *Monitoring petroleum fuel adulteration: A review of analytical methods*. *TrAC Trends Anal Chem*. 2017 Jul 1;92:1-1.
14. Johnson TV. *Review of vehicular emissions trends*. *SAE Int J Engines*. 2015 Jun 1;8(3):1152-67.
15. Aierzhati A, Watson J, Si B, Stablein M, Wang T, Zhang Y. *Development of a mobile, pilot scale hydrothermal liquefaction reactor: Food waste conversion product analysis and techno-economic assessment*. *Energy Convers Manag X*. 2021 Jun;10:100074.
16. Kalghatgi GT. *Fuel anti-knock quality-Part I. Engine studies*. *SAE Trans*. 2001 Jan 1:1993-2004.
17. Fragkoulis N, Archontaki G, Karavasilis C, Velegrakis M, Samartzis PC. *Fuel in Fuel Adulteration Investigated with Optical Spectroscopy & Chemometrics*. Available at SSRN 4606435. [Fragkoulis N, Archontaki G, Karavasilis C, Velegrakis M, Samartzis PC. *Fuel in Fuel Adulteration Investigated with Optical Spectroscopy & Chemometrics*. Rochester (NY): Social Science Research Network; 2023. Available at SSRN: <https://ssrn.com/abstract=4606435>].
18. Knothe G. *Biodiesel and renewable diesel: a comparison*. *Prog Energy Combust Sci*. 2010 Jun 1;36(3):364-73.
19. Lee JE, Jang HS, Yun YJ, Yang YC, Jang JH. *Comparison of Fuel Properties of Alternative Fuels from Insect Lipids and Their Blending with Diesel Fuel*. *Sustainability*. 2025 May 9;17(10):4295.
20. Lin CY, Lin SA. *Effects of emulsification variables on fuel properties of two-and three-phase biodiesel emulsions*. *Fuel*. 2007 Jan 1;86(1-2):210-7.
21. Zhang Q, Liu P, Li S, Zhang X, Chen M. *Progress in the analytical research methods of polycyclic aromatic hydrocarbons (PAHs)*. *J Liq Chromatogr Relat Technol*. 2020 Aug 26;43(13-14):425-44.
22. Bello MN, Pantoya ML, Kappagantula K, Wang WS, Vanapalli SA, Irvin DJ, Wood LM. *Reaction dynamics of rocket propellant with magnesium oxide nanoparticles*. *Energy Fuels*. 2015 Sep 17;29(9):6111-7.
23. Meher LC, Sagar DV, Naik SN. *Technical aspects of biodiesel production by transesterification—a review*. *Renew Sustain Energy Rev*. 2006 Jun 1;10(3):248-68.
24. Luecke J, Naser N, Yang Z, Heyne J, McCormick RL. *Measurement of spray chamber ignition delay and cetane numbers for aviation turbine fuels*. *Energy & fuels*. 2025 May 26;39(22):10479-87.
25. Belchior F, Andrews SP. *Evaluation of cross-contamination of nylon bags with heavy-loaded gasoline fire debris and with automotive paint thinner*. *Journal of forensic sciences*. 2016 Nov;61(6):1622-31.
26. Kwao-Boateng E, Ankudey EG, Darkwah L, Danquah KO. *Assessment of diesel fuel quality*. *Heliyon*. 2024 Jan 30;10(2):e24115.
27. Kojima M, Matthews W, Sexsmith F. *Petroleum markets in sub-Saharan Africa*. Washington (DC): World Bank and ESMAP; 2010 Mar.
28. Payri R, Salvador FJ, Gimeno J, De la Morena J. *Effects of nozzle geometry on direct injection diesel engine combustion process*. *Appl Therm Eng*. 2009 Jul 1;29(10):2051-60.
29. Lohrenz J, Bray BG, Clark CR. *Calculating viscosities of reservoir fluids from their compositions*. *J Pet Technol*. 1964 Oct 1;16(10):1171-6.
30. Da Silva JC, Queiroz A. *Advances in the application of spectroscopic techniques in the biofuel area over the last few years*. In: *Frontiers in bioenergy and biofuels*. London (UK): IntechOpen; 2017 Jan 25. p. 25.
31. Sibilieva O, Dokshyna S, Topilnytskyi P. *International requirements and modern state in sphere of motor fuels quality control: basic principles of monitoring and control*. In: *Modern Technologies in Energy and Transport*. 2023 Dec 1; Cham: Springer Nature Switzerland; p. 249-272.

32. Abdoun A. Global fuel quality developments. In: Presentation to the 12th Global Partners Meeting of the Partnership for Clean Fuels and Vehicles (PCFV), Paris, March 2019. Nairobi (KE): United Nations Environment Programme; 2019 Mar 5. p. 5–6.
33. Leng L, Li W, Li H, Jiang S, Zhou W. Cold flow properties of biodiesel and the improvement methods: a review. *Energy Fuels*. 2020 Aug 3;34(9):10364-83.
34. Speight JG. *Handbook of petroleum product analysis*. Hoboken (NJ): John Wiley & Sons; 2015 Feb 2.
35. Speight JG. *The chemistry and technology of petroleum*. Boca Raton (FL): CRC Press; 2006 Oct 31.
36. Pundir BP, Singal SK, Gondal AK. Diesel fuel quality: Engine performance and emissions. *SAE Tech Pap*. 1994 Oct 1;942053. doi:10.4271/942053.
37. Joshi A. Review of vehicle engine efficiency and emissions. *SAE Int J Adv Curr Pract Mobil*. 2022 Mar 29;4(2022-01-0540):1704-33.
38. Dotson G, Maghamfar DJ. The clean air act amendments of 2022: clean air, climate change, and the inflation reduction act. *Envtl Law Rep*. 2023;53:10017.
39. Balakrishnan K, Dey S, Gupta T, Dhaliwal RS, Brauer M, Cohen AJ, Stanaway JD, Beig G, Joshi TK, Aggarwal AN, Sabde Y. The impact of air pollution on deaths, disease burden, and life expectancy across the states of India: the Global Burden of Disease Study 2017. *Lancet Planet Health*. 2019 Jan 1;3(1):e26-39.
40. AC MB, Model MC. 2010 combined subject index IEEE Industry Applications Society publications. *IEEE Trans Ind Appl*. 2011 Jan;47(1):497–516.