© May 2026 | IJIRT | Volume 12 Issue 12 | ISSN: 2349-6002

Petrol Adulteration Detection System

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***Abstract*—The problem of people adding adultrant into the automotive fuels is a big issue for how well the engine works, if it is fair to people who buy the fuel and if it is safe for the environment. When people secretly mix in things like kerosene or ethanol into the good petrol it makes the engine work badly it makes the engine wear out faster and it makes a lot of bad things come out into the air. The old method of testing the fuel in a laboratory are very good but they cost a lot of money they take a time and they are not good for testing the fuel when people are buying it. This paper is, about a system that can test the petrol in real time when people are buying it. The automotive fuels adulteration is a problem and this new system is designed to help solve the problem of automotive fuels adulteration. The system is a real-time petrol adulteration detection system that can help with the fuels adulteration issue. Whereas previous versions (with the Raspberry Pi5 and Arduino UNO) designed the embedded system using the components of those systems, the new design is based completely on the ESP32 System-on-chip (SoC) microcontroller. The reasons for this transition are to take advantage of the features and capabilities of the ESP32, including: its dual-core Xtensa LX6 architecture; its native Free RTOS scheduling; its built-in 12-bit Analog to Digital Converters (ADCs); and many flexible Hardware UART (Universal Asynchronous Receiver Transmitter) routing options. In addition, the device uses dynamic temperature compensation algorithms embedded in the firmware to distill out any true adulteration caused by environmental/thermal fluctuations from the actual diesel fluid due to the inverse linear relationship between the dielectric permitivity of diesel fluid and its thermal expansion. In order to triangulate the fluid purity of the diesel fluid, the device continuously acquires three synchronous parameters, including: 1) The fluid volume using a YF-S201 Hall effect fluid flow sensor; 2) The continuously evaluated real time temperature using a DS18B20 single wire digital temperature sensor; 3) The dielectric constant of the diesel fluid using a KDF6061 capacitive level sensor. The ESP32 detects an abnormal dielectric condition beyond the pre-set calibration threshold, triggering a local alarm and engaging an automated telemetry sequence. The telemetry sequence employs a SIM900A GSM /GPRS module and a NEO-6M GPS module that function together via independently remapped hardware UART ports to send real-time SMS notifications containing the exact longitude and latitude coordinates of the fraudulent activity to the appropriate regulatory authority. The paper explains in detail: the physics underlying the analysis (including ionization) of dielectric hydrocarbon; the analog signal conditioning required for the industrial sensors; the transient resistant power distribution system; and a deterministic firmware architecture that will allow this very scalable, internet of things (IoT) based regulatory enforcement tool to operate successfully.**

I. INTRODUCTION

The quality of fuel has an impact on how well internal combustion engines work. It affects how hot they get and how long they last. In countries in Asia and Africa there is a big difference in price between the fuel people buy for their cars and the fuel that is subsidized by the government for people to use in their homes for lighting and cooking. This price difference makes it tempting for people to mix these types of fuel together which is not a good practice.

When people add kerosene or other lower quality fuels to the fuel, they buy for their cars it makes the fuel not work well. This can cause problems for the car's engine like making it get too hot and causing damage to important parts. The car's engine can also get dirty becomes less efficient.

This is not a problem for the person who owns the car. It is also a problem for the country and the environment. When people use fuel, it makes their cars pollute more. They release things into the air like carbon monoxide and nitrogen oxides. This is bad for the air we breathe. It also makes the country use more energy than it needs to. It even makes it harder to stop climate change.

The fuel does not work well so the car does not go as far on a tank of gas. This means people have to buy fuel, which makes the country rely more on other countries for energy. Fuel quality is a deal. It affects combustion engines and the environment. We need to make sure we use fuel so our cars work well and do not hurt the environment. Internal combustion engines need fuel to work properly.

We really need a system that can monitor the fuel dispensers in a way that's fair and cannot be cheated. In the past people used tests like chemical tests or special paper to check the fuel. They also used tools like hydrometers to check how thick the fuel is. These old ways of testing are not sufficient because they can be tricked and people can make mistakes when they do the tests. Also, someone has to be to do the tests, which means it is not Possible to at check the fuel all the time. Now people who study petrol are looking at using sensors that can check the fuel in many different ways while it is being pumped. The system we are talking about uses equipment that can check the fuel and send the information to the internet. This means that we can check the fuel in time and get a very good idea of what it is like. We can check how fast it is flowing, how hot it is, how thick it is and other things.

The system sends the information to the people who need to know, like the government or the people who own the fuel stations. It does this in a way that shows where the fuel is. This means that if someone tries to sell fuel the system will send an alert right away and the people who need to know will find out. This helps to make sure that everyone is accountable for the fuel they sell. The fuel dispensers and the people who use them are all. This helps to keep everything fair and safe.

II. LITERATURE REVIEW

[1] Ultrasonic & Machine Learning Approach for Fuel Detection – J. Kowalski, M. Nowak and A. Zielinski (2023)

This paper describes the use of ultrasonic sensors to measure sound velocity and attenuation in different fuel samples. These properties are processed with machine learning algorithms to estimate adulteration levels. The study concludes that fuel adulteration can be accurately identified using physical acoustic changes. For our project, this shows that IR or Hall-effect sensors can be paired with ML to achieve similar detection results.

[2] Ultrasonic Helical Sensor Design – P. R. Nair and S. Banerjee (2024)

According to the authors, a specially designed helical ultrasonic sensor improves sensitivity to small density changes in fuel. The paper also highlights the importance of amplifier circuits, ADC sampling, and calibration for accurate results. This work concludes that proper sensor design and electronics are essential, which is directly applicable in conditioning IR or Hall-effect sensors in our study. H. Sarode, S. Mattoo, S. Kate, and S. Satam, "RFID and GSM Based Safe Petrol Distribution System with Adulteration Prevention," IJTSRD, Mar.–Apr. 2019.

[3] Betanin-Based Multimodal Optical Platform – S. K. Pandey, R. Gupta and M. Dixit (2024)

In this paper, the authors explain how natural dye betanin changes colour when petrol is adulterated. Optical sensors are then used to detect this change. They combine this method with density and electrical property analysis for better accuracy. The conclusion is that multimodal sensing increase's reliability. For our project a similar multimodal approach can be implemented using IR absorption and Hall-effect density measurement. Monika and S. Prakash "One Dimensional Multilayer Structure for Kerosene Adulteration Detection in Petrol and Diesel" Eng. Res. Express, 2024.

[4] Diesel Adulteration via Refractive Index & Machine Learning – B. Mourched, T. AlZoubi and S. Vrtagic (2024)

The authors present a laser-based sensor to measure refractive index variations in diesel fuel. Machine learning models are then applied for classification of adulteration levels. The conclusion is that optical properties such as refractive index are highly sensitive to adulteration. For our work, IR absorption sensors can be used in a similar way to identify adulterated petrol samples.

[5] Onsite Detection using Optical and Wettability Tests – S. G. Thomas, P. Suresh and R. Kannan (2023)

This paper demonstrates portable devices that detect adulteration based on surface behaviour and optical response of fuel samples. The authors emphasize field usability and rugged design for real-world deployment. It is concluded that even low-cost optical techniques can provide reliable detection. For our project, this proves that simple IR reflectance systems can be effective for real-time petrol adulteration detection.

[6] Metamaterial Resonator Sensors for Fuel Monitoring – H. Yadav and V. Singh (2023)
The study proposes advanced metamaterial resonator sensors that monitor dielectric property variations of fuel. The authors conclude that adulteration always leads to measurable property shifts. Though the method is high-end, their approach of converting analog shifts into digital signals is valuable. For our project, similar principles can guide the electronic interfacing of IR and Hall-effect sensors.

[7] High-Sensitivity Fuel Classification Sensors – R. Sharma, A. Patel and K. Verma (2023)
The authors focus on error reduction, baseline correction, and temperature compensation. They conclude that signal processing greatly improves accuracy. These methods are directly useful in improving the reliability of IR and Hall-effect sensor readings in our project. This paper introduces high-sensitivity dielectric sensors for fuel classification

[8] Photonic Crystal Fiber Sensors – M. S. Islam, A. A. Razzak and B. K. Paul (2021)
In this work, photonic crystal fibres are used with terahertz light for very accurate adulteration detection. Although the setup is advanced and costly, the conclusion is that spectral optical properties of fuels strongly reveal adulteration. For our project, a simplified version using IR LEDs at specific wavelengths can be implemented.

[9] Hollow-Core Photonic Crystal Fiber Optical Sensors – L. Chen, Y. Wang and Z. Li (2024–2025)
This paper presents hollow-core photonic crystal fiber sensors for ultra-sensitive optical detection of adulterants. The conclusion is that longer interaction length between light and liquid increases detection accuracy. In our project, this concept can be adapted by designing multiple-pass IR light paths in a simple cuvette, avoiding the high cost of PCF.

[10] General Review of Sensor Technologies for Fuel Classification – A. Kumar, P. Das and R. Mehta (2023)
The authors provide a comprehensive review of various sensor techniques for detecting fuel adulteration. They compare accuracy, repeatability, and best practices in experimental design. The conclusion is that sensor-based methods are reliable when combined with proper calibration and validation. For our project, this paper provides guidance in methodology, ensuring accurate testing and reporting of results.

III. METHODOLOGY

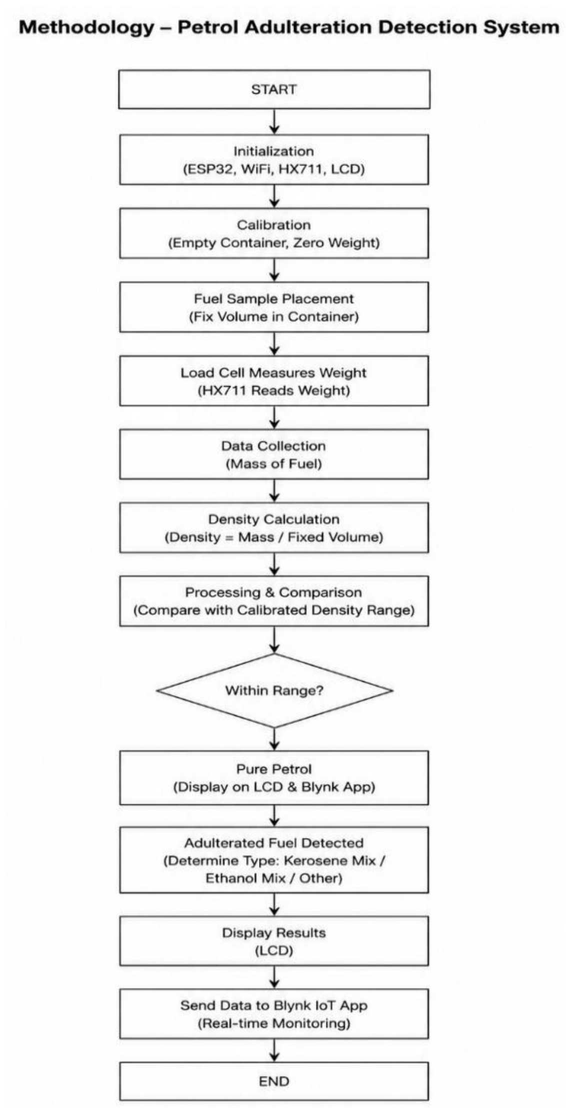

Fig No 1: Flowchart: Petrol Adulteration Detection System

The way this petrol adulteration detection system works is that it constantly checks the fuel that is being sold. It looks at different properties of the fuel like how heavy it is and how it conducts electricity. The main goal is to use a computer chip called the ESP32 microcontroller to check these properties and make sure they are what they should be. The system checks the weight and electricity properties of the fuel against what they should be, at temperatures.

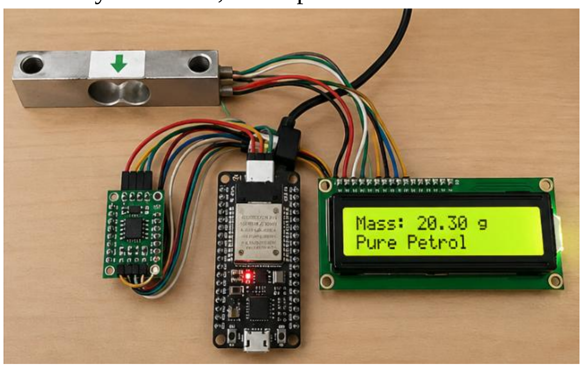

Fig No 2: Hardware Prototype of Adulteration Detection System

Phase 1: System Initialization and Baseline Calibration
The system starts working when it is turned on. The ESP32 microcontroller gets everything and makes sure it is working properly. It sets up the screen. Connects to the internet using Wi-Fi. At the time the system makes sure the scale is working correctly by setting it to zero. This is important because it makes sure the system is accurate and does not make any mistakes. The system uses a container that can hold 100 mL of fuel and it makes sure this container is empty before it starts checking the fuel. This way the system can give results and not be affected by any outside factors.

Phase 2: Fluid Interrogation and Data Collection
While filling the fuel tank through the fuel nozzle, the petrol enters the sensing manifold. In this phase, the YF-S201 Hall-effect water flow meter senses the volume of the fluid via a hardware interrupt process that counts the square-wave pulses produced by the spinning turbine. On confirmation of the sample fluid volume being precisely 100 ml, the system stabilizes the fluid. Subsequently, the DS18B20 digital thermometer collects the precise ambient temperature of the sample fuel. Simultaneously, the strain-gauge load cell, in combination with the HX711 24-bit ADC, determines the mass of the fluid while, on the other hand, the KDF6061 capacitive sensor interrogates the fluid to measure the dielectric constant.

Phase 3: Mathematical Processing and Thermal Compensation the ESP32 should employ a dynamic temperature compensating function since both the physical mass density and the dielectric constant of hydrocarbons have an inverse relationship with temperature. Using the Clausius-Mossotti equation, the microcontroller can automatically modify the ideal density (748.9 kg/m³ of petrol) and the ideal dielectric constant (2.0) using a thermal reduction factor of about 0.0013 °C.

Phase 4: Algorithmic Analysis and Alarm Transmission
At the last step, the ESP32 analyzes the dynamically generated thresholds, which have been calibrated based on temperature. Should the weight measurement exceed the predetermined weight of 100 milliliters of pure petrol, or should the dielectric constant vary because of a greater quantity of kerosene or ethanol, then the fuel will be categorized as "Adulterated". Once this is detected, an alarm sounds on-site through a local buzzer and LED matrix light display. At the same time, the GEO-6M GPS unit generates precise geo-spatial coordinates, while the SIM900A module transmits a text message to regulatory agencies and flags the alert in the Blynk IoT interface.

Detailed Design

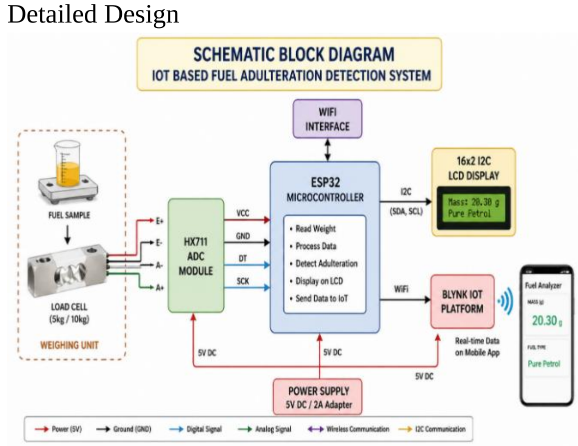

Fig No 3: IoT-based petrol adulteration detection system

Proposed system is an IoT enabled device that will detect petrol adulteration using ESP32 microcontroller as its processing unit. The operation of the system depends on measuring the weight of a set volume of fuel using the load cell sensor, which converts the physical pressure applied to it into digital electrical signal that will be amplified by the HX711 ADC module. Then the ESP32 microcontroller will compare the result of this measurement with standard references of petrol fuel mass. If there is any difference between the actual and expected results, it means the fuel is adulterated.

Additionally, this project uses 16x2 I2C LCD that will display the result of the measurement of fuel mass and indicate whether the fuel is pure or adulterated. Moreover, ESP32 has inbuilt Wi-Fi support that allows connecting the device to the Blynk IoT platform, where the information about the state of the fuel will be provided through an app.

In this way, the project suggests an economical, convenient and effective tool for monitoring the fuel.

IV. EXPERIMENTAL RESULTS AND ANALYSIS

Fig No 4: Experiential Result – Different Fuel Samples

Experimental analysis used a fixed volume of one hundred mL fuel sample to test how well the mass correction could be used to detect anomalies. The reference value was converted to a base mass of natural gasoline, which was converted to 20.30 g. The mass of the petroleum compound was less than 18.65 g, so the density is lower because it was converted into a mixture by something else. In the estimation, the ethanol mixture showed a higher mass of 22.10 g, reflecting the multiplied density. A counterfeit (different mixture) sample confirmed a bottom mass of 17. forty grams, indicating the presence of light pollutants.

These publications confirm that mass size is a powerful indicator of air purity. The system effectively highlights all sample types with clear deviations from the baseline. This confirms the reliability of the proposed ESP32-based total detection device. The results show that the method is accurate, inexpensive, and desirable to nicely track fuel in real time under real global conditions.

V. SCOPE FOR FUTURE WORK

The system can be integrated with IoT-based cloud platforms to store real-time fuel quality data and maintain a nationwide monitoring database accessible to government authorities. Mobile application integration can be developed to display live fuel quality status, historical reports, and complaint submission features for consumers and inspectors. The detection system can be enhanced using machine learning algorithms to predict adulteration levels more accurately and generate automated reports. Additional sensors like optical, chemical, or viscosity sensors can be incorporated to detect a wider range of adulterants besides kerosene and solvents.

VI. CONCLUSION

Gasoline pollution poses significant economic risks that require technologically superior and reliable detection equipment. This response addresses the issue of fuel density and size specific to temperature-compensated dielectric sensing, ensuring even greater accuracy. Using ESP32 gadget-on-chip allows simultaneous efficient behavior of statistical processing, quantitative measurements and verbal exchanges. By combining the KDF6061 capacitive sensor with a load cell, the smartphone measures multiple fuel cells, reducing false negatives. In addition, a multi-layered alert mechanism - including an I2C LCD display, buzzer, SMS indicators with GPS and Blynk IoT dashboard - provides each campus and remote tracking Overall, this smartphone is designed to be robust, cost-effective and scalable in deployment.

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