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GASEOUS VAPOR EMISSION (GVE) TECHNIQUE FOR DETECTION OF PETROL ADULTERATION AT POINT OF SALE (POS) TERMINALS

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ABSTRACT

Adulteration of petrol is difficult to detect at point of sale terminals (POS) because current detection methods require chemical laboratory experiments to measure parameters such as density, API gravity and evaporation point, are extremely bulky, time-consuming, and require experienced technicians to operate. This paper explores a new technique for adulteration detection at POS terminals, known as Gaseous Vapor Emission (GVE). GVE was performed on 1 L of pure petrol obtained from a Nigerian National Petroleum Corporation (NNPC) Retail Outlet, using a portable Petroleum Product Volume Estimator and Tracker (PPVET). Results showed that pure petrol gave a peak methane emission in 30 seconds, and a peak butane emission in 60 seconds. In an enclosed space of 19,000 cm^3, a sample of pure petrol emits 4,466,841-5,308,924 ppm of methane, 12.23-19.09 ppm of LPG, and 216,667-383,408 ppm of butane. GVE correctly identified the petrol sample as being pure, by verifying the presence of the characteristic methane and butane emission peaks, and the technique can be used at POS terminals to test for petrol adulteration. Future work includes the expansion of the GVE chemical signature for petrol to include other gases in addition to methane, LPG, and butane, the ability to utilize GVE in detecting adulterated petrol, and when present, estimation of the level of adulteration, as well as accurate identification of the adulterant used.

Contribution/Originality: This paper proposes and explores a new technique for detecting petrol adulteration at Point of Sale (POS) terminals.

1. INTRODUCTION

Premium Motor Spirit (PMS), also known as Gasoline or Petrol, is a major product in the refining of crude oil [1] and is used as the primary source of energy for vehicles. Codes, Standards, and specifications exist in different countries to ensure that supplied PMS meets a minimum standard or quality to ensure vehicles run satisfactorily [2]. However, the adulteration of petrol (gasoline) has become a flourishing business in many developing countries [3]. Adulteration is defined as the illegal or unauthorized introduction of foreign substances into gasoline or similar substance, with the result that the product does not conform to the requirements and specifications of the product [4, 5]. In 2012, a nationwide sampling conducted by the Standards Organization of Nigeria (SON) on Petroleum products showed a high level of adulteration at different levels of distribution [6]. The primary cause of adulteration is greed, fuelled by differential tax system on different petroleum fractions [7].

Adulteration of PMS leads to increased tailpipe emissions of hydrocarbons, carbon monoxide, nitrogen oxides, particulate matter and the consequent ill effects on public health [6-8]. Adulterated petroleum products cause explosions that result in deaths, deformities and incalculable damages to consumers of the petroleum products in the country [6]. With a large number of adulterants available in the market (both local and imported) and the fact that adulterated products are difficult to detect at point of sale terminals (POS), the magnitude of these adulterations has grown to alarming proportions [9].

Current methods to detect adulteration in petroleum products require chemical laboratory experiments to measure parameters such as density [10, 11] API gravity [1] viscosity, flash point, and evaporation point [8]. These methods cannot be utilized by consumers at point of sale terminals (POS). Hydrometers and digital densitometers are used to measure the density fuel samples, with 0.74-0.75 Kg./L reported for gasoline [8]. Although adulteration of petrol causes a change in density, this change is very small, densitometers are expensive and need a controlled environment (for correct operation) which is unlikely to be available in the field at the distribution point [8]. Evaporation techniques are capable of detecting very low concentrations (1-2%) of diesel in gasoline and fairly low concentrations (5%) of kerosene in gasoline. However this is basically a laboratory technique that is unsuitable for field use. The distillation technique exploits the difference in the boiling points of different liquids comprising the fuel sample. The technique, however, is not suitable for field use as the measurement set up is generally bulky and measurement process is time consuming. Gas Chromatography (GC) can be used to detect hydrocarbon-based adulterants. However, it requires an experienced technician to operate the equipment and interpret the results, and cannot be used at point of sale terminals [12]. The use of optical fiber sensors and ultrasound-based methods are still being explored [8, 13].

To check the adulteration effectively, it is necessary to monitor the fuel quality at the distribution point itself. The equipment for this purpose should be portable and the measurement method should be quick, and capable of providing test results within a very short time [8]. Gaseous Vapor Emission (GVE) is a relatively new technique that has been developed to characterize pure petroleum products in order to detect adulteration. This techniques uses emission sensors to detect, measure, and characterize the gases that are emitted by samples of petroleum products [14]. A portable electronic device called the Petroleum Product Volume Estimator and Tracker (PPVET) has been designed to employ this technique at POS terminals for easy adulteration detection in petroleum products [15].

This paper explores the use of GVE technique in identifying and detecting pure petrol at distribution points in Nigeria. The emissions given off by pure petrol is measured, monitored, and characterized to provide a chemical signature that can be utilized to verify the purity of petrol, and to potentially detect adulteration of the petroleum product.

2. MATERIALS AND METHODS

2.1. Materials

2.1.1. Petrol Sample Obtained from a Nigerian National Petroleum Corporation (NNPC) Retail Outlet

Samples of pure petrol was obtained from a Nigerian National Petroleum Corporation (NNPC) retail outlet. This source receives its petrol directly from the Nigerian Government, and is therefore guaranteed to be unadulterated. It is the most reliable source of pure petrol in the country. 10 Litres of pure petrol was obtained from this source see Figure 1.

Figure-1. 10 L Sample of Unadulterated Petrol obtained from NNPC Retail Outlet.

2.1.2. PPVET

A Petroleum Product Volume Estimator and Tracker (PPVET) for adulteration detection at POS terminals was obtained from RACETT NIGERIA LTD [15] see Figure 2.

(a) (b) (c)

Figure-2. Petroleum Product Volume Estimator and Tracker (PPVET) [15] (a) Front View (b) Back View (c) Side View.

The PPVET is a small portable, battery-powered, electronic device (23.8 cm x 17 cm x 10.2 cm) that performs GVE analysis on samples of petroleum products. It was used in this study to characterize the GVE signature of pure petrol in Nigeria.

2.1.3. Test Vessel

A plastic container was used to house the petrol sample during GVE testing Figure 3. The authors selected a vessel that could be accessed and procured by any petrol consumer in the country for POS terminal adulteration testing. The inner measurement for the vessel was 21.4 cm x 16.8 cm x 31.3 cm.

Figure-3. Test vessel used for GVE testing and analysis.

2.2. Methods

When the PPVET device was switched on, the user was instructed to select one of four options: Volume Estimation, Adulteration Sensing, Product Tracking, or All of the Above see Figures 4 a & b. This experiment made use of the Adulteration Sensing component, and so option 'B' was selected using the keypad.

Next, the device asked the user to select which petroleum products he or she wished to examine for the presence of adulteration see Figure 4c. Four options were available for the user: Crude Oil, Diesel, Kerosene, and Petrol see Figure 4d. This experiment focused only on the characterization of petrol, and so option 'D' was selected using the keypad.

Figure-4. GVE test on unadulterated petrol sample from NNPC Retail Outlet. (a) PPVET welcome message asking user to select a function to perform (b) PPVET listing available functions, including Adulteration Sensing (c) User is asked to select a type of petroleum product for Adulteration detection (d) Options available for Adulteration Sensing (e) Instructions to commence Adulteration Sensing (f) Setup for GVE test (g) GVE test in progress (h) Result of GVE test on pure petrol sample (i) GVE gas concentration measured during the test.

Next, the device instructed the user to place the PPVET inside a vessel containing 1 L of the selected Petroleum Product, to press the '#' key, and then seal the vessel for 2 minutes see Figure 4e. 1 L of the pure petrol obtained from the NNPC retail outlet was poured into the test vessel. The PPVET was then mounted at the top of the vessel see Figure 4f. The '#' key on the keypad was pressed, and the vessel was kept sealed for 2 minutes. Figure 4g shows the PPVET performing GVE test on the petrol sample. After 2 minutes, the test vessel was opened, and the PPVET was retrieved. Figure 4h shows the PPVET informing the user of the result of the GVE test. In addition to the final result informing the user whether or not the petrol sample is unadulterated, the PPVET also provides the concentration of the gases measured during the GVE test see Figure 4i.

3. RESULTS

The PPVET was able to successfully detect and identify the sample from the NNPC Retail Outlet as Pure Petrol. GVE was performed on the sample for two (2) minutes. The results of the GVE analysis on the petrol sample are shown in Figure 5. Enclosed within a space of aproximately 19,000 cm^3, it was observed that peak emission of methane (CH_4) from pure petrol occurred in approximately 30 seconds and then decreased slightly to a steady-state value. Minimal emission of LPG was recorded. Peak emission of butane (C_4H_{10}) occurred in approximately 60 seconds, followed by a decrease to a steady-state value. The timing and sizes of the characteristic emission peaks for methane and butane served as the emission chemical signature for pure petrol and were utilized in validating the purity of the petrol sample. The minimum and maximum emission data for a pure sample of petrol is shown in Table 1.

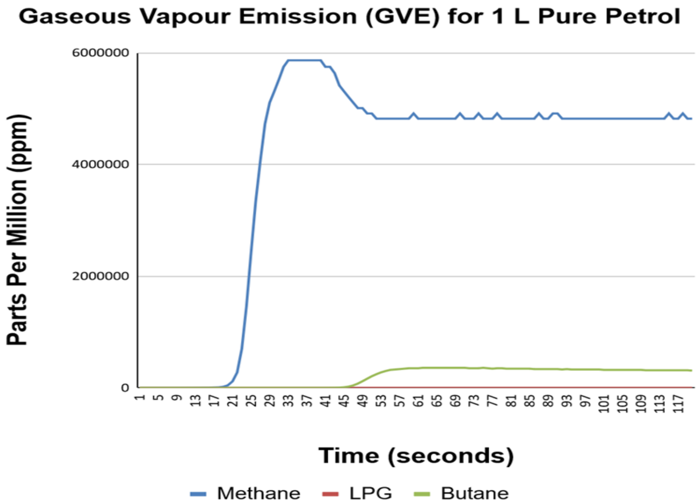

Figure-5. GVE Analysis on 1 L Petrol Sample from NNPC Retail Outlet.

Table-1. Emision Data from 1 L Petrol Sample in 18,952 cm^3 Enclosure.

1 L Pure Petrol	Minimum Peak Emission (ppm)	Maximum Peak Emission (ppm)
Methane (CH_4)	4,466,841	5,308,924
LPG	12.23	19.09
Butane (C_4H_{10})	216,667	383,408

4. DISCUSSION

The PPVET used in this experiment was portable and extremely user-friendly. It provided step-by-step instructions for the user to carry out adulteration checks for a variety of petroleum products. The adulteration test conducted was based on the GVE technique and the results of the test were displayed on the screen for the user to see. PPVET successfully identified the petrol sample from the Nigerian National Petroleum Corporation (NNPC) as being pure, by verifying the presence of the characteristic methane and butane emission peaks.

Data obtained by performing numerous GVE tests with the PPVET showed that in an enclosed space of 19,000 cm^3, a sample of pure petrol would emit 4,466,841-5,308,924 ppm of methane, 12.23-19.09 ppm of LPG, and 216,667-383,408 ppm of butane. Pure petrol would give a peak methane emission in 30 seconds, and a peak butane emission in 60 seconds. The timing and sizes of the characteristic emission peaks for methane and butane served as the emission chemical signature for pure petrol and were utilized by the PPVET in recognizing the NNPC petrol sample as unadulterated. It is expected that adulterated samples of petrol will produce emission profiles that are different from the emission signature exhibited by pure petrol. The authors are currently working on acquiring and testing samples of adulterated petrol to see if the GVE technique can detect and identify adulterated petrol, in addition to being able to detect pure petroleum products. The advantages of the GVE technique include the key ability of portability and user-friendliness. Consumers of petrol can purchase a sample of the product at any POS terminal, perform GVE analysis on the sample, and personally confirm if the petrol at that terminal is unadulterated within two (2) minutes, using the PPVET. If the results of the GVE test indicate purity of product, the consumer can then confidently make a purchase from that terminal. If not, the consumer can look for another location where he or she will get access to pure petrol. The GVE technique can also be used by regulatory officials to quickly and easily sample and test the quality of petrol at different points of distribution across the country.

Future work includes the expansion of the GVE chemical signature for petrol to include other gases in addition to methane, LPG, and butane. The ability to utilize GVE to detect adulteration in petrol, to estimate the level of adulteration present in a sample, and to accurately identify the adulterant (when present), needs to be thoroughly investigated. The effect of the size of the testing vessel on the emission signature for petrol, as well as the volume of the product used in the GVE test, also needs to be examined.

5. CONCLUSION

Gaseous Vapor Emission (GVE) is a relatively new technique that can be used to detect and identify pure petroleum products in order to guard against the dangers of adulteration. The GVE technique was tested on 1L of pure petrol obtained from the Nigerian National Petroleum Corporation (NNPC) retail outlet by means of a portable Petroleum Product Volume Estimator and Tracker (PPVET). Results showed that pure petrol gave a peak methane emission in 30 seconds, and a peak butane emission in 60 seconds. In an enclosed space of 19,000 cm^3, a sample of pure petrol emitted 4,466,841-5,308,924 ppm of methane, 12.23-19.09 ppm of LPG, and 216,667-383,408 ppm of butane. GVE correctly identified the petrol sample as being pure, by verifying the presence of the characteristic methane and butane emission peaks. This technique can be used at POS terminals to test for petrol adulteration. Future work includes the expansion of the GVE chemical signature for petrol to include other gases in addition to methane, LPG, and butane. The ability to utilize GVE to detect adulteration in petrol, to estimate the level of adulteration present, and to accurately identify the adulterant needs to be further explored.

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