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Detection and Extraction of Aroma Characteristics of Fuel Oil Using Gas Sensors Through Electronic-Nose System

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Abstract. Fuel oil is an indispensable strategic source of energy for the fuel of vehicles and other engines. This study aims to detect and differentiate fuel oil using an electronic-nose system. The fuel oil used is Pertalite, Pertamax, and Pertamax Turbo. Four gas sensors are used, namely MQ 4, MQ 7, MQ 9, and MQ 136. The average output voltage values of Pertalite, Pertamax, and Pertamax Turbo fuel oil for MQ 4 sensors are 1.07 V, 1.22 V, and 0.96 V. For MQ 7 sensors, the output voltage values of the samples are 1.44 V, 1.43 V, and 1.37 V, respectively. For the MQ 9 gas sensor, the sample output voltage values are 1.23 V, 1.43 V, and 1.09 V. As for the MQ 136 gas sensor, the output voltage value of each oil is 1.26 V, 1.25 V, and 0.91 V. Sensors that provide the highest response in each sample are MQ 136 sensors. The electronic-nose system can extract characteristics from all three samples using the principal component analysis (PCA) method.

Keywords: Electronic nose, Fuel Oil, Gas sensor, Principal Component Analysis.

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1 Introduction

The development of technology regarding electronic nose systems is very wide and commonly used for various fields, and identifying hazardous gases is indispensable in many fields [1]. The use of some instrumentation equipment that uses a series of gas sensors that mimic the workings of the human nose is an electronic nose system. The electronic nose's working principle mimics the human nose's function, in which the device contains various odor-identifying receptors [2]. An electronic nose consists of an array of gas sensors (arrays) as a substitute for olfactory receptors that function to detect odors or aromas. The aroma detected by some of these gas sensors will form a pattern, recognized as the pattern recognition system.

Kasenda et al. (2019) have conducted research to design-build a microcontroller-based sulfur dioxide gas concentration measuring instrument using the MQ136 sensor. This tool determines the sulfur dioxide gas concentration in the environment. Sulfur dioxide gas has different

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individual sensitivities and affects human health, such as eye irritation, throat, and respiratory tract [3].

Rizki et al. (2017) also detected the gas type in underground mining excavations. These include methane gas (CH_4), carbon dioxide (CO_2), and hydrogen sulfide (H_2S). This gas is classified as toxic when inhaled by humans. For example, for hydrogen sulfide, if exposed continuously to low concentrations or directly exposed to high concentrations, the sense of smell can become paralyzed [4].

Sihombing and Ritonga (2020) designed a cooking oil aroma detector to distinguish the aroma of cooking oil that is widely consumed by the public. This tool uses the TGS2611 gas sensor as an electronic nose system. The results showed that the average output voltage of the gas sensor was 172.3 mV, 204.8 mV, and 181.4 mV for samples of packaged cooking oil, bulk cooking oil, and used cooking oil. Furthermore, the data from the output voltage show that bulk cooking oil has the highest response. In contrast, packaged cooking oil has the lowest response [5].

Baskara et al. (2016) conducted research with the development of an electronic nose to clarify the quality of cooking oil, carried out using the PCA (Principal Component Analysis) method. This study used six gas sensors consisting of MQ-9, TGS-2600, MQ-2, MQ-4, TGS-2620, and TGS-822 sensors, and a heat exchange system was carried out that can reduce steam in cooking oil samples of palm oil and coconut oil types with a mixture of oil. The study's results on the sensor output response were stable and according to the data obtained, pure cooking oil, both palm oil and virgin coconut oil, can be classified as mixed cooking oil [6].

The use of e-nose systems has been widely used to detect gases or materials that emit odors/gases when heated, for example, detecting the smell of alcohol in perfumes [7], distinguishing the aroma and types of teak and mahogany [8], detecting cancerous breasts through urine [9], detecting rotting of the base of palm trunks [10], detecting hydrocarbon compounds in premium oils [11], detecting the aroma of robusta coffee [12]. The e-nose is an alternative to the aroma test instrument that is easy to use, versatile, and relatively inexpensive [2].

Pertalite is one of the new types of fuel oil (BBM) released by PT Pertamina on 24 July 2015. Pertalite has an octane value of 90, and Pertamax-type fuel has an octane value of 92; the emergence of fuel makes irresponsible individuals combine various fuel types to achieve higher profits [13]. Pertamax Turbo is a fuel with a Research Octene Number (RON) of at least 98, which is fuel for gasoline-engine vehicles obtained from the development of the Pertamax Plus product [14]. Therefore, a fuel purity identification test is carried out in one way: using an electronic-nose system. This study focuses on the aroma discrimination of Pertalite, Pertamax, and Pertamax Turbo fuel oil, which reside in our environment.

2 Methods

2.1 Diagram Block and Flowchart

Figure 1 and Figure 2 are the block diagram and the flowchart of the electronic-nose system with Arduino Uno.

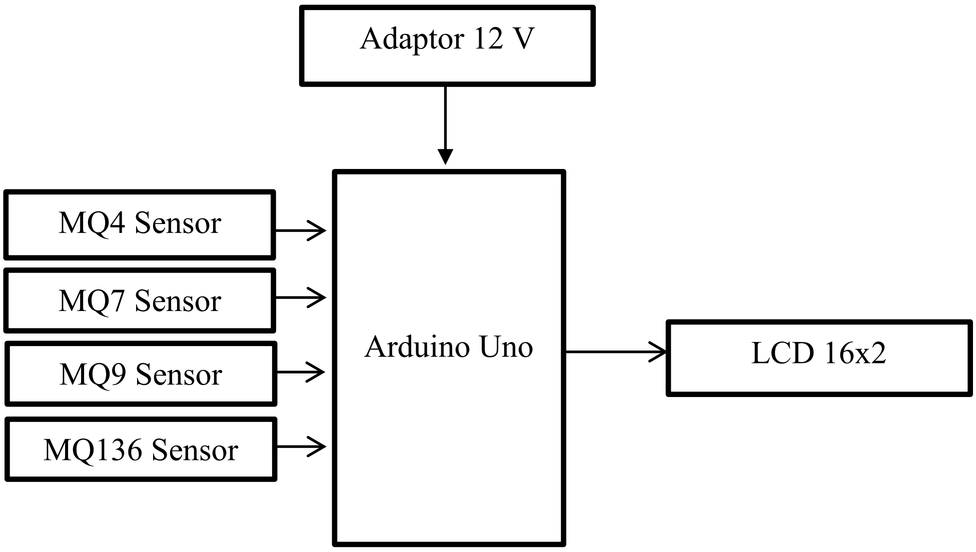


Figure 1. The Block Diagram of The Electric-Nose System

In order to obtain the value of each sample used, the output value of the sensor was calculated before entering the sample chamber; after the sensor was scaled, the sensor waited approximately 5 minutes to reach the stable sensor point. After reaching the stable point of the sensor, the first sample was inserted and held for approximately 1-2 minutes so that the gas or aroma in each sample reached the sensor, then recording or data collection was carried out for 20 minutes per 30 seconds after the first sample was inserted. Next, the sample room was normalized for approximately 5 minutes by opening the sensor room door and turning on the fan so that the sensor returned to the following normal values of the no-load sensor. Then, other samples were measured in the same way. Each sample measurement was carried out three times.

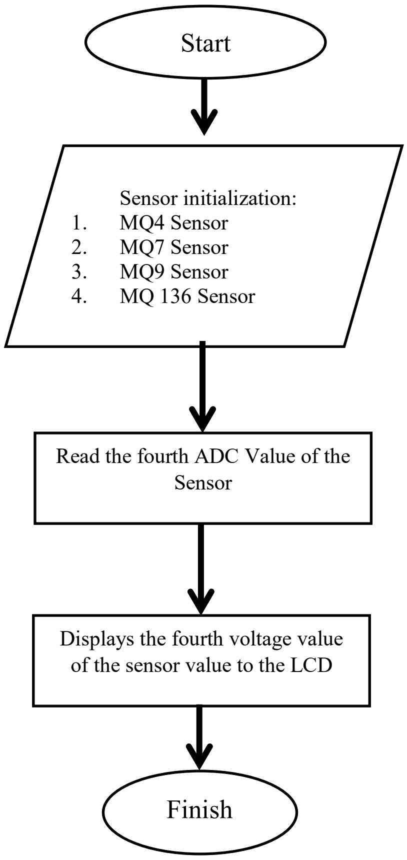


Figure 2. Electronic-Nose System Flowchart

3 Result and Discussion

Before the sample was tested to reach the sensor output stable point, the electronic nose was first turned on for 20 minutes until the number released was stable enough. Then the sensor output voltage was recorded every 30 seconds to see the baseline or normal voltage of the sensor before the sample was inserted for testing.

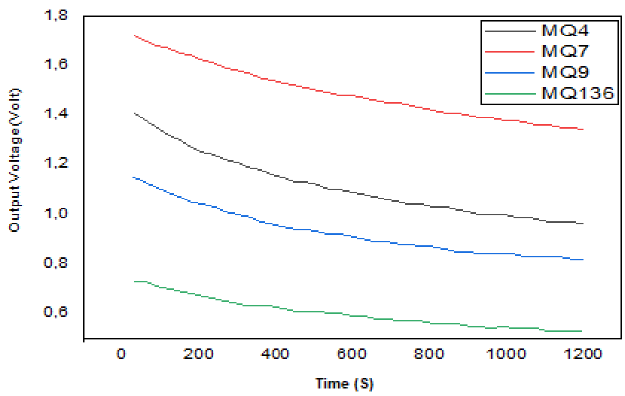
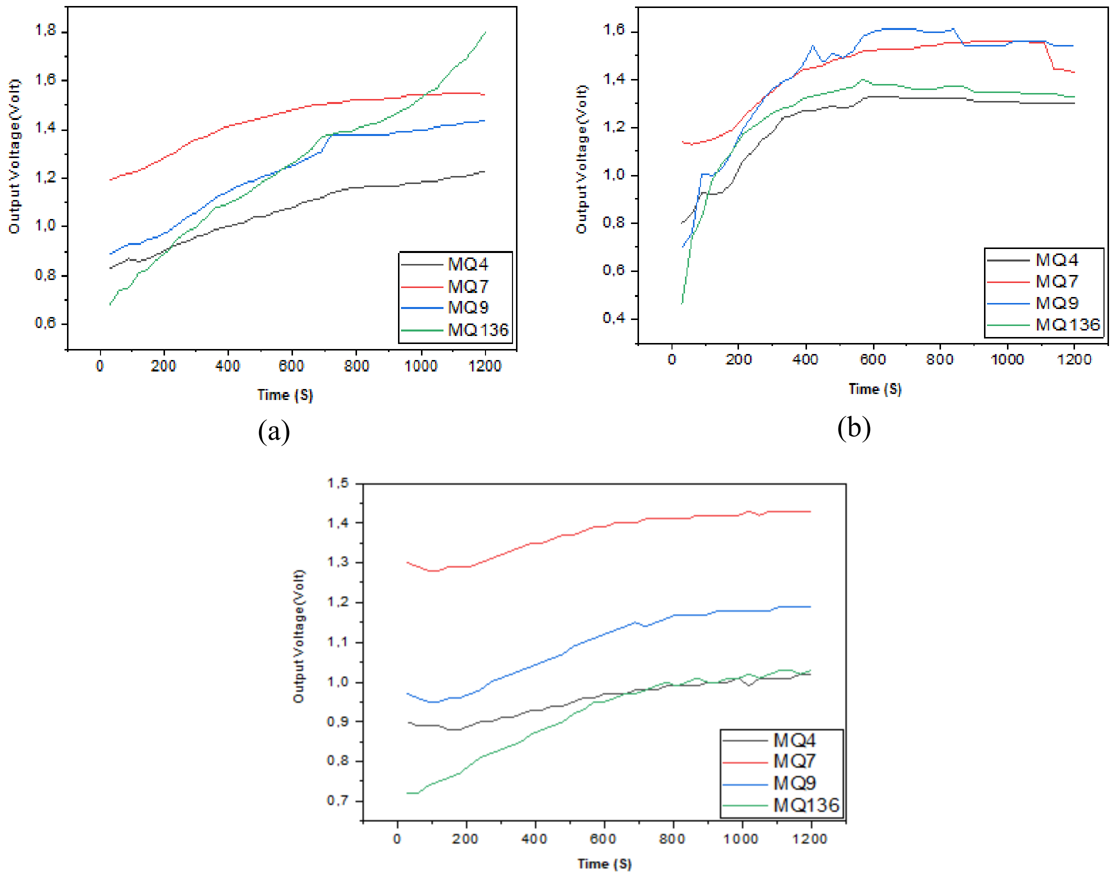


Figure 3. The Output Voltage of Each Sensor Before Sample Testing

Figure 3 shows that the voltage changes produced by the MQ 4, MQ 7, MQ 9, and MQ 136 sensors are quite stable.



(a) (b)

(c)

Figure 4. (a) The output voltage for 20 minutes of samples (a) Pertalite, (b) Pertamax, and (c) Pertamax Turbo

Figure 4 shows that the average output voltage values of Fuel Oil (BBM), namely Pertalite, Pertamax, and Pertamax Turbo for MQ 4 sensors are 1.07 V, 1.22 V, and 0.96 V. For MQ 7 sensors, the output voltage values of each sample are 1.44 V, 1.43 V, and 1.37 V. For MQ 9 gas sensors, the sample output voltage value is 1.23 V, 1.43 V, and 1.09 V. As for the gas sensor MQ 136 obtained the output voltage values of the oil respectively are 1.26 V, 1.25 V, and 0.91 V. From the resulting output voltage values, the order of voltage values from highest to lowest based on the MQ 4 sensor is Pertamax, Pertalite, and Pertamax Turbo. Based on the MQ 7 gas sensor, the voltage values from highest to lowest are Pertalite, Pertamax, and Pertamax Turbo. In comparison, for MQ9 gas sensors, the voltage values from highest to lowest are Pertamax, Pertalite, and Pertamax Turbo. The orders for MQ 136 gas sensors are Pertalite, Pertamax, and Pertamax Turbo.

In order to check whether the gas sensor used can distinguish or extract the aroma of the fuel, the principal component analysis (PCA) using Origin 2019 software was conducted. The extraction results of the four sensors for Pertalite, Pertamax, and Pertamax Turbo oil samples are given in Figure 5.

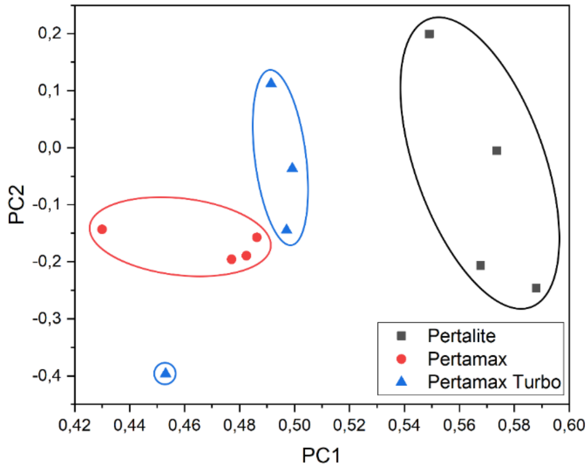


Figure 5. PCA test plot

Figure 5 shows the PC1 score plot, and PC2 shows the data grouping based on each sample's scent. Based on these results, it can be said that the four sensors with an electronic-nose system can distinguish the three aromas of fuel oil well.

4 Conclusion

The Pertalite sample shows that the average output voltages of the MQ 4, MQ 7, MQ 9, and MQ 136 sensors are 1.06 V, 1.44 V, 1.23 V, and 1.25 V, respectively. Then, the Pertamax sample shows that the average output voltages of the MQ 4, MQ 7, MQ 9, and MQ 136 sensors are 1.22 V, 1.43 V, 1.43 V, and 1.26 V, respectively. Furthermore, the average output voltages of the MQ 4, MQ 7, MQ 9, and MQ136 sensors for Pertamax Turbo are 0.96 V, 1.37 V, 1.09 V, and 0.91 V. The plot principal component analysis (PCA) shows three groups of aromas in the sample used: Pertalite, Pertamax, and Pertamax Turbo. Based on the PCA plot, the electronic-nose system can distinguish the aroma of fuel oil of varying types.

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