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Microcontroller – Based H2S Detector Using MQ136 and SMS Gateway

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ABSTRACT

Hydrogen Sulfide (H2S) is a toxic gas that can endanger humans at high levels. Therefore, developing an H2S gas detector is crucial for environmental safety and human health. This study developed an H2S gas detection device using Arduino that provides notifications via SMS. The device uses an MQ-136 gas sensor as the main component to detect H2S gas concentration in the air. The Arduino Uno microcontroller processes data from the sensor and displays gas concentration on a 20x4 LCD screen. For easy information dissemination, the SIM900A module sends SMS notifications every minute and when there is a change in gas concentration. Sensor calibration techniques were implemented to ensure optimal H2S gas accuracy, with field tests showing an error rate of 0.21% for the MQ-136 sensor readings. The device is also equipped with a buzzer and a rotary light; the buzzer and rotary light activate when gas concentrations exceed 30 ppm, while the rotary light operates when H2S concentrations are between 10-30 ppm. This system ensures safe conditions in areas with H2S gas presence. Testing involved simulating H2S gas exposure at various concentrations to assess the detector's responsiveness. Results show the developed device effectively detects H2S gas. This microcontroller-based H2S gas detector with SMS gateway is expected to be widely used in industries and environments for safety and air quality.

Keywords: *Gas H2S, microcontroller, buzzer, warning light, MQ-136.*

ABSTRAK

Hidrogen Sulfida (H2S) adalah gas beracun yang dapat membahayakan manusia pada tingkat tinggi. Oleh karena itu, pengembangan alat pendeteksi gas H2S sangat penting untuk keamanan lingkungan dan kesehatan manusia. Penelitian ini mengembangkan alat pendeteksi gas H2S menggunakan Arduino yang memberikan notifikasi melalui SMS. Alat ini menggunakan sensor gas MQ-136 sebagai komponen utama untuk mendeteksi konsentrasi gas H2S di udara. Mikrokontroler Arduino Uno memproses data dari sensor dan menampilkan konsentrasi gas pada layar LCD 20x4. Untuk memudahkan penyebaran informasi, modul SIM900A mengirimkan notifikasi SMS setiap menit dan ketika terjadi perubahan konsentrasi gas. Teknik kalibrasi sensor diterapkan untuk memastikan akurasi gas H2S yang optimal, dengan uji lapangan menunjukkan tingkat kesalahan 0,21% untuk pembacaan sensor MQ-136. Perangkat ini juga dilengkapi dengan bel dan lampu putar; bel dan lampu putar aktif ketika konsentrasi gas melebihi 30 ppm, sedangkan lampu putar beroperasi ketika konsentrasi H2S antara 10-30 ppm. Sistem ini memastikan kondisi yang aman di area yang terdapat gas H2S. Pengujian melibatkan simulasi paparan gas H2S pada berbagai konsentrasi untuk menilai daya tanggap detektor. Hasilnya menunjukkan bahwa perangkat yang dikembangkan secara efektif mendeteksi gas H2S. Alat pendeteksi gas H2S berbasis mikrokontroler dengan SMS gateway ini diharapkan dapat digunakan secara luas di industri dan lingkungan untuk keamanan dan kualitas udara.

Kata kunci: *Gas H2S, mikrokontroler, buzzer, lampu peringatan, MQ-136*

I. INTRODUCTION

Indonesia has the largest geothermal resources in the world. According to data from the Ministry of Energy and Mineral Resources (ESDM) in 2016, Indonesia has a geothermal energy potential of 29,543.5 Megawatts (MW). With these geothermal resources, various methods of drilling (exploration) and exploitation, namely geothermal production operations, are conducted. However, while the utilization of geothermal resources has positive values, it also has negative impacts, particularly the hazardous waste (B3) produced by geothermal power plants. The waste includes geothermal brine and sludge, with one type being the gas H2S. Hydrogen sulfide (H2S) is a colorless, flammable, explosive, highly dangerous, highly toxic, corrosive gas, heavier than air, and has a distinctive smell of rotten eggs [1]. Due to the fatal health hazards posed by this gas, every company is required to establish safety standards for the environment and workers in accordance with the regulations

of the Minister of Environment Regulation No. 21 of 2008 [2].

Industries operating in the mineral and gas energy sector are developing the potential of natural resources in geothermal power generation. The geothermal power generation process requires many complex pieces of equipment. A byproduct of the electricity processing in geothermal power plants is hydrogen sulfide (H2S) gas, which can lead to various risks, including workplace accidents, fires or explosions, occupational diseases, and environmental pollution, with pipe leaks being common. Hydrogen sulfide (H2S) is a colorless, toxic, flammable gas with a rotten egg smell [3]. H2S is corrosive to natural gas production equipment and must be removed from the production process. This research aims to design and implement a hydrogen sulfide alert system to detect H2S concentration exposure in companies involved in geothermal, oil, and gas power generation. Additionally, the study seeks to understand the operational methods of the hydrogen sulfide alert system as a safety device against H2S gas exposure in companies operating in the mineral energy, gas, and geothermal power generation sectors [4].

The advancement of technology and science has impacted the demand for energy resources. Humanity still relies on natural energy resources. With this advancement, several hazardous factors must be considered in gas detection [5]. Research related to H2S gas, published in the journal titled "Design and Development of Hazardous Gas Measurement Tools for Wireless-Based Mining Excavations," aims to help workers measure toxic gas levels using MQ-7 sensors for Carbon Monoxide (CO), MQ-4 for Methane (CH4), and MQ-136 for detecting Hydrogen Sulfide (H2S). The goal is to monitor safe levels of these gases, with data sent wirelessly [6].

Existing research has developed the use of Wireless Sensor Networks (WSN), which offers better perspectives compared to wired networks, facilitating system repairs and helping predict some workplace accidents [7]. Based on the previous descriptions, the authors initiated the development of a safety device for workplaces and communities to minimize losses due to industrial and community accidents. Therefore, the authors will develop an H2S gas detector that can provide danger notifications via SMS, which can be applied in locations with limited internet data.

II. METHOD

Based on Figure 1, the first stage of the research involves identifying problems in the field. This stage includes observing and collecting issues in the field, followed by a literature study to gather data and materials on the design of an H2S gas detector based on a microcontroller with an SMS gateway. The second stage involves purchasing and designing the device by recording data and designing components according to requirements. The third stage involves assembling the previously designed components by connecting the Arduino Uno to the SMS gateway to connect with the provider network, enabling notifications via smartphone. The next stage involves calibrating the device to align it with company standards and HSE tools. During the simulation, the device is tested to ensure it functions as specified. The following stage involves testing the device for feasibility in field applications. In field applications, the device will be implemented according to field requirements. If calibration or application results in damage or issues, corrections will be made. If no issues arise, analysis, reporting, and conclusions from the research and observations at the test site will be conducted.

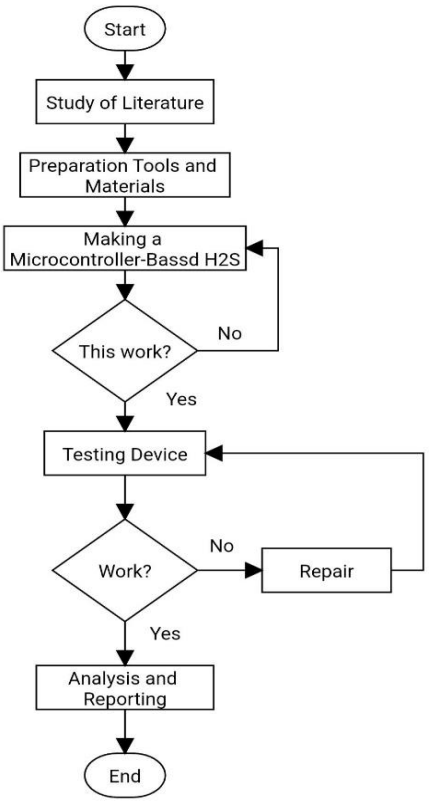

Figure 1. Method flow diagram

In Figure 1, the initial step is to identify problems in the field, followed by a literature review, then preparing the necessary tools and materials, designing the H2S gas monitoring device, calibrating the device, and simulating the device. If any issues occur during the calibration, simulation, testing, or application of the device, repairs will be made first. If successful, the next step is to write the analysis and create a report based on the test results.

A. Design and Construction

This stage involves programming the Arduino Uno and SIM900A, which are the main components for controlling the system and sending SMS notifications. The SIM900A GSM module is compatible with Arduino, being a quad-band GSM/GPRS module. This module is used for data transmission via the SMS (Short Message Service) system. The SIM900A is controlled using ATCommands [8]. The MQ-136 sensor will detect H2S gas and send information via SMS to indicate the quality of the H2S gas level. The purpose of the design and construction stage is to facilitate the identification of successes and failures of the device before the hardware is built and to identify the components to be made.

1. Process and Operation of the Device

The design aims to provide an overview and assess the suitability of the device being created. In this design, a process diagram will be shown to illustrate the workflow or process of the device to be made. This stage will explain the input block, which collects data from the MQ-136 sensor, then processed by the Arduino Uno, and subsequently displays an SMS notification. Short Message Service (SMS)

is a feature of mobile phones that allows sending and receiving short text messages containing characters and numbers. The SMS Gateway is a gateway for sending, receiving, and processing SMS [9]. In case of a dangerous situation, it will activate a Buzzer and a Rotary Lamp. The process diagram for the system creation can be seen in Figure 2.

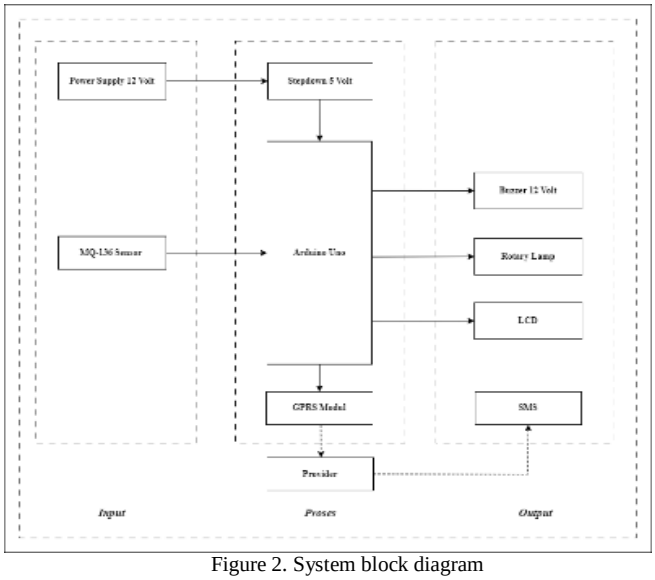

Figure 2. System block diagram

2. *Electrical Design*

This stage involves designing the installation system for each component to be used in the device creation, with designs made using Fritzing software. The design of the H2S gas detector based on a microcontroller with an SMS gateway requires an MQ-136 sensor. The MQ-136 sensor detects the ppm value of H2S gas [10]. Hydrogen sulfide (H2S) is a colorless gas that is almost flammable and has a rotten egg smell. People are usually exposed to hydrogen sulfide from the air, also known as swamp gas. People can typically smell hydrogen sulfide at low air concentrations between 0.0005 ppm and 0.3 ppm [11]. This device uses a microcontroller, specifically the Arduino Uno, to process data from the sensor. The device allows monitoring via SMS notifications using the SIM900A module and also displays data on an LCD. The SMS transmission will send the ppm value of H2S gas and indicate whether the condition is normal or dangerous, as shown in Figure 3.

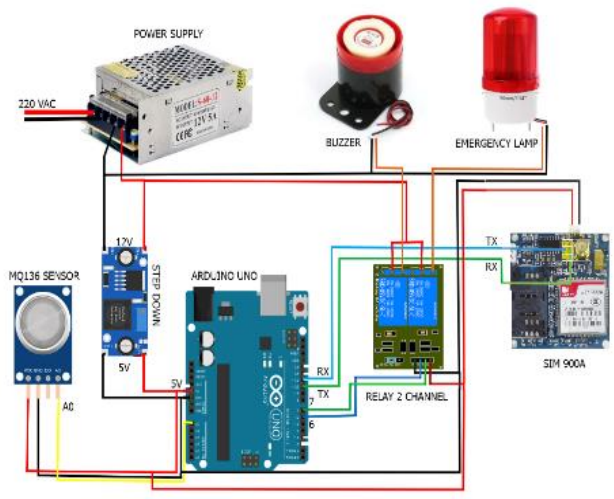

Figure 3. Wiring diagram

- Normal Condition

TABLE 1. INDICATORS ARE IN NORMAL CONDITION

Rate Gas H2S (<10 ppm)	
Indicator	***Condition***
Lampu Rotary	OFF
Buzzer	OFF
SMS Gateway (SIM900A)	ON

- Alert Condition

TABLE 2. INDICATOR ON ALERT CONDITION

Rate Gas H2S (10 – 30 ppm)	
Indicator	***Condition***
Lampu Rotary	ON
Buzzer	OFF
SMS Gateway (SIM900A)	ON

- Emergency Conditions

TABLE 3. EMERGENCY INDICATOR

Rate Gas H2S (10 – 30 ppm)	
Indicator	***Condition***
Lampu Rotary	ON
Buzzer	ON
SMS Gateway (SIM900A)	ON

3. *Mechanic Design*

This stage involves creating a design of the physical form of the device in three-dimensional images. This physical design will provide an illustration of the shape of the device. The device consists of a special outdoor box that is waterproof and corrosion-resistant. The design of the device adheres to standards for field use, such as a height of 150 cm. Additionally, the MQ-136 gas sensor is standardized at a height of 80 cm from the ground, as regulated by ISO 45001. ISO 45001:2018 (Occupational Health and Safety Management Systems) Requirements with Guidance for Use was released on March 12, 2018. ISO 45001:2018 is an international standard that sets requirements or guidelines for occupational health and safety management systems (OHSMS) [12]. The safe placement of the device from the gas source, at a distance of 200 cm – 300 cm, is regulated by occupational health and safety (OHS) standards. Occupational health and safety encompass all conditions and factors that may impact the safety and health of workers or other individuals in the workplace, as regulated by Indonesian Law No.1/1970 on work safety, which defines the workplace as a room or field, enclosed or open, mobile or stationary, where workers perform their duties [13]. The box also serves as storage for the microcontroller and several output components. In this design, the sensor will be mounted on a stand since H2S gas readings are only effective at one meter above the ground. The mechanical design of the H2S gas detector is illustrated in Figure 4.

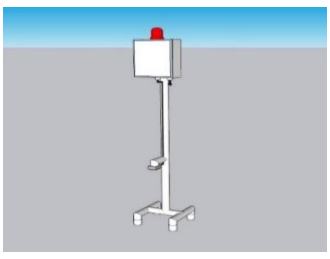

Figure 4. Design 3D device

4. *Software Design*

The software design involves programming the microcontroller and SIM900A module, which function as the controller and for sending notifications about the H2S gas status. The software design has two stages: the first stage is programming the Arduino Uno microcontroller to receive readings from the H2S sensor system, and the second stage is sending SMS notifications using the SIM900A module. The SMS program is focused on notifications to facilitate the transmission of information about the H2S gas status to workers and the public. The software design flow can be seen in Figure 5.

Figure 5. Flowchart

5. *SMS Gateway System Design*

At this stage of software development, an SMS notification system will be created to provide information about hazardous conditions in the surrounding area. This SMS gateway works by connecting messages to a cellular network or through an HTTPS (Hypertext Transfer Protocol Secure) interface. Hypertext Transfer Protocol Secure (HTTPS) is an encrypted version of Hypertext Transfer Protocol (HTTP) called through a web server using HTTPS [14], whereas SSL (Secure Socket Layer) is an encrypted internet security protocol that provides privacy, authentication, and integrity for Internet communications [15]. Short Message Peer-to-Peer (SMPP) is one of the most successful protocols used to support Application to Person (A2P) SMS applications such as mobile marketing, SMS notifications, account verification, and more [16]. The interface of the SMS gateway will be shown in Figure 6.

Figure 6. SMS gateway display

The notification from this device is designed to inform users about the high intensity of H2S gas in the surrounding area. The system sends this information as a text message to the user's mobile phone via an SMS Gateway, processed by an Arduino Uno R3 microcontroller. The notification is then transmitted using a GPRS module, alerting the user to the danger based on the H2S gas concentration levels in parts per million (PPM).

III. RESULT AND DISCUSSION

This research aims to serve as an indicator of the success of the device created, to determine whether it aligns with the design and whether the output meets the desired results. Testing is conducted on each input sensor, specifically the MQ-136 sensor, to determine if it is working correctly or if there are any errors. The measurement results will determine whether the device's output functions properly or if there are any issues. If issues are detected, repairs will be made to ensure the device operates optimally. Before testing the device, an HSE (Health, Security, and Environment) check is conducted to ensure the device's feasibility. The sensor will be tested directly by bringing it close to the H2S gas source to see if the device functions correctly.

A. Simulation of H2S Gas Detection Equipment

The simulation of the H2S gas detection tool was carried out to ensure that the tool could work according to the workflow. This simulation will be the main guideline for whether the tool is working normally or not. The simulation system has three categories of conditions which can run according to these conditions, such as Normal, Alert and Emergency.

TABLE 4. RESULTS OF H2S GAS DETECTION EQUIPMENT

No.	Sensor Gas H2S (ppm)	Condition	Buzer	Rotary Lamp	SMS Gateway
1	1,8	Normal	OFF	OFF	Sent
2	3,1	Normal	OFF	OFF	Sent
3	11,6	Alert	OFF	ON	Sent
4	27,3	Alert	OFF	ON	Sent
5	33,1	Warning	ON	ON	Sent
6	45,9	Warning	ON	ON	Sent

Based on Table 3.1, the simulation results show that the H2S gas detector can operate according to the workflow and display predetermined conditions. This simulation aims to ensure that the readings for Normal, Alert, and Emergency conditions function perfectly.

B. Testing H2S Gas Sensor (MQ-136)

Testing The sensor testing is conducted to compare the measurement results of the sensor with the existing device to determine the accuracy of the sensor used. These measurements will be tested directly in the field with a comparison device. This testing will reveal the error value or the comparison between the readings of the two devices.

Figure 7. Gas detector H2S BW honeywell clip single

Based on Figure 7, it shows the BW Honeywell Clip Single H2S Gas Detector which is used to calibrate the H2S or MQ-136 gas sensor. Calibrate this sensor by comparing the measurement results from the Honeywell Clip Single H2S BW Gas Detector with the MQ-136 sensor.

TABLE 5. H2S SENSOR TESTING

No.	Reading Device (ppm)	Reading Sensor (ppm)	Error (%)
1	15,13	15,16	0,19
2	25,80	25,82	0,07
3	29,79	29,83	0,13
4	34,55	34,65	0,28
5	37,10	37,24	0,37
6	40,30	40,39	0,22
Rata – rata error			0,21

$$Error\ \% = \frac{Sensor\ test\ results - H_2S\ gas\ detector}{Sensor\ test\ results} x100\% \quad (1)$$

Based on Table 5, it can be seen that the comparison between the device readings and the sensor readings has an average error of 0.21%. Both the device readings and the sensor readings have delays that can vary depending on the release of H2S gas. Therefore, the comparison of these readings shows that the difference between the two devices is not significant.

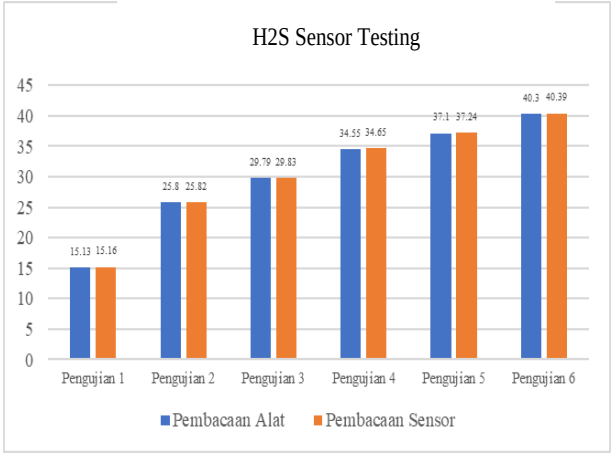

Figure 8. Graph of test difference values

The results obtained show a graph for the H2S gas test values, comparing the instrument readings with the sensor readings. In Figure 3.2, it can be seen that the instrument readings are not significantly different, while the H2S gas test values are almost close to the instrument readings from the company. In the bar graph, the blue bars represent the instrument readings from the company, and the red bars represent the H2S gas readings from the sensor. The measurement differences between the two are not significantly different, with a measurement range difference of only 0.02 – 0.14 ppm.

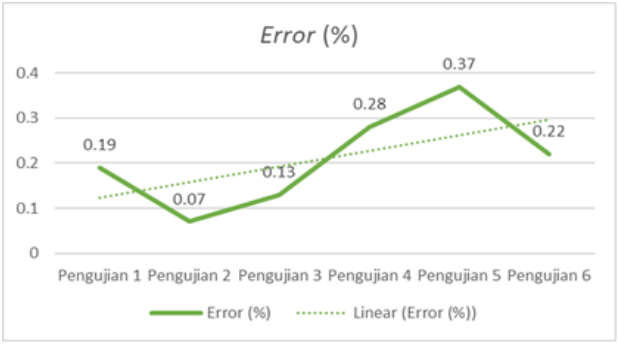

Figure 9. Graph error values

For the error, a graph was obtained showing the error values from the readings between the instrument readings and the sensor readings. In Figure 3.3, it can be seen that the highest error value was in test 5 with an error of 0.37%, and the lowest was in test 2 with an error of 0.07%. These error values were caused by the quality of the sensor used or the temperature around the sensor.

C. Testing the SMS Gateway (SIM900A)

This testing of the SIM900A is conducted by sending phone numbers to see if they can be successfully sent or not. The testing process for the SIM900A involves sending an SMS or notification sequentially between different phone numbers. During this process, there is a delay in transmission, and it is evaluated whether the SMS gateway can send messages according to the desired data or not.

TABEL 6 RESULT SMS GATEWAY

No.	Time	Information		
		Number Handphone 1	*Number Handphone 2*	*Number Handphone 3*
1	13.30	Sent	Sent	Sent
2	13.31	Sent	Sent	Sent
3	13.32	Sent	Sent	Sent
4	13.33	Sent	Sent	Sent
5	13.34	Sent	Sent	Sent
6	13.35	Sent	Sent	Sent

In the SMS Gateway testing, we can see in Table 3.3 that there are three numbers designated to receive messages about the condition of the H2S gas. The SMS gateway will send a message every minute and will also send a message when there is a drastic change in the H2S gas ppm value. As shown in Table 3.3, the SMS gateway sends messages according to the command to do so every minute.

D. Application Device on H2S Gas

In the application of this tool, it will be connected to several components that work sequentially. The H2S gas sensor reading will send an SMS notification to indicate whether the H2S gas level is normal or not. When the tool

detects H2S gas levels of 10-30 ppm, it will indicate a warning status, activate the rotary light, and send an SMS notification through the gateway. If the H2S gas level exceeds 30 ppm, both the buzzer and the rotary light will be activated simultaneously, and an emergency status SMS notification will be sent through the gateway.

TABEL 7. APPLICATION OF THE TOOL TO H2S GAS$_2$S

No.	Sensor Gas H2S (ppm)	Rotary Lamp	Buzzer	Keterangan		
				Number Hp 1	*Number Hp 2*	*Number Hp 3*
1	1,1	OFF	OFF	Sent	Sent	Sent
2	1,3	OFF	OFF	Sent	Sent	Sent
3	3,3	OFF	OFF	Sent	Sent	Sent
4	9,5	OFF	OFF	Sent	Sent	Sent
5	10,5	ON	OFF	Sent	Sent	Sent
6	12,1	ON	OFF	Sent	Sent	Sent

Based on the application of the tool on H2S gas, as shown in Table 3.4, there is one input, namely the MQ-136 sensor, which is used to read the ppm value of H2S gas. This value is then calibrated according to the reading obtained from the detector tool. The sensor has a range of 1–200 ppm and a heater voltage of 5V. The outputs of this application are threefold: a rotary light, a buzzer, and an SMS gateway, which serve as indicators of the H2S gas reading conditions. Each output has its respective function: the rotary light indicates a warning state, while both the buzzer and the rotary light being active indicate an emergency state. Consequently, the SMS gateway will send notifications or SMS every minute. The SMS is sent using a 2G GSM network.

IV. CONCLUSION

From the testing results of the Microcontroller-Based H2S Gas Detector with SMS Gateway, this research successfully designed and implemented an effective H2S gas detection system using the SIM900A and Arduino Uno. This H2S gas detection system will continuously provide real-time data and send notifications continuously according to the readings from the MQ-136 sensor. The data analysis conducted shows that the H2S gas detection system can detect with high measurement accuracy and quick response time, and it facilitates the dissemination of information in the form of SMS notifications, as well as providing warning signals like buzzers and rotary lights. This device could be equipped with solar panels to be applied in areas far from the power grid, and it could also be enhanced with the provision of information via radio frequency or RF transmitter modules, which are useful in areas without network coverage. For more accurate sensor readings, there are alternative H2S sensors such as Solid-State Sensors and Electrochemical Sensors that focus on H2S gas levels.

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