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Development of a Pollutant Monitoring System at a Final Processing Place Based on Internet of Things

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Abstract*—The Final Disposal Site (TPA) has the potential to cause air pollution due to emissions of pollutant gases such as Methane (CH4) and Carbon Dioxide (CO2), which can have negative impacts on the environment and the health of the surrounding community. Therefore, monitoring gas emissions at TPA is important to maintain air quality. This research aims to design a pollutant gas monitoring system at TPA based on the Internet of Things (IoT) and to design an Android application that allows users to access realtime gas monitoring data. Additionally, this research also aims to analyze the impact of TPA on residential areas based on monitoring results of methane (CH4) and carbon dioxide (CO2) gases, which are compared to the Threshold Limit Values (TLV) set by the National Institute for Occupational Safety and Health (NIOSH). The device design in this research consists of an ESP32 microcontroller and MQ-4 (CH4) and MQ-135 (CO2) gas sensors. The device is connected to the internet to communicate with the Firebase database, serving as a communication bridge between the microcontroller and the user (Android application). Gas concentration measurements were carried out at the Tegalgondo Village TPA and compared to the standards set by NIOSH and the Occupational Safety and Health Administration (OSHA). The measurement results showed that the highest methane concentration reached 30.2 ppm in the morning and 23.3 ppm at night, while the highest carbon dioxide concentration was recorded at 423.2 ppm in the morning and 192.2 ppm at night. Both concentrations are below the limits set by NIOSH and OSHA, thus remaining safe for the surrounding environment.*

Keywords*— Integrated Disposal Site,Pollutants, Internet of Things (IoT), Waste.*

I. Introduction

The emergence of Landfills (TPA) as sites for waste management in various regions has had an impact on the surrounding environment, including the potential for air pollution due to the emission of pollutant gases [1]. One landfill that has gained attention is the Tegalgondo Village landfill. Based on observations made by the authors, methane gas (CH4) and carbon dioxide (CO2) are the two main pollutant gases produced from the decomposition of organic waste [2].

The accumulation of organic waste can produce harmful gases. The primary gases generated from the decomposition of organic waste are methane (CH4) and carbon dioxide (CO2). Methane is the most produced gas from the anaerobic decomposition of organic material by methanogenic microbes [3]. Carbon dioxide is produced from the decomposition of organic materials in waste through both aerobic and anaerobic respiration by microorganisms [4]. The emissions of carbon dioxide (CO2) and methane (CH4) are major contributors to global warming and climate change occurring worldwide. The increase in the concentration of these gases in the atmosphere causes the greenhouse effect, where the sun's heat is trapped in the earth's atmosphere, leading to a rise in global temperatures [5].

In 2021, Lova Nugroho et al. conducted research titled "Monitoring System for Methane (CH4), Ammonia (NH3), and Carbon Dioxide (CO2) Gas Levels at Landfills for Preventing Respiratory Diseases Based on a Wireless Sensor Network." In that study, they designed a device to detect gas content around landfills and identify whether the gas levels could cause respiratory infections for the surrounding communities. This study will focus on measuring air quality around landfills, equipped with a temperature sensor to help understand conditions affecting pollutant gas levels. With this technology, a real-time pollutant gas monitoring system allows landfill management to take preventive action immediately if gas concentrations exceed the Threshold Limit Value (TLV) set by the National Institute for Occupational Safety and Health (NIOSH).

Proper landfill management and environmental monitoring are necessary to minimize its negative impact on surrounding residents. However, in reality, landfills like the one in Tegalgondo Village are still not managed optimally. Observations show that large piles of waste remain at the site and are left to decompose, creating unpleasant odors. In addition to suboptimal management, the awareness level of some residents regarding the dangers of gases from waste decomposition at the landfill is also lacking.

Based on these issues, a solution is needed to minimize the impact of landfills on the environment and the health of nearby residents. Therefore, this thesis proposes the design of an " Development of a Pollutant Monitoring System at a Final Processing Place (TPA) Based on Internet of Things." The system is equipped with an MQ-4 sensor to detect methane gas and an MQ-135 sensor to detect carbon dioxide gas. The system also features an Android application for real-time monitoring.

II. Method

The research stages will begin with a literature review of previous studies. After completing the literature review, the research focus will be determined. In the next stage, the device will be modified by referring to previous studies. Following this, the device will be designed and tested after the modifications are complete. Data will then be collected from

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the device testing and analyzed to evaluate both the device design and its readings, allowing conclusions to be drawn from this research.

A. *Flowchart System*

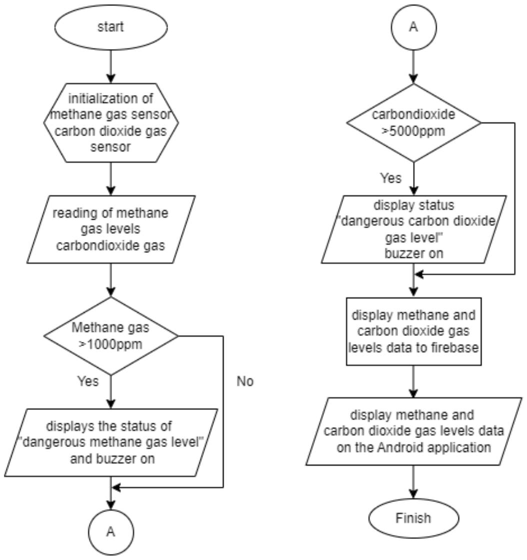

Fig. 1. Flowchart System

The system's performance will be explained through the following flowchart. The flowchart is shown in Figure 1 with the explanation as follows. Initialization of the methane gas sensor MQ-04, carbon dioxide gas sensor MQ-135, and temperature sensor DHT22. Reading data from the methane gas sensor MQ-04, carbon dioxide gas sensor MQ-135, and temperature sensor DHT22. Does the methane gas level indicate more than 1000 ppm? If yes, then send a notification "Dangerous Methane Gas Level" and activate the buzzer alarm. Does the carbon dioxide gas level indicate more than 5000 ppm? If yes, then send a notification "Dangerous Carbon Dioxide Gas Level" and activate the buzzer alarm. Store the monitoring data of methane gas levels, carbon dioxide, and air temperature to the Firebase database. Display real-time gas level monitoring data in the Android application.

B. *Block Diagram*

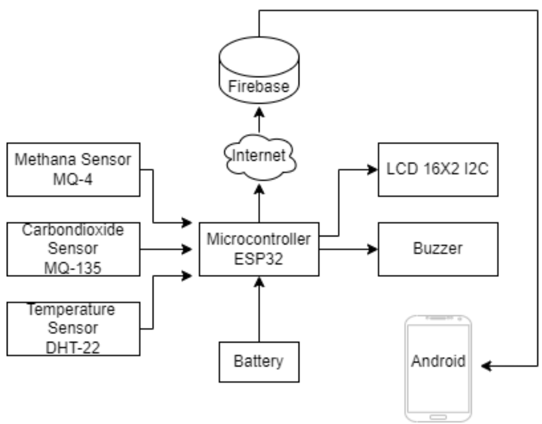

Fig. 2. Block Diagram

Figure 2 above represents the block diagram of the entire system, explained as follows. All system components, such as the microcontroller, sensors, LCD, and buzzer, receive power supply from a battery. The microcontroller connects to a Wi-Fi network to communicate with the Firebase database. The methane gas sensor, carbon dioxide sensor, and air temperature sensor send monitoring data to the ESP-32 microcontroller. The ESP-32 microcontroller receives the sensor data and sends it to the Firebase database via the internet. The LCD displays the monitored variables from the sensors. The buzzer sounds as a warning when specific gas levels are detected. The Android application receives real-time data for remote monitoring of methane gas levels, carbon dioxide, and air temperature, and also serves as a medium for receiving warning alerts when certain gas levels are reached.

C. *Activity Diagram*

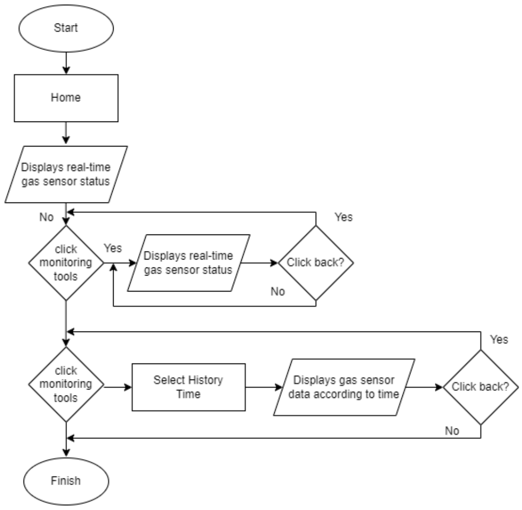

Fig. 3. Activity Diagram

The flowchart in Figure 3 starts with account registration; if the user does not have an account, they are required to register first. After that, the process moves to the login stage, where the user can enter the account they have created. In this login stage, the account is validated to check if it is correctly registered in the application. If the account is valid, the application will display the homepage, showing the real-time status of the gas sensors. The user is provided with two options: the monitoring tool and the history tool. The monitoring tool is designed to display gas sensor data in real-time, while the history tool is used to show gas sensor data at specific times.

III. Results

This chapter will discuss the overall results of everything that has been planned based on the software and hardware design. In this chapter there are the results of testing the sensors that will be used.

A. *Tools Making Results*

Figure 4. The result of making the climber is that there is an ESP32 as a microcontroller and there are 3 sensors and push buttons.

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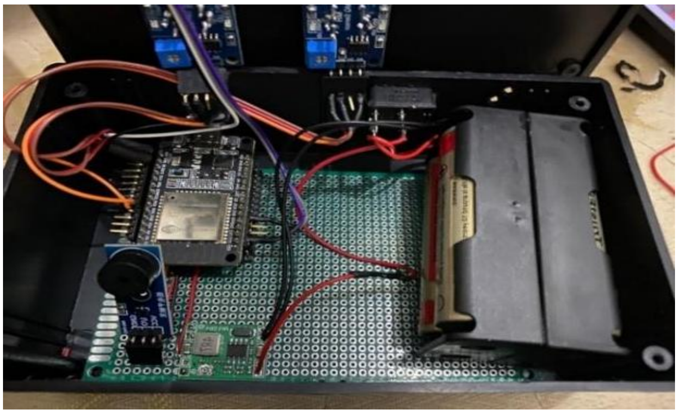

Fig. 4. Front View of the Device

Figure 4. It shows the internal view of the device box, which contains the ESP32 microcontroller, lithium-ion battery, charger module, and jumper wires leading to each sensor, DHT22, buzzer, step-down module, switch, and LCD display.

Fig 5. Internal View of the Device Box

The result There is a 16 x 2 LCD display, MQ4 gas sensor, MQ135 gas sensor, and a buzzer module.

A. Overall System and Analysis

TABLE I. Testing in the Morning at Final Processing Place Based Tegalgondo.

Testing Time (WIB)	Gas Methane (CH4)	Gas Carbon Dioxide (CO2)	Temperature (°C)
08.30	29.2ppm	400.4ppm	29.2
08.31	29.0ppm	400.1ppm	29.5
08.32	28.8ppm	390.2ppm	29.2
08.33	28.9ppm	389.3ppm	29.1
08.34	28.5ppm	390.4ppm	29.5
08.35	29.2ppm	400.7ppm	29.7
08.36	29.7ppm	403.2ppm	29.9
08.37	29.9ppm	420.4ppm	30.3
08.38	30.2ppm	423.2ppm	30.1
08.39	29.9ppm	415.2ppm	30.4
08.40	30.1ppm	423.2ppm	30.7

During the testing period from 08:30 to 08:40 WIB, data showed variations in the concentration of methane (CH_4), carbon dioxide (CO_2), and air temperature at the TPA Tegalgondo. The concentration of methane ranged from 28.5 ppm to 30.2 ppm, while the concentration of carbon dioxide varied between 389.3 ppm and 423.2 ppm. The air temperature during this period ranged from 29.1°C to 30.7°C. In the morning conditions, the waste at the TPA Tegalgondo was abundant due to recent collection by the waste management personnel. This could affect the increase in pollutant gas concentrations. The data in Table 4.1 indicate that the concentration of methane tends to increase as the air temperature rises. At 08:30 WIB, the methane concentration was 29.2 ppm with a temperature of 29.2°C, reaching its peak at 08:38 WIB with a concentration of 30.2 ppm and a temperature of 30.1°C. A similar trend was observed with carbon dioxide, which peaked at a concentration of 423.2 ppm at 08:38 WIB and 08:40 WIB, when the air temperature was also high, at 30.1°C and 30.7°C.

TABLE II. Testing in the Evening at Final Processing Place Based Tegalgondo.

Testing Time (WIB)	Gas Methane (CH4)	Gas Carbon Dioxide (CO2)	Temperature (°C)
19.02	16.3ppm	150.1ppm	26.1
19.03	16.7ppm	150.9ppm	26.6
19.04	14.6ppm	170.2ppm	25.7
19.05	17.4ppm	160.2ppm	26.4
19.06	23.3ppm	173.8ppm	27.8
19.07	19.1ppm	190.3ppm	26.4
19.08	20ppm	192.2ppm	26.7
19.09	16.2ppm	188.6ppm	26.5
19.10	16.9ppm	189.3ppm	26.3
19.11	17.8ppm	190.4ppm	26.5

During the testing period from 19:02 to 19:11 WIB, data showed variations in the concentration of methane (CH_4), carbon dioxide (CO_2), and air temperature at the TPA Tegalgondo. The concentration of methane ranged from 14.6 ppm to 23.3 ppm, while the concentration of carbon dioxide varied between 150.1 ppm and 192.2 ppm. The air temperature during this period ranged from 25.7°C to 27.8°C. In the evening conditions, the TPA Tegalgondo had minimal waste since it had been transferred to another location for incineration, showing lower pollutant levels compared to the morning tests. At 19:02 WIB, the methane concentration was 16.3 ppm with a temperature of 26.1°C, and the highest concentration occurred at 19:06 WIB with 23.3 ppm when the temperature reached 27.8°C. The carbon dioxide also peaked at 19:08 WIB with a concentration of 192.2 ppm at a temperature of 26.7°C.

IV. Conclusion

The research successfully developed an Internet of Things (IoT)-based pollutant gas monitoring system that can detect and monitor methane (CH_4) and carbon dioxide (CO_2) emissions at the Final Disposal Site (TPA) in Tegalgondo Village. The system integrates an ESP32 microcontroller with MQ-4 and MQ-135 gas sensors, and transmits real-time data to an Android application via Firebase. Field testing demonstrated that gas concentration levels remained below the safety thresholds established by NIOSH and OSHA, with the

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highest recorded methane level being 30.2 ppm and carbon dioxide at 423.2 ppm during morning tests.

The real-time monitoring system allows users, especially landfill managers, to take preventive action promptly when gas levels rise. Additionally, the presence of an Android-based interface improves accessibility and public awareness about environmental safety near waste disposal areas. This system represents a scalable and effective solution to support environmentally responsible waste management practices and reduce the health risks posed by air pollutants in residential areas near landfills.

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