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ESP32 Real-Time Smoke Detection Integrated with WhatsApp in Tamansari, Karawang

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ABSTRACT: *This research develops an air quality monitoring system based on the ESP32 microcontroller, utilizing an MQ2 gas sensor and a DHT22 temperature-humidity sensor. The system is designed to monitor gas concentration and environmental conditions (temperature and humidity) in real-time in Tamansari Village, an area known for frequent open burning activities. Sensor readings are periodically transmitted to users via WhatsApp notifications using the CallMeBot API, providing early warnings when potentially hazardous gas levels are detected. Test results indicate that the system effectively detects changes in gas concentrations and temperature with reasonable accuracy and delivers timely alerts. Thus, the system can function as a supportive tool in mitigating air pollution risks in the study area.*

KEYWORDS: *air quality monitoring, DHT22, ESP32, MQ2 sensor, Tamansari Village, WhatsApp Bot*

I. INTRODUCTION

Air pollution is one of the most serious environmental issues, especially in regions with intensive open burning activities. Tamansari Village is one of the areas significantly affected by air pollution due to waste burning and traditional limestone processing. This situation poses health risks to local residents due to the exposure to harmful gases released during combustion. In fact, the problem has drawn the attention of the West Java provincial government, where Governor Dedi Mulyadi personally visited the area to observe the air quality conditions firsthand [1].

According to data from the local Environmental Agency and several studies on air pollution in industrial and residential areas surrounding Tamansari, the levels of hazardous gases such as carbon monoxide (CO) often exceed the safe limits recommended by the World Health Organization (WHO), which is 9 ppm for CO over an 8-hour average exposure. Long-term exposure to these pollutants has led to increased cases of respiratory disorders and lung diseases among the local population [2].

As part of mitigation efforts and to raise environmental awareness, this research aims to develop an air quality monitoring device based on the MQ2 gas sensor and DHT22 temperature-humidity sensor, capable of detecting hazardous gas levels as well as temperature and humidity parameters in real-time. The MQ2 sensor is selected for its sensitivity to various dangerous gases commonly found in combustion smoke, while the DHT22 sensor measures environmental conditions that can affect gas dispersion. The sensor readings are sent directly to the local government through WhatsApp notifications using the CallMeBot API, providing quick insights into the danger level of air pollution around Tamansari Village [3].

The ESP32 microcontroller was chosen as the core of the monitoring system due to its high capability in Wi-Fi and Bluetooth connectivity, low power consumption, and affordable cost. The MQ2 gas sensor is highly sensitive to hazardous gases such as LPG, carbon monoxide, and combustion smoke and is easy to integrate with microcontrollers. The DHT22 complements the system with temperature and humidity measurements that can influence the dispersion of gases in the environment [4]. This combination allows for the creation of an effective, accurate monitoring device capable of sending real-time data through WhatsApp notifications using the CallMeBot API, enabling rapid responses to pollution incidents.

Previous studies have developed air quality monitoring systems using MQ2 sensors and ESP32 microcontrollers, but most were limited to conventional data transmission methods such as mobile applications or web dashboards. This research improves on those aspects by integrating automatic WhatsApp notifications, which are more accessible for local governments and the general public, and applying the system directly in an area with specific pollution conditions like Tamansari Village [5].

This research is significant not only as a localized solution for Tamansari but also as a model for developing low-cost, practical, real-time IoT-based air quality monitoring systems. The implementation of this device can help governments and communities take swift action to reduce health risks caused by air pollution, and it contributes to the advancement of environmental monitoring technologies applicable to other areas facing similar challenges.

II. OVERVIEW

A. ESP32 MIKROKONTROLER

The ESP32 is a System on Chip (SoC) microcontroller equipped with wireless connectivity features such as Wi-Fi 802.11 b/g/n and Bluetooth version 4.2. It offers several critical features, including a dual-core processor, onboard memory, and GPIO (General Purpose Input Output) pins for interfacing with various sensors and actuators. Compared to other microcontrollers like Arduino, ESP32 stands out for its built-in Wi-Fi capability, making it highly suitable for Internet of Things (IoT) applications [6].

Hardware-wise, ESP32 comes in two main variants, with 30 and 36 GPIO pins. The 30-pin version is often preferred due to its flexible GND pin configuration. Each pin is clearly labeled for ease of wiring, and the board supports USB-to-UART interfacing for programming through platforms such as Arduino IDE. The board can be powered through a micro USB port [7].

B. INTERNET OF THINGS (IOT)

The Internet of Things (IoT) represents a significant evolution of internet technology, establishing a global infrastructure that facilitates seamless interaction between devices and humans. Since the public adoption of the internet in the early 1990s, its initial development centered on transforming daily services, particularly in areas such as financial transactions, e-commerce, and information exchange. These changes were driven by rapid advancements in communication technologies. Today, the integration of the internet into both domestic and professional environments reflects a complex network of machine-to-machine and human-to-machine connectivity [8], [9].

C. DHT 22 SENSOR

The DHT22 is a digital sensor designed to measure environmental temperature and humidity with high accuracy. It utilizes capacitive sensing for humidity and a thermistor for temperature detection. The sensor is digitally calibrated, ensuring accurate and stable long-term performance, making it an ideal choice for environmental applications, including storage systems requiring strict climate control [10], [11].

Technically, the DHT22 can measure temperatures from -40°C to 80°C and relative humidity from 0% to 100% RH, operating on 3.3 to 6 VDC. It uses a single-wire digital communication protocol. The temperature measurement accuracy is ±2°C, and the humidity accuracy is ±5% RH. These specifications make the DHT22 a strong candidate for IoT-based environmental monitoring systems [12].

D. MQ 2 SENSOR

The MQ2 gas sensor is designed to detect a range of flammable and hazardous gases, including smoke, LPG, propane, methane, hydrogen, and alcohol. It is a semiconductor-type sensor that uses SnO_2 (tin dioxide) as the sensing element. The MQ2 operates based on changes in its internal resistance when exposed to certain gases. This resistance variation is then converted into an analog voltage readable by a microcontroller [13].

In practice, MQ2 is widely used in air quality monitoring systems and fire detection alarms due to its high sensitivity to smoke and combustible gases. The sensor has both analog and digital outputs, allowing users to manually set thresholds using the onboard potentiometer. This flexibility makes MQ2 suitable for a range of applications, from simple to complex systems [14].

E. WHATSAPP BOT

A WhatsApp bot is an automation system designed to respond to messages sent via the WhatsApp platform without direct human interaction. This technology is widely used in customer service, system notifications, and interactive communication. The bot operates by recognizing patterns or keywords in incoming messages and replying with pre-programmed responses. In more advanced implementations, some bots integrate artificial intelligence (AI) algorithms to enable more natural, human-like interactions [15].

III. METHODOLOGY

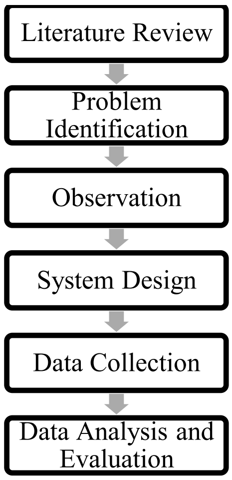

Fig. 1 research workflow

A. LITERATURE REVIEW

This research begins with a literature review on the impact of air pollution caused by open burning and traditional limestone processing, especially in rural areas. Various reports and studies from environmental institutions show that long-term exposure to harmful gases such as carbon monoxide (CO) can cause serious respiratory problems. This study also examines different air quality monitoring technologies based on IoT that are used for real-time detection and data transmission via the internet.

B. *Problem Identification*

In this phase, the researcher analyzes challenges in preventing fire incidents in campus laboratories. Issues identified include delays in smoke detection and the lack of prompt alerts to authorities. These challenges point to the need for a real-time detection system that can automatically notify relevant personnel via accessible communication platforms such as WhatsApp, enabling faster preventive and mitigation actions.

C. *Observation*

Observations were made to understand the actual conditions in the study area, including sources of pollution and the pattern of burning activities. Researchers also recorded environmental factors such as temperature, humidity, and wind direction, which may affect the spread of gases. These observations are important for deciding the best locations to install the monitoring device.

D. *System Design*

The monitoring system is designed using the ESP32 microcontroller integrated with an MQ2 sensor (to detect smoke and harmful gases) and a DHT22 sensor (to measure temperature and humidity). Sensor data is sent via the ESP32 Wi-Fi connection to the CallMeBot API, which automatically sends notifications to WhatsApp users (such as local government officials). The electrical circuit and the program for the microcontroller are developed and tested step by step until the system works in real-time.

E. *Data Collection*

After the system is assembled, data is collected from the sensors over a certain period to observe the air pollution patterns in the area. The data includes gas concentration, temperature, and humidity, and is automatically sent and recorded through WhatsApp notifications. Data collection is carried out during times when burning activities are more likely, to see how the system responds to pollution changes

F. *Data Analysis and Evaluation*

The collected data is analyzed to assess the effectiveness of the system in detecting pollution and the speed of its notifications. The evaluation includes technical aspects (such as sensor accuracy, data transmission stability, and response time), as well as practical aspects (such as the ease of receiving alerts by decision-makers). Based on this analysis, conclusions and recommendations are made for further development of the system or for its application in other areas with similar problems.

IV. Results and Discussion

A. *Observation Location*

Fig. 2 Observation Location

The system testing was conducted in Tamansari Village, a rural area with relatively low ambient air pollution. However, local sources of pollution, such as cooking smoke and open burning of household waste, were frequently observed. Most houses in the area have limited ventilation, which increases the risk of indoor air pollution. This condition emphasizes the importance of an air quality monitoring system to provide early warnings and help prevent potential health issues. During observation, cooking activities and waste burning were identified as the main contributors to the increase in hazardous gases like carbon monoxide (CO). The high humidity in the area also affected the performance of the DHT22 sensor, which measures temperature and humidity. Despite these environmental challenges, there were no significant physical interferences such as heavy dust or mechanical vibrations that could disrupt the sensor operation. Therefore, the data collected was considered valid and representative of the actual conditions in the testing environment.

B. *Diagram System*

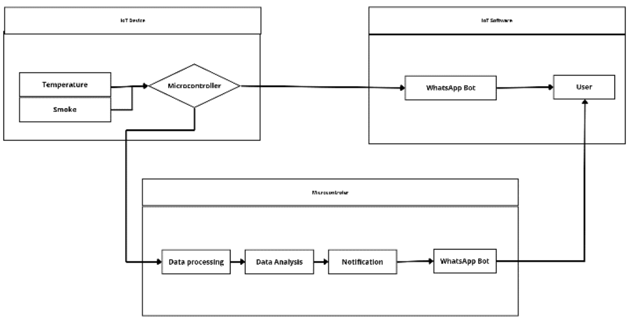

Fig. 3 System Diagram

As shown in Fig 3, this system is designed as a temperature and smoke monitoring solution based on the Internet of Things (IoT), integrated with automatic notifications via a WhatsApp Bot. The system is composed of three main components: the IoT device for data collection, the microcontroller for data processing, and the IoT software for sending notifications. In the initial stage, a temperature sensor (DHT22) and a smoke sensor (MQ2) are installed to monitor environmental conditions in real-time. These two sensors measure key parameters such as temperature, humidity, and the concentration of smoke or harmful gases that may indicate a potential fire. The data collected by the sensors is then transmitted to the ESP32 microcontroller, which acts as the central processing unit of the system. The microcontroller processes the raw data into more meaningful information, such as temperature in degrees Celsius or smoke concentration based on predefined thresholds.

Once the data is processed, the system analyzes it to determine whether the environment remains within safe limits or has reached a hazardous level. If abnormal conditions are detected, such as excessive heat or a significant amount of smoke, the system will trigger the generation of a notification. This alert is then sent through the internet using the CallMeBot API to a WhatsApp Bot. The WhatsApp Bot serves as a bridge to deliver warning messages directly to the registered user's phone number. In this way, users can receive instant alerts via WhatsApp when an emergency occurs in the monitored area. The notification includes critical information such as the type of hazard, the detected values, and the time of the incident. This integration enables a fast response to emergencies, making the system highly effective for use in air pollution-prone areas such as Tamansari Village.

C. FLOWCHART

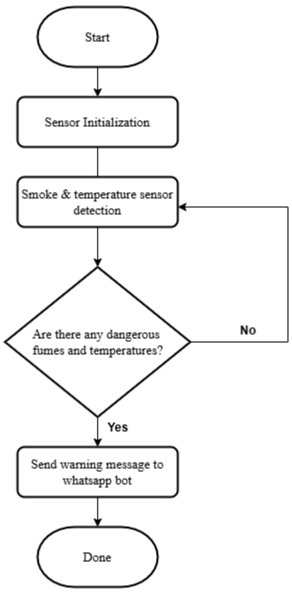

Fig. 4 Flowchart

As shown in Fig 4. The system starts by initializing the temperature (DHT22) and smoke (MQ2) sensors to ensure they are ready for monitoring. These sensors continuously collect data on environmental temperature and smoke levels, which the ESP32 microcontroller processes to check if any values exceed predefined safe limits. If the readings remain normal, the system keeps monitoring in real-time. However, if dangerous conditions such as high temperature or significant smoke presence are detected, the system automatically sends a warning message via the CallMeBot API to a WhatsApp bot, which then forwards the alert directly to the user's WhatsApp. This immediate notification includes important details about the hazard, enabling users to respond promptly to potential emergencies. After sending the alert, the system continues monitoring to ensure ongoing protection.

D. SCHEMATIC

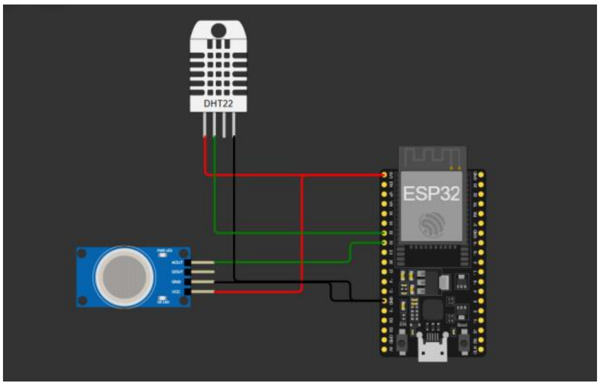

Fig. 5 Schematic

The schematic in fig 5 works by connecting the DHT22 temperature and humidity sensor and the MQ-2 smoke sensor to the ESP32 microcontroller, which acts as the central processing unit. Both sensors receive power from the ESP32's 3.3V and ground pins. The DHT22 sends temperature and humidity data to the ESP32 via its data pin connected to a digital GPIO, while the MQ-2 outputs analog or digital signals representing smoke or gas concentration to another GPIO pin on the ESP32. The ESP32 continuously reads these sensor signals, processes the raw data into meaningful environmental measurements, and evaluates whether the readings exceed predefined safety thresholds. If hazardous conditions such as high temperature or significant smoke levels are detected, the ESP32 triggers the system to send an alert notification through an internet-connected service, such as a WhatsApp Bot, ensuring timely warnings to the user.

E. HARDWARE

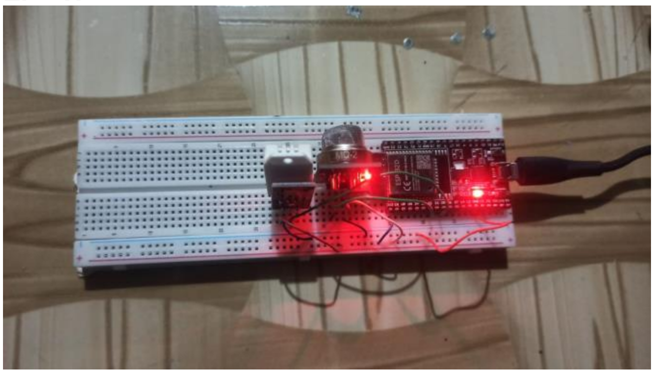

Fig. 6 Hardware

The system consists of an ESP32 development board connected to a DHT22 temperature and humidity sensor and an MQ-2 gas/smoke sensor on a breadboard using jumper wires. The ESP32, powered and programmed via USB, acts as the main controller with built-in WiFi and Bluetooth, ideal for IoT applications. The DHT22 sensor provides temperature and humidity data to a digital pin on the ESP32, while the MQ-2 sensor sends smoke and gas concentration readings to an analog or digital pin. Both sensors receive power through the breadboard connected to the ESP32's 3.3V and ground pins. The ESP32 continuously processes the incoming data and, if dangerous conditions such as high temperature or smoke are detected, it sends an automatic alert via WiFi to a WhatsApp Bot. This setup allows users to receive immediate warnings, making the system effective for real-time environmental monitoring and early smoke detection.

F. SOFTWARE

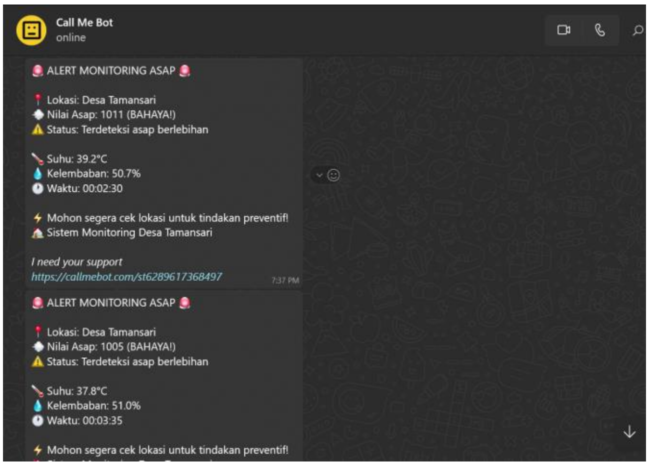

Fig. 7 Software Whatsapp Bot

The software serves as an automatic monitoring system designed to send real-time alert notifications via WhatsApp when smoke is detected in a specific area, such as Tamansari Village. It operates by continuously reading environmental data from sensors connected to the ESP32 microcontroller, specifically the DHT22 for temperature and humidity, and the MQ-2 for gas or smoke detection. When the gas or smoke level exceeds a predefined threshold, the system identifies it as a potential danger, such as a fire risk or gas leak. The software then generates an alert message containing key information, including the location, current temperature, humidity, and gas level. This message is automatically sent through a WhatsApp API (e.g., CallMeBot), ensuring that the user receives the notification instantly. As a result, users can take immediate action in response to hazardous environmental conditions, making the system highly effective for early warning and disaster prevention.

G. TESTING

The test was conducted to check the response of the air quality monitoring system based on the readings from the installed sensors. These sensors are used to detect air quality (harmful gases) and temperature/humidity in the surrounding environment. Based on the data obtained, the system is able to provide notifications or warnings that match the detected conditions.

1. Calibration
   Table 1 shows the calibration results of the sensor as an indicator for the system to function properly.

Tbl 1. Indikator Kalibrasi Sensor

1	Air Quality	Safe	In safe conditions, the MQ-2 sensor data ranges from 0 to 999.
		Hazardous	In hazardous conditions, the MQ-2 sensor data ranges from 1000 to 4095, and the microcontroller will send a warning notification via WhatsApp bot.
2	Temperature	Safe	In safe conditions, the temperature data ranges from 0°C to 36°C.
		Hazardous	In hazardous conditions, the temperature data ranges from 37°C to 80°C, and the microcontroller will send a warning notification via WhatsApp bot.

2. Performance Evaluation
   The system was tested 10 times for each sensor with variations in air quality and temperature. The purpose of this testing was to ensure that each sensor can accurately detect danger and send warnings through WhatsApp. The data obtained was used to assess the sensitivity and effectiveness of the system in responding to hazardous conditions in the laboratory.

Tbl 2. Testing MQ2 sensor

No	ADC Value (Air Quality)	Air Quality	Action
1	300	Safe	

2	458	Safe	No action, air quality is normal
3	670	Safe	
4	1020	Dangerous	Warning sent via WhatsApp
5	1090	Dangerous	
6	1230	Dangerous	
7	1450	Dangerous	
8	1780	Dangerous	
9	1999	Dangerous	
10	2400	Dangerous	

Based on the data obtained from the MQ2 sensor, the ADC values range from 300 to 2400. Values below 999, as seen in trials 1 to 3 (300, 458, and 670), indicate safe air conditions and do not require further action. However, starting from the 4th trial with a value of 1020, the sensor detected hazardous air conditions due to an increase in smoke concentration. The values continued to rise, reaching 2400 in the 10th trial, indicating that the level of air pollution caused by smoke became increasingly high, most likely due to active combustion occurring near the sensor. The danger threshold (≥1000) was successfully used as a trigger for automatic actions, such as sending notifications via WhatsApp. Therefore, the MQ2 sensor functions effectively in monitoring air quality and providing a quick response to hazardous air pollution.

Tbl 3. Testing DHT 22 sensor

No	Fire Distance (cm)	Temperature (°C)	Fire Detection	Action
1	100	35.0	Safe	No action, temperature within normal limits
2	80	38.2	Dangerous	Warning sent via WhatsApp
3	60	41.6	Dangerous	
4	50	45.3	Dangerous	
5	40	49.1	Dangerous	
6	35	52.4	Dangerous	
7	30	56.0	Dangerous	
8	25	60.5	Dangerous	
9	20	64.7	Dangerous	
10	15	68.9	Dangerous	

The DHT22 sensor is used to monitor air temperature at various distances from a fire source. At a distance of 100 cm, the measured temperature is 35.0°C, which is still in the safe category, as the danger threshold is defined at ≥37°C. Starting from 80 cm, the temperature gradually increases, reaching 68.9°C at a distance of 15 cm. This rise in temperature reflects the heat intensity produced by the fire source and the effectiveness of the sensor in detecting real-time temperature changes. The system's response is shown by sending the first warning when the temperature reaches 38.2°C at 80 cm, indicating that the threshold has been exceeded. This trend shows that the closer the sensor is to the fire, the higher the detected temperature, and the system automatically sends a notification as a preventive action. Therefore, the DHT22 has proven capable of providing accurate data to detect the presence of fire based on environmental temperature.

The smoke monitoring device, designed using a combination of MQ2 and DHT22 sensors, has successfully demonstrated good performance in detecting air quality and environmental temperature around the burning area. Based on the MQ2 sensor test results, the system can detect air quality with sufficient sensitivity. When the ADC value is below 999, the system classifies the environment as safe and does not trigger any action. However, when the ADC value rises above the danger threshold (≥1000), the system automatically sends a warning notification via WhatsApp in response to the hazardous condition. An ADC value reaching 2400 in the tenth trial shows that the device is capable of detecting very high smoke or gas concentrations, indicating that the MQ2 sensor functions optimally as a detector.

Meanwhile, the DHT22 sensor also makes an important contribution in monitoring the surrounding air temperature. From the test results, the detected temperature consistently increases as the sensor is brought closer to the fire source, from 35.0°C at 100 cm to 68.9°C at 15 cm. This significant temperature increase was successfully captured by the DHT22 and used as an indicator of potential fire hazards. The danger temperature threshold (≥37°C) was accurately set, where at 80 cm the temperature was already in the dangerous category and triggered the system to send a warning. This shows that the device is capable of detecting not only smoke but also the heat from the fire source quite accurately, enhancing the overall reliability of the system. The combination of these two sensors allows the system to provide effective and rapid early warnings against potential fire hazards in the surrounding environment.

V. CONCLUSION

1. The smoke detection system uses an ESP32 microcontroller to monitor air quality in real-time with an MQ2 sensor and environmental temperature with a DHT22 sensor.
2. When smoke or temperature exceeds set limits, the system automatically sends a warning notification via WhatsApp using the CallMeBot API service.
3. The MQ2 sensor has high accuracy in detecting smoke and harmful gases.
4. The DHT22 sensor consistently and quickly records changes in temperature.
5. The set thresholds are ADC value ≥ 1000 for MQ2 and temperature ≥ 37°C for DHT22, which effectively indicate dangerous conditions.
6. The system uses easy-to-find, low-cost components, allowing for wide implementation, especially in burning areas like Tamansari, Karawang.
7. This system increases awareness among the community and authorities about the importance of early detection and fast response to potential air pollution.

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Furkhon Nurdiyanto, was born in Bekasi on December 4, 2003. He is currently studying Electrical Engineering at Singaperbangsa University Karawang since 2021. His research focuses on electrical systems, instrumentation, control, and developing monitoring systems based on microcontrollers and renewable energy. As an active student, Furkhon has practical experience in installing and operating off-grid solar power systems and maintaining instruments and control devices through various professional training programs.

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