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Microcontroller-Based Air Pollution Monitoring System

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ABSTRACT
The increase in air pollution is a serious environmental issue in many major cities in Indonesia. This study aims to develop an effective and efficient air pollution monitoring system using a microcontroller. The designed system consists of air pollution sensors capable of detecting pollutants such as PM10, CO2, and NO2. The data collected from the sensors are processed by the microcontroller and displayed in real-time to users through a web-based interface. This method allows users to accurately and promptly monitor the air quality in their surroundings. The results show that the microcontroller-based monitoring system operates stably and provides accurate data on the concentration of pollutants in the air. This system is expected to be a valuable tool for the general public and authorities in monitoring and managing air quality and taking preventive measures against the adverse effects of air pollution.

Keywords*: Air Pollution, Microcontroller, Sensors, Monitoring, Air Quality*

INTRODUCTION

The occurrence of air pollution is caused by factory chimneys, motor vehicles, volcanic eruptions, toxic natural gases, fires, and other sources containing harmful compounds, one of which is carbon monoxide (Weebly, accessed in 2020). Each air quality control has its own needs, so the use of monitoring methods should be adjusted to the objectives of ambient air monitoring itself (Akmal, 2009). The results of ambient air quality monitoring can be used to calculate the Air Quality Index. The Air Quality Index (AQI) is one of the instruments that can be used to assess air quality in a simple way using several selected parameters. According to the Decree of the Minister of Environment No.: KEP 45/MENLH/10/1997 and KEP107/KABAPEDAL/11/1997 on the Air Pollutant Standard Index (ISPU), the parameters used to determine ISPU are Sulfur Dioxide (SO2), Nitrogen Dioxide (NO2), Ozone (O3), Carbon Monoxide (CO), and Carbon Dioxide (CO2).

In contrast, the calculation of the AQI uses two main parameters: Nitrogen Oxides (NOx) and Sulfur Oxides (SOx). The results of the AQI calculation can be used to determine the air pollution conditions in a region and evaluate the success of air pollution management and control efforts (Meteorology, Climatology, and Geophysics Agency, 2012).

According to data from the Central Statistics Agency (BPS) in Jombang Regency, the population was 1,318,062 people in 2020 (https://jombangkab.bps.go.id), and population density correlates directly with the transportation needs of the community to support daily activities. The transportation needs of the community can subsequently impact air quality due to high transportation activity.

Moreover, the city's economic growth leads to increased industrial activities that also contribute to the deterioration of air quality. Air quality degradation can also originate from agricultural activities, waste management, dust, household energy use, and power generation activities. In 2023, the air pollution index was categorized as "Moderate" with an AQI of 93, meaning the concentration of PM2.5 in the air reached a level that could negatively affect human health. Therefore, it is essential to take measures to reduce exposure to air pollution, such as avoiding excessive outdoor activities, wearing masks when necessary, and improving indoor ventilation.

From the above discussion, the author is interested in conducting research titled "Design and Development of an Air Pollution Monitoring System".

METHOD

Type of Research

In designing this air pollution monitoring device, the author uses the RAD (Rapid Application Development) method with the following stages:

1. Project Needs Identification Identifying the needs and objectives of the research, which includes the project goals, importance, and key features required.
2. Prototyping Creating an initial prototype of the product, usually featuring basic functionalities that reflect the main features of the final product.
3. Rapid Construction and Feedback Quickly and iteratively building the prototype with a primary focus on producing a testable product as soon as possible.
4. Implementation and Final Product Completion Implementing the tested and accepted prototype into the final product. This stage includes further prototype development, addition of extra features, debugging, performance optimization, and preparing the product for market release or research purposes.

Research Design

The research design for the air pollution monitoring system involves several components that outline how the study was structured and executed. Here are the key elements of the research design:

1. **System Design**
   The system is designed to include air pollution sensors capable of detecting pollutants such as PM10, $CO2$, and $NO2$. The data from these sensors is processed by a microcontroller, which then displays the information in real-time through a web-based interface 1.
2. **Prototyping**
   The research employs a prototyping approach where an initial version of the monitoring system is created. This prototype includes essential features that allow for the basic functionality of monitoring air quality 2.
3. **Data Collection**
   The system continuously collects data from the sensors. The microcontroller monitors the output from the sensors and updates the web interface accordingly, allowing for real-time data access 4.
4. **Testing and Implementation**
   The prototype is tested in areas prone to air pollution to evaluate its effectiveness. The system must be connected to Wi-Fi to ensure that data can be updated and displayed in real-time on the website 7.
5. **Feedback Mechanism**
   The design includes a feedback mechanism where the system can indicate changes in air quality through visual indicators on the web interface, enhancing user awareness and response to pollution levels 4.

Overall, the research design is focused on creating a functional and user-friendly air quality monitoring system that can provide valuable data for both the public and authorities.

Research Approach

The research approach in the study of the air pollution monitoring system is applied research, aimed at developing practical solutions to the problem of air pollution. This research integrates microcontroller technology to design a device that provides real-time data on air quality. The Rapid Application Development (RAD) method is employed to create prototypes iteratively, focusing on user feedback. The system is designed to be easily accessible to the public and authorities, and it is tested in real-world conditions to ensure reliability and accuracy of the data presented. Thus, this approach focuses on developing a functional and effective system for monitoring air pollution.

Research Design

a. Working Mechanism of the Device

The software running on the Wemos D1 Mini for controlling the air pollution monitoring device operates as follows:

1. When powered on, the microcontroller detects the output from the MQ-135 sensor, which will detect air pollution.
2. If the output value is high, the indicator will light up red on the website.
3. The microcontroller will continuously monitor for any changes in the sensor's value.
4. If there is a change in the value indicating an increase or decrease in air pollution, the

microcontroller will send data to the website and light up the red indicator on the website.
5. This process will continue indefinitely.

b. Block Diagram of the Device

To form the air pollution monitoring device, all the components mentioned above need to be integrated. The block diagram below illustrates the connection between these components:
1. MQ-135 Sensor: Detects air pollutants.
2. Wemos D1 Mini: The microcontroller that processes data from the sensor.
3. WiFi Module (built into Wemos D1 Mini): Transmits data to the web server.
4. Web Server: Receives data from the microcontroller and updates the website in real-time.
5. Website Interface: Displays real-time data and status indicators to users.
of the following phases:

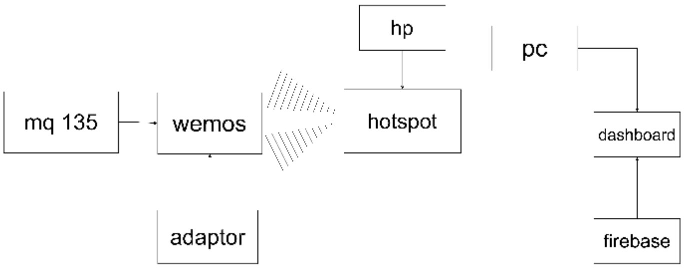

Figure 1. Block Diagram

c. lowchart

Below is the design of the air pollution monitoring system represented in a flowchart.

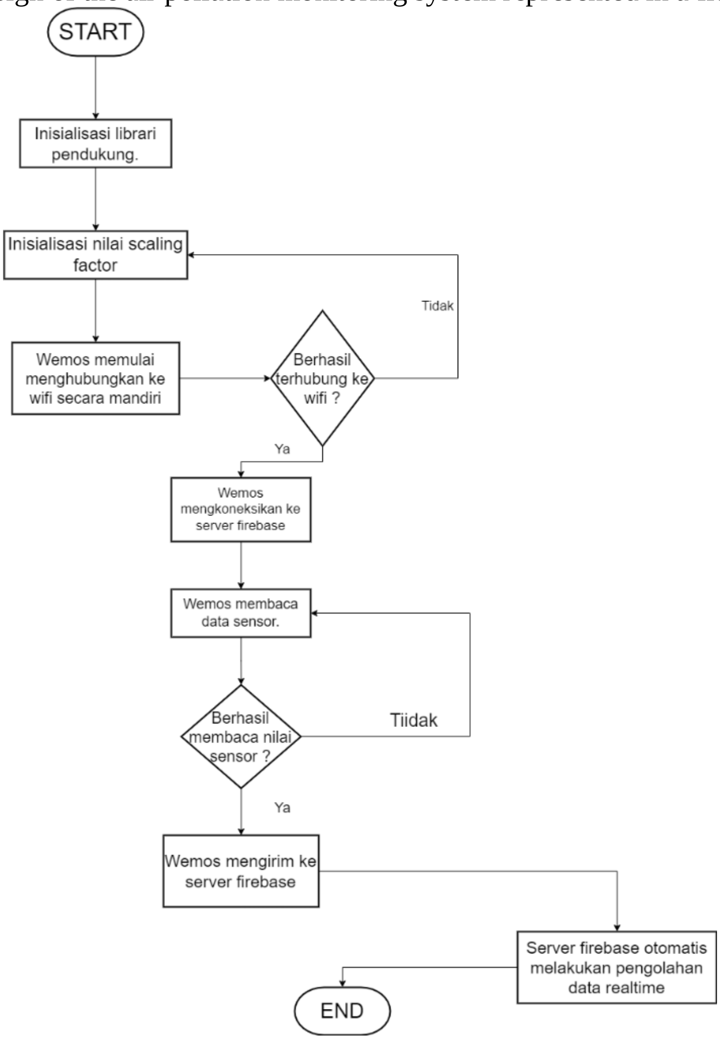

Figure 2. Device Flowchart

d. Device Design

After understanding the working mechanism of the air pollution monitoring system through the flowchart above, we need to know the device's design.

Table 1. Components Used

No	Component
1	Wemos D1 Mini
2	MQ-135 Sensor
3	Jumper Wires
4	Battery

The tool design drawing is as follows,

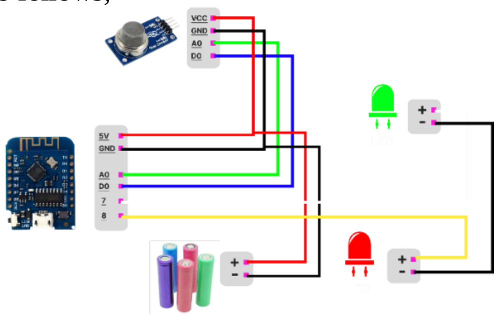

Figure 3. Device Circuit

e. User Interface Design

In addition to the output from the MQ-135 sensor, the system is also IoT (Internet of Things) based. Therefore, the air pollution monitoring data will also be displayed on a website accessible from your smartphone or any other device with a browser. For this to work, the Wemos D1 Mini must be connected to WiFi.

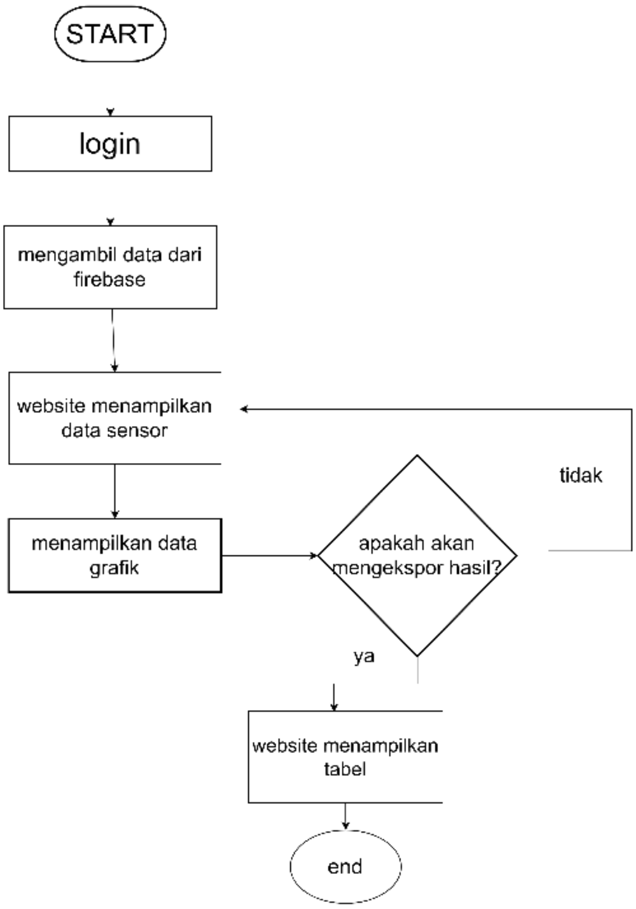

Figure 4. Website flowchart

1. **Login Page**

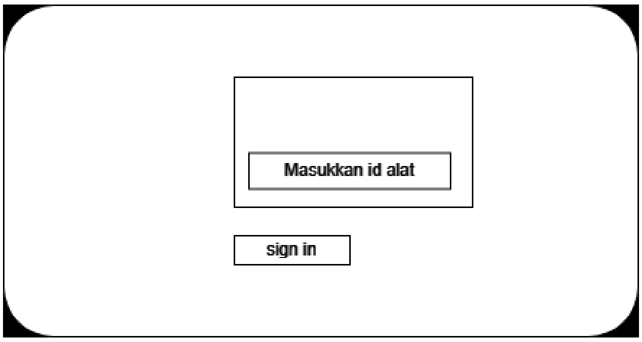

Figure 5. Login Page

2. **Dashboard Page**

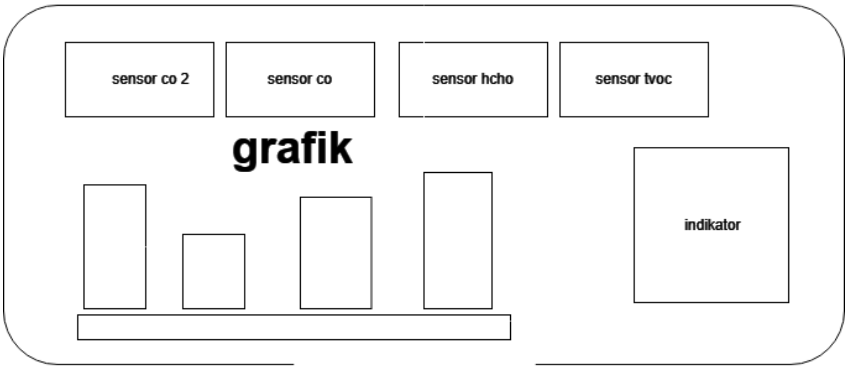

Figure 6. Dashboard Page

f. Database Design

The table structure ensures that data from the MQ-135 sensor is effectively captured and stored, making it readily available for real-time monitoring via the designed website. The Wemos D1 Mini's continuous WiFi connection facilitates the seamless transmission of data to the database, allowing for up-to-date and accurate air quality monitoring.

Table 2. Database Design

#	Name	Type	Descriptions
1	Id	Int(11)	Unique identifier for each new data entry.
2	CO	Decimal(10,3)	Stores the concentration of carbon monoxide, precise to 3 decimal places.
3	CO2	Decimal(10,3)	Stores the concentration of carbon dioxide, precise to 3 decimal places.
4	H2S	Decimal(10,3)	Stores the concentration of hydrogen sulfide, precise to 3 decimal places.
5	HCHO	Decimal(10,5)	Stores the concentration of formaldehyde, precise to 5 decimal places.
6	Tanggal	Date	Stores the date of the data entry in YY-MM-DD format.
7	Waktu	Time	Stores the time of the data entry in HH format.

RESULT AND DISCUSSION

Research Results

This research has developed an IoT-based air pollution monitoring device. The device provides real-time data display on a connected website. For testing, the device will be installed or placed in areas prone to air pollution. To ensure real-time monitoring data is accessible through the website, the device must be connected to WiFi. The faster the WiFi connection, the quicker the data will be updated and displayed on the website.

The device utilizes the Wemos D1 Mini as the microcontroller and the MQ-135 sensor to detect air quality. If the air pollution levels exceed the predefined thresholds set in the system, the device will identify the increase in pollution and send this data to the website for real-time display.

Device Circuit Layout

Previously, we discussed the necessary components, the system's working mechanism, and the design of the display. Below is the circuit layout for the air pollution monitoring device. This setup will be connected to WiFi, and notifications will be displayed on the website. The website will, of course, show the data in real time.

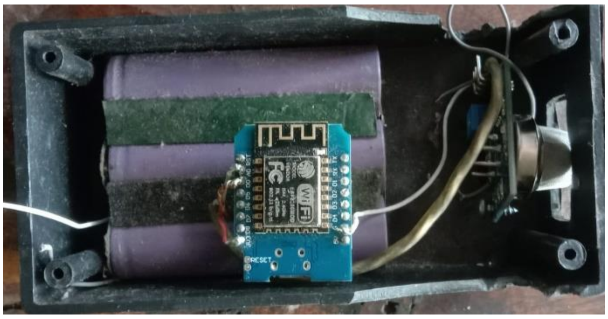

Figure 7. Device Circuit Layout

Device Appearance

Below is the image of the air pollution monitoring device that will be installed on the roadway, equipped with the MQ-135 sensor. This sensor is designed to detect and measure the air quality in its surroundings. The data collected by the sensor is then transmitted in real time to the monitoring system connected to the website.

Figure 8. Air Monitoring Device

After completing the air pollution monitoring device, it's time for testing. The purpose of the testing is to evaluate the air quality in the surrounding environment. Below are the results of the air pollution monitoring device testing.

Website Display

Below is the website display for the air pollution monitoring system. The website features a graph showing air quality data with measurements in parts per million (ppm) for four pollutants: CO, CO2, H2S, and SO2.

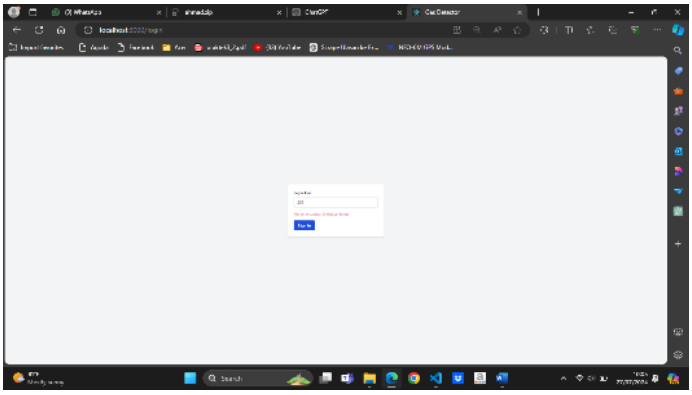

Figure 9. Login Screen

The initial page displays a login screen. To access the dashboard, you must enter the existing device ID. If the ID is incorrect, access to the dashboard will be denied.

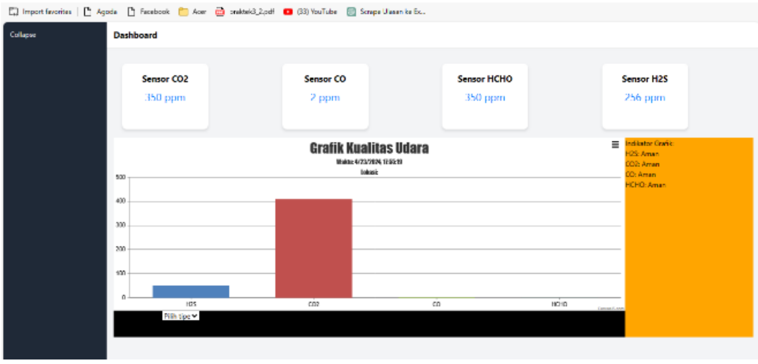

Figure 10. Dashboard Page

On the website dashboard image above, there are several functions explained as follows:

1. PPM Value Column: This column displays the ppm values. The PPM column shows real-time ppm values connected to Firebase. Below is the display of the PPM column:

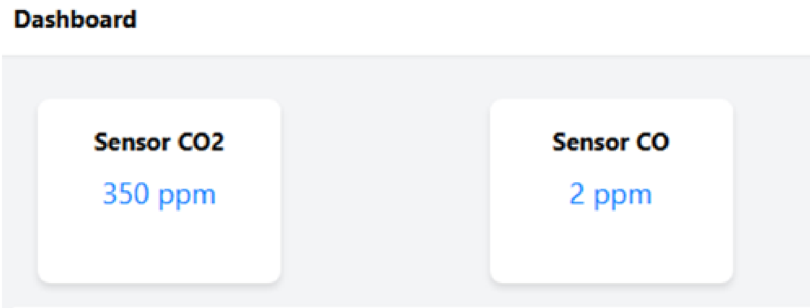

Figure 11. PPM Column

2. Graph: The graph display includes two types: column and pie charts, which provide information in different formats. The options button is located at the bottom left of the graph.

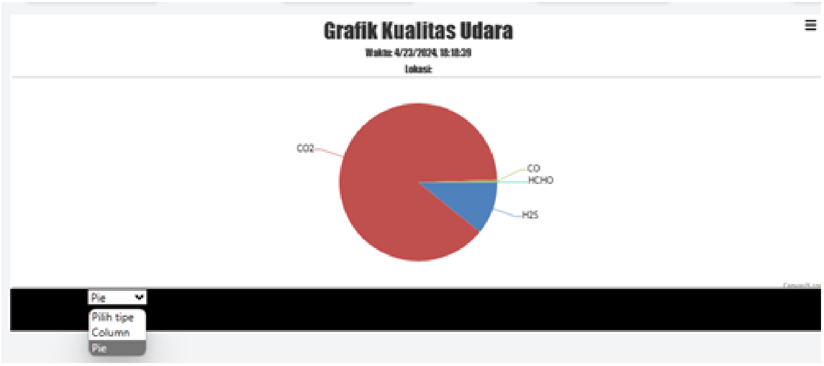

Figure 12. Graph

3. Graph Indicator: This indicator provides warnings regarding the air quality, indicating whether it is in a safe or hazardous state.

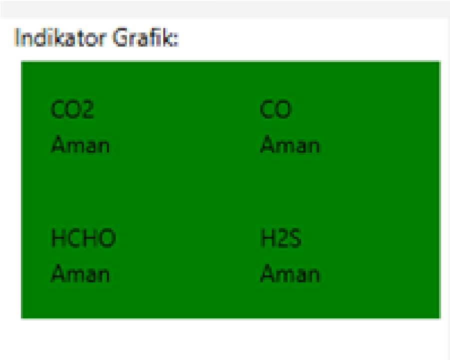

Figure 13. Indicator

Testing Results

After completing the air pollution monitoring device, testing was conducted to assess the air quality in the surroundings. Below are the results from the air pollution monitoring device testing.

Table 3. Testing Results

No	Sensor Distance	Air Quality Result	MQ Sensor Reading	Sensor Response Time	Error from MQ-135 Results
1	1 meter	425	435	10 seconds	215
2	1 meter	425	380	10 seconds	90
3	2 meters	457	333	7 seconds	217
4	2 meters	380	428	7 seconds	270

CONCLUSIONS

Summary

From this research, This research leads to several key conclusions. Firstly, placing the sensor closer to the pollution source proves to be more effective in monitoring air quality. The sensor requires approximately 6 to 10 seconds to display the air quality readings from the surrounding environment. It has a detection range of up to one meter indoors, making it suitable for localized monitoring. Each sensor reading provides air quality values in parts per million (ppm), which are updated in real time. Additionally, the response time of these readings fluctuates in line with the variations observed in the air quality graph.

Recommendations

1. Component Enhancement: In this study, the MQ-135 sensor was used. For future research on similar topics, it is recommended to include additional components, such as the Sensirion SCD30 sensor, for enhanced accuracy and measurement capabilities.
2. Graphical Design and Platform: The current design of the website for displaying air quality and notifications is functional. However, it is suggested to explore other platforms, such as Android applications, for a more streamlined and versatile user experience.

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