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Article

Stability Testing of an Air Quality Monitoring System for Particulate Matter (PM2.5 and PM10) Based on The SEN0233 Sensor

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A B S T R A C T

Particulate Matter (PM) is an air pollutant that poses a potential risk to public health, including respiratory and cardiovascular diseases. This study aims to design and develop a real-time monitoring system for PM2.5 and PM10 using the SEN0233 sensor. The system is expected to provide accurate data on airborne particle concentrations. The research methodology includes selecting the appropriate sensor, designing a microcontroller-based system using NodeMCU, and testing the sensor to ensure measurement accuracy. The collected data will be stored in a database and accessible through a web interface, allowing users to monitor air quality in real time. Initial test results indicate that the SEN0233 sensor can effectively detect PM2.5 and PM10 concentrations. This research contributes to the development of a more efficient and reliable monitoring system to improve air quality and public health.

1. Background

Particulate Matter (PM), such as PM2.5 and PM10, is a type of pollutant that can enter the respiratory system and cause various health problems, including lung disorders, heart disease, and even premature death (Dewi et al., 2021; Fikri et al., 2024a). PM2.5, with a particle diameter of less than 2.5 micrometers, is particularly hazardous as it can reach the alveoli in the lungs and enter the bloodstream (Aulia and Azizah, 2015; Fikri et al., 2024b). Meanwhile, PM10, with a particle diameter of up to 10 micrometers, can cause irritation in the upper respiratory tract (Chiqita, 2020).

Long-term exposure to high PM concentrations has been proven to correlate with increased incidence of respiratory and cardiovascular diseases in various populations (Bahri et al., 2021). Therefore, continuous air quality monitoring is crucial to identify pollution levels and take necessary measures to protect public health. Air quality measurement in many locations is still conducted manually, which may lead to delays in decision-making and potential health risks for the community.

With technological advancements, the use of Internet of Things (IoT)-based sensors offers an innovative solution for real-time air quality monitoring (Wanabil et al., 2024). The SEN0233 PM sensor can be used to detect PM2.5 and PM10 concentrations (Kaur and Sharma, 2023). This study aims to design and develop an efficient and accessible monitoring system that not only provides real-time air quality data but also assists the public and authorities in making informed decisions regarding health and safety.

2. METODHOLOGY

2.1 Monitoring System Design

The monitoring system design begins with selecting the main components, including the SEN0233 sensor for measuring PM2.5 and PM10 concentrations, the NodeMCU ESP8266 microcontroller as the main controller, an I2C LCD module for real-time data display, and Firebase as the real-time data storage platform.

The SEN0233 sensor is connected to the NodeMCU with the following configuration: the sensor's VCC pin is connected to the 3.3V pin of the NodeMCU, the sensor's GND pin to the NodeMCU’s GND pin, and the TX/RX pin of the sensor to the digital pin of the NodeMCU to enable data transfer. Additionally, the I2C LCD module is connected with the SDA pin linked to D2 and the SCL pin to D1 of the NodeMCU, while the LCD’s VCC and GND pins are connected to the power source and ground.

This system utilizes the I2C communication protocol, which simplifies device integration while optimizing pin usage. Firebase is employed as the data storage platform, allowing remote air quality monitoring.

2.2 System Testing

The system testing was conducted by placing the SEN0233 sensor-based monitoring device alongside a reference instrument in the same location within a server room. Measurements of PM2.5 and PM10 concentrations were taken at predetermined time intervals, with data recorded every minute throughout the testing duration. The collected sensor data was transmitted to Firebase for storage and further analysis while being displayed in real-time via the I2C LCD module.

2.3 Data Analysis

Data analysis was performed by comparing the SEN0233 sensor readings with those of the reference instrument to evaluate system accuracy. The trends in detected value differences at each time interval were analyzed to identify patterns in particulate concentration variations. The measurement evaluation aimed to determine the extent of detected PM concentration differences and assess the sensor's reliability in providing real-time air quality data.

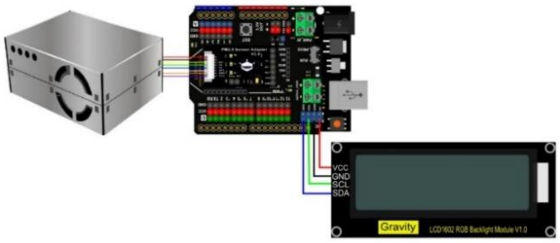
3. RESULTS AND DISCUSSION

3.1 Monitoring System Design

The air quality monitoring system developed in this study utilizes the SEN0233 sensor to detect real-time concentrations of Particulate Matter (PM2.5 and PM10), with the NodeMCU ESP8266 microcontroller as the main controller. The use of the I2C protocol in this system enables more efficient communication between the sensor, microcontroller, and display module, reducing pin usage while enhancing data transfer reliability. Additionally, Firebase serves as the data storage platform, allowing remote monitoring and further analysis of air quality trends over time.

The SEN0233-based PM2.5 and PM10 monitoring system consists of several key components that are interconnected and function synchronously.

Figure 1. Monitoring System Circuit



PM sensors come in various types, each with different specifications and operating principles. The dashboard frame was designed using the SEN0233 PM sensor, which operates based on the laser scattering method to detect particle dispersion with a minimum size of 0.3 µm. The NodeMCU was selected as the main microcontroller to control the sensor and transmit data due to its built-in Wi-Fi capability, allowing direct internet connectivity.

Figure 2. SEN0233 Sensor

Tabel 1. Spesifikasi Sensor SEN0233

Parameter	Specification
Particle Measurement Range	0,3~1,0µm;1,0~2,5µm;2,5~10µm
Effective Mass Concentration Range	0~500µg/m³
Mass Concentration Resolution	1µg/m³
Mass Concentration Consistency	±10%@100~500 µg/m³, ±10 µg/m³@0~100 µg/m³
Humidity Measurement Range	0~99%
Operating Temperature	-10~50℃
DC Supply Voltage	Tipe: 5V Min: 4.5V Maks: 5.5V
Measurement Mode Current	≤100mA
Dimensions	50mm*38mm*21mm

3.2 System Testing

The test results indicate that the SEN0233 sensor can detect real-time variations in PM2.5 and PM10 concentrations, with data displayed directly on the LCD I2C and stored in Firebase. The monitoring device was placed in a server room to evaluate the sensor's effectiveness in a controlled indoor environment with stable pollutant sources. Data recording was conducted every minute to capture detailed fluctuations in particulate concentrations.

The measurements revealed that the two SEN0233-based monitoring systems consistently reported higher PM2.5 and PM10 concentrations compared to the reference device. Data from both the new system and the reference device were recorded at the same time intervals to analyze trends and result consistency (Figure 3 and Figure 4).

Figure 3. PM2.5 Measurement Results

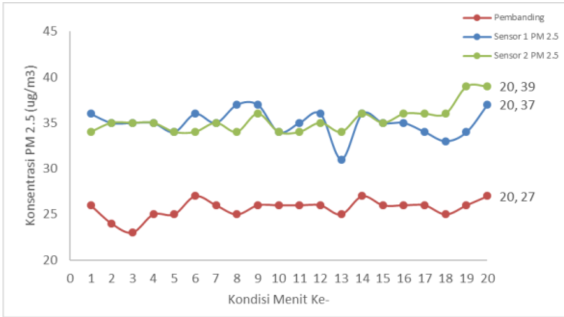
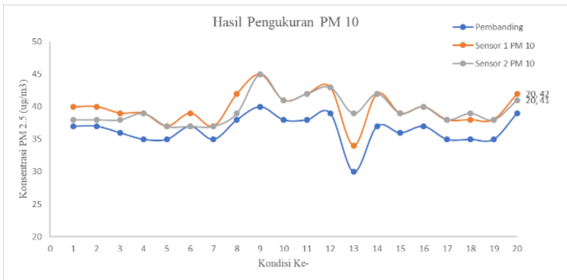


Figure 4. PM10 Measurement Results



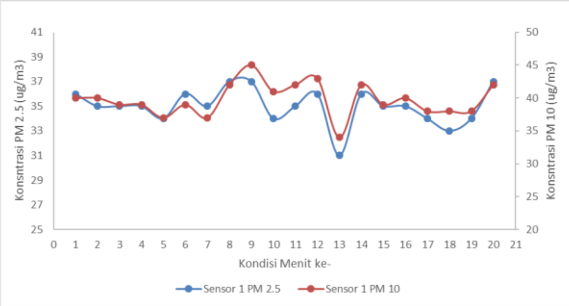
3.3 Data Analysis

Comparison with the reference device revealed value discrepancies at certain time intervals, likely due to differences in sensor sensitivity, environmental conditions, and technical factors such as sensor calibration and data processing algorithms in the microcontroller. Despite these differences, the SEN0233-based monitoring system demonstrated stable PM measurements, as indicated by the relatively consistent value range across the tested sensors.

In this system, two sensor units (Sensor 1 and Sensor 2) exhibited similar PM concentration variations, suggesting that the SEN0233 sensor performs consistently when detecting PM2.5 and PM10 in the same environment. This stability is crucial for long-term air quality monitoring. The close range of results between Sensor 1 and Sensor 2 implies that the SEN0233 sensor provides reliable particulate matter detection. Although the detected concentrations were higher than those recorded by the reference device, the consistent results across multiple sensor units indicate that the developed system can deliver stable and dependable data. This finding suggests that, with further calibration, the SEN0233 sensor has significant potential for accurate PM monitoring.

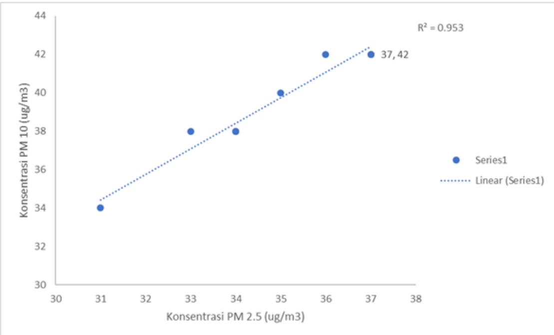
The PM2.5 and PM10 measurement results from the monitoring system showed a strong correlation between the two parameters (Figure 5 and Figure 6).

Figure 5. Correlation Between PM2.5 and PM10 Measurements



Testing data demonstrated that when PM2.5 concentrations increased, PM10 concentrations also tended to rise, and vice versa. This consistent relationship throughout the testing period indicates that both particle sizes exhibit correlated variation patterns in the tested environmental conditions. This correlation is supported by regression analysis, which shows a linear relationship between PM2.5 and PM10, where an increase in PM2.5 is generally followed by a proportional increase in PM10.

Figure 6. Regression Analysis of PM2.5 and PM10



Measurements using the SEN0233 sensor confirmed that an increase in PM2.5 corresponded with an increase in PM10. This finding aligns with the principle that PM2.5 is a subset of PM10, meaning PM10 includes all particles with a size ≤10 µm, including fine particles ≤2.5 µm. Therefore, an increase in PM2.5 contributes directly to an overall rise in PM10 values.

The SEN0233 sensor used in this study operates on the laser scattering principle, where particles passing through a laser beam cause light scattering, which is then converted into particulate concentration data. The sensor can detect particles as small as 0.3 µm, allowing it to measure both PM2.5 and PM10 simultaneously. The measurement results indicate a similar trend in PM2.5 and PM10 increases, suggesting that the sensor effectively detects particulate concentration changes with a good response rate.

However, despite the overall consistency between PM2.5 and PM10 trends, some value discrepancies were detected. These variations could be due to the sensor's sensitivity in detecting different particle sizes, as well as environmental factors such as humidity and airflow, which influence particulate dispersion. Additionally, the SEN0233 sensor has limitations in achieving the same precision as more advanced laboratory-grade instruments, highlighting the need for further calibration to enhance data accuracy.

Overall, the use of the SEN0233 sensor in this study provided a clear understanding of the relationship between PM2.5 and PM10 and demonstrated that this sensor can be utilized for real-time air quality monitoring. However, to improve system reliability, future research should focus on sensor calibration, comparisons with more precise reference instruments, and testing under various environmental conditions.

4. Conclusion

This study demonstrated that both SEN0233 Sensor 1 and SEN0233 Sensor 2 were stable and suitable for real-time monitoring of PM2.5 and PM10 concentrations. The sensors effectively detected particulate variation patterns with consistent trends. The SEN0233 sensor exhibited good stability and reliability for air quality monitoring. While further calibration is necessary to improve accuracy, the system is already viable for air quality monitoring in industrial and urban environments.

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