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Design and Implementation of a Portable Air Quality Monitoring Device Using Nova Fitness SDS011 Sensor Technology in Urban Areas

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ABSTRACT

This study presents the design and implementation of a portable air-quality monitoring device based on the Nova Fitness SDS011 sensor to measure PM2.5 concentrations. The system integrates a microcontroller-based processing unit with real-time data display and audio warning features. Device performance was evaluated by calibrating against a reference instrument (BAM 1020, BMKG), yielding an average measurement error of 2.43%. In addition, validation by media experts indicated a high feasibility level of 95%, confirming the device's suitability for practical use. Field testing conducted in several urban locations revealed significant variations in PM2.5 concentration, influenced by factors such as traffic density, industrial activity, and population distribution. The results demonstrate that the proposed device provides a reliable, low-cost, and portable solution for real-time PM2.5 monitoring in urban environments. This study contributes to the development of easy-to-use tools for monitoring air quality in support of environmental awareness and educational applications.

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1. INTRODUCTION

Air quality is a key indicator for assessing environmental sustainability and public health (Wang & Cao, 2024; Syuhada et. Al., 2025; Simatupang et al., 2022; Husnina et al., 2023 and Pramono et al., 2025). Over the past few decades, the increasing intensity of anthropogenic activities such as vehicular traffic, industrial growth, and open waste burning has significantly contributed to the rise of atmospheric particulate matter (Kelly & Fussell, 2022), particularly fine particles (PM2.5). These particles are capable of penetrating deep into the respiratory system and are associated with various health risks, including respiratory and cardiovascular diseases (Liu et al., 2022; Kelly & Fussell, 2022))

In Indonesia, air quality standards are regulated under BMKG Regulation No. 6 (2023), which establishes threshold limits and classification categories for PM2.5 concentrations in ambient air (Husnina et al., 2023 and Pramono et al., 2025; Santoso et al., 2025). These standards provide an important reference for evaluating air pollution levels, especially in urban areas where PM2.5 concentrations often exceed recommended limits. According to the operational standards issued by BMKG (Regulation No. 6, 2023), PM2.5 concentrations exceeding 55.4 μg/m^3 are classified as extreme air quality, encompassing categories such as Unhealthy, Very Unhealthy, and Hazardous. In 2025, the PM2.5 concentration in Medan reached 25 μg/m^3, indicating moderate air quality conditions and requiring continuous monitoring (CNN Indonesia, 2024; Sari & Hasibuan, 2025; Santoso et al., 2025).

From the perspective of environmental physics, air quality monitoring involves understanding the interaction between particulate matter and electromagnetic radiation, particularly in optical-based sensing systems (Santoso et al., 2025; Kuula et al., 2021)). The detection of PM2.5 using low-cost sensors such as the Nova Fitness SDS011 is based on the principle of laser light scattering, where suspended particles scatter incident light and produce signals proportional to their concentration (Santoso et al., 2025; Kuula et al., 2021; Jayaratne et al., 2021; Chen et al., 2022; Nothhelfer et al., 2023). In addition, from an instrumentation standpoint, the integration of sensors with microcontroller-based systems enables real-time data acquisition, signal processing, and visualization, which are essential components in modern environmental monitoring systems (Sari & Putra, 2024; Inzagi et al., 2025; Santoso et al., 2025).

Currently, air quality monitoring systems in Indonesia largely rely on fixed, high-precision instruments operated by government agencies such as the Meteorology, Climatology, and Geophysics Agency (BMKG) (BMKG, 2025; Sari & Hasibuan, 2025). One of the standard instruments used is the Beta Attenuation Monitor (BAM 1020), which provides highly accurate measurements and complies with international standards. However, such systems are expensive, require regular maintenance, and lack portability (Kuula et al., 2021; BMKG, 2025), limiting their widespread deployment in diverse urban environments (California Air Resources Board, 2019; Badura et al., 2018).

To overcome these limitations, recent studies have explored the use of low-cost sensors for air quality monitoring. The Nova Fitness SDS011 sensor has gained attention due to its affordability, ease of integration, and capability to measure particulate matter concentrations in real time (Chen et al., 2022; Nothhelfer et al., 2023). Previous studies have demonstrated the potential of low-cost sensors when compared with reference instruments such as the BAM 1020, reporting strong correlations (e.g., r=0.96*r*=0.96; MAPE = 15.44%) (Nugroho et al., 2025; AirVisual, 2025). However, most implementations still lack comprehensive urban-scale deployment validation and standardized colocation testing according to national regulations such as SNI 9178:2023 (BSN, 2023; Kementerian LH, 2024).

Despite the increasing use of low-cost sensors for air quality monitoring, previous studies have not adequately addressed the integration of portability, real-time public information display, and validation against reference-grade instruments (Bulot et al., 2023; Sari & Putra, 2025). In addition, limited studies provide quantitative error analysis under real urban conditions. Therefore, this study aims to design, implement, and calibrate a portable air quality monitoring device based on the Nova Fitness SDS011 sensor and evaluate its performance through comparison with a standard BAM 1020 instrument. Furthermore, this study contributes to the field of environmental physics and instrumentation by demonstrating the application of sensor-based systems for accurate and real-time monitoring of PM2.5 concentrations in urban environments.

2. METHODS

This research uses the Experimental method. The research method Experiment is the influence or an event between certain variables (Ramdhan, 2021). The purpose of the experiment in this study is to test and measure the ability of detection tools that have been designed in real-time in the city of Medan. The model used in this study is the development of a 4D model (Herowati & Azizah., 2022; Thiagarajan et.al., 1975). Modified into 3D, Modification is Define (Specification), Design (Design), and Development (Development). The modification was carried out due to the limited research time

and design of detection tools resulting from the Development stage because it has been validated by experts and tested in the field (Wulandari & Satria, 2021; Fadilla & Wulandari, 2021; Kuula et al., 2021).. The 3D method can be seen in Figure 1.



Figure 1. 3D Method

Based on Figure 1 At the define stage, according to one of the news media, Kompas.com, identifying the air quality in Medan City, was found to be generally moderate to unhealthy on February 6, 2025. Therefore, this research aims to design and implement air particle detection in the city of Medan. At the design stage, the tool makes a diagram design consisting of 2 Solder Iron and Multimeter tools. The components used in this study include the Nova Fitness SDS011 sensor used to measure PM2.5 and PM10 concentrations, Mini Breadboard, Arduino Uno Micro chronograph, Step Down XL 4015 used for voltage lowering, BMS used to manage and protect batteries, Lithium-Ion batteries used for energy storage, DFPlayer Mini MP3 used for audio player modules, 20 x 4 LCD used to display data in alphanumeric characters, and Speaker as sound output. After the series is ready, write and upload the C++ program to Arduino Uno using Arduino IDE software. Use the Arduino IDE software to write and upload the C++ program to the Arduino Uno once the series is complete.

The system was programmed using the Arduino IDE with embedded C/C++ language. Only the essential parts of the code are presented to illustrate the core functionality of the device. The program integrates several libraries, including *Wire*, *LiquidCrystal_I2C*, *SoftwareSerial*, *AltSoftSerial*, *DFRobotDFPlayerMini*, and *SDS011*, to support communication between the microcontroller, display module, audio module, and particulate matter sensor. The SDS011 sensor is used to measure PM2.5 concentrations at regular intervals (every 5 seconds). The acquired data are processed and adjusted using a calibration correction factor. Based on the measured PM2.5 values, the system classifies air quality into several categories, namely *Good*, *Moderate*, *Unhealthy*, *Very Unhealthy*, and *Hazardous*, according to predefined threshold values. Furthermore, the system is equipped with an audio notification feature using the DFPlayer Mini module. When a hazardous air quality level is detected, an immediate warning sound is triggered. For other conditions, audio notifications are played periodically at defined intervals (every 60 seconds). This feature is designed to enhance real-time user awareness of environmental conditions. Here is how to program the Air Quality Detection Tool Using the Nova Fitness SDS011 Sensor:

```
#include "SDS011.h"
SDS011 mySensor;

float pm25;
int error = mySensor.read(&pm25);

if (! error) {
  pm25 += 3; // calibration correction

  String kualitas;

  if (pm25 > 250.4) {
    kualitas = "HAZARDOUS";
    myDFPlayer.play(5);
  } else if (pm25 > 150.5) {
    kualitas = "VERY UNHEALTHY";
  } else if (pm25 > 55.5) {
    kualitas = "UNHEALTHY";
  } else if (pm25 > 15.6) {
```

```
    kualitas = "MODERATE";
  } else {
    kualitas = "GOOD";
  }
}
```

The core algorithm of the system is shown in the code snippet above. PM2.5 data are acquired using the SDS011 sensor and corrected using a calibration factor to improve measurement accuracy. The processed data are then classified into air quality categories based on predefined PM2.5 threshold values. In hazardous conditions, an audio warning is automatically triggered to provide real-time alerts to users.

The development stage involves the creation and testing of the system, validation by media experts, and calibration of detection devices with the North Sumatra Climatology Station Class 1. Four validators conducted media expert validation to assess the feasibility of the system from both technical and functional aspects. Testing of calibration results with BAM 1020 data belonging to the North Sumatra Class 1 Climatology Station (BMKG), and measurement results using detection tools in several locations in the city of Medan. For the data collection process, using validation sheets, calibration measurement tests, and measurement of several locations in the city of terrain. The discussion can be made in several sub-sections.

Table 1. Concentration Range Per Hour Particulate

Color	$PM_{2.5}$ (µg/m^3)	Category
Green	0 - 15.5	Good
Blue	15.6 - 55.4	Moderate
Yellow	55.5 - 150.4	Unhealthy
Red	151.5 - 250.4	Very Unhealthy
Black	> 250.4	Hazardous

Based on Table 1. This is the hourly concentration range of particulate matter according to BMKG Regulation No. 6 of 2023 (translated). It is divided into five categories, each with a different color. In this study, the air quality category standard from BMKG was used as the primary reference in analyzing the results of particulate concentration monitoring. This standard was chosen because it has been nationally recognized and is relevant to the environmental context in Indonesia.

The data collection instruments used in this study included validation sheets from media experts, calibration measurement result sheets, and measurement sheets obtained from several locations in Medan City. The feasibility of the developed device was assessed through expert validation involving four evaluators. The experts evaluated the validation sheets to determine the technical and functional suitability of the detection tool. The validation score was calculated using a Likert-scale-based percentage, and the device was categorized as highly feasible, achieving a score of 95%. This quantitative validation indicates that the developed device meets the required standards for practical implementation in environmental monitoring applications. The calibration measurement sheets were used to compare the measurements obtained from the developed device with reference data from the BAM 1020 instrument operated by the Class 1 Climatology Station of North Sumatra (BMKG). In addition, these data were used to analyze variations in PM2.5 concentrations across different locations in Medan under varying environmental conditions. The percentage error between the developed device and the reference instrument was calculated using the following equation (1) and (2):

$$PM_{error} = \left| \frac{PM_{ref} - PM_{Sensor}}{PM_{ref}} \right| x\ 100\% \quad (1)$$

Where: PM_{ref} = Particulate Matter measured by BMKG

PM_{sensor} = Particulate Matter measured by Nova Fitness SDS011 Sensor

$$Average = \frac{Sum\ Of\ All\ Values}{Number\ Of\ Data\ Points}\ x\ 100\% \quad (2)$$

In this test, the electrical current consumption of the device was measured to determine the power usage and evaluate battery performance during operation. The power consumption of the device was calculated using Equation (3), P=V×I, where P represents power, V is the voltage, and I is the current. Furthermore, the estimated operating time of the device was determined using Equation (4), t=C/I, where t is the operating time, C is the battery capacity, and I is the current consumption.

3. RESULTS AND DISCUSSION

3.1 Result

The results of the design of the air quality detection device using the Nova Fitness SDS011 sensor as for the tool used can be seen in Figure 2.

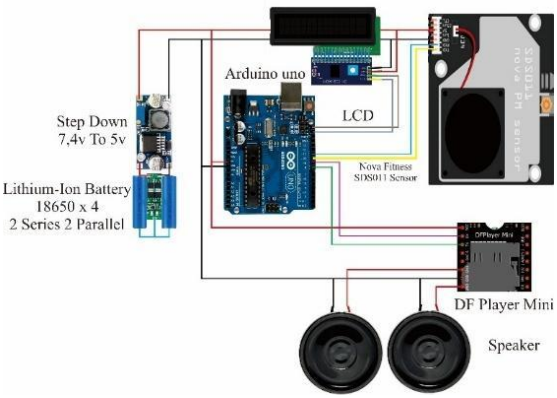


Figure 2. Design of the Overall Air Quality Detection Tool Suite

Based on Figure 2. Illustrating the connection of the Li-ion 18650 battery circuit connected in a parallel two-series two configurations and 2S BMS to the battery to regulate battery charging and discharging, the 7.4V BMS 2S output is connected to the step-down module to lower the voltage from 7.4V to 5V. Connect the VCC and GND pins of the step-down module to the VIN and GND pins on the Arduino Uno, Nova Fitness SDS011 Sensor, DFPlayer Mini, and speaker, connect the SDA to SDA, SCL to SCL pins from the Arduino Uno to the LCD 20 × 4 12C, connect the RX and TX of the Nova Fitness SDS011 sensor to the D11 and D10 pins. Connect the RX and TX of the DFPlayer Mini to pins D9 and D8. Insert the microSD memory card containing the MP3 sound file into the microSD slot on the DFPlayer Mini, and connect the two speakers to the DFPlayer Mini on the Left, Right, and Ground Speaker pins as the sound output.

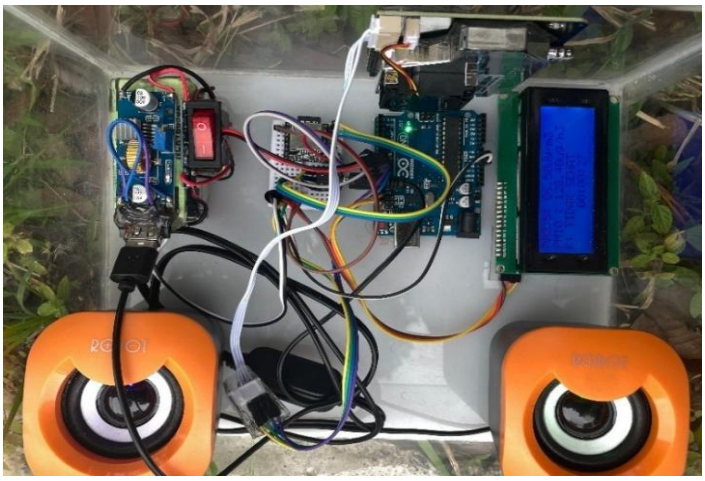


Figure 3. Physical Display of the Overall Air Quality Detection Device Suite

Based on Figure 3. Showing the physical results of a series of air quality detection devices using the Nova Fitness SDS011 sensor. This series consists of Arduino Uno as a microcontroller, Nova Fitness SDS011 Sensor as PM2.5 and PM10 Sensor, LCD 20 × 4, DFPlayer Mini as a small MP3 player module, and Speaker as a sound output.

Table 2. Media Expert Validation Test Results

No.	Indicator	Questionnaire Item	Media Expert				Average	Indicator Percentage
			Ex 1	Ex 2	Ex 3	Ex 4		
1.	Detection Accuracy	Detection tool capable of detecting PM2.5	5	5	5	5	5	100%
		Detection tool capable of detecting PM10	5	5	5	5	5	
2.	Sensor Response Time	Sufficiently fast response time in real–time	5	5	5	5	5	97.5%
		No significant lag time during concentration changes	5	4	5	5	4.75	
3.	Sound Quality	Clear alarm sound when values exceed the threshold	4	5	4	5	4.5	90%
4.	Output Data	This tool can detect PM2.5 and PM10 without a significant difference from the Air Quality Index (AQI) database	5	5	4	4	4.5	90%
5.	Portable	The tool is easy to carry and operate in various locations	5	4	5	5	4.75	95%
Total			**34**	**33**	**33**	**34**	**33.5**	
Percentage			**95%**					

Based on Table 2. The results of the air quality detection tool validation were presented using the Nova Fitness SDS011 sensor, which was assessed based on several aspects. The validation results show a high level of validity, a score of 95%. This tool is considered very suitable for use as a device for detecting air quality with detection efficiency; in addition, this tool can detect in real-time and is equipped with a sound output as a warning.



(a) (b)

Figure 4. (a) PM2.5 Measurement Results of BMKG North Sumatra, (b) PM2.5 Measurement Results of Nova Fitness SDS011 Sensor

Based on Figure 4. (a) shows the measurement results of the North Sumatra Climatology Station Class 1 (BMKG), while Figure 4 (b) shows the measurement results of the detection device. The difference in the value of the measurement results between the detection device and BMKG was

3 (µg/m³). Before the calibration process is carried out, it is necessary to compare the specifications between the Nova Fitness SDS011 sensor and the BAM 1020 reference device belonging to the Class 1 Climatology Station (BMKG). The SDS011 sensor works using the laser scattering method with the advantages of low cost and high portability, but has limitations in accuracy, especially in high-humidity environmental conditions. Meanwhile, BAM 1020 is a reference standard tool that uses the beta light absorption method and has been proven to have high accuracy and resistance to extreme environmental conditions. This study only focuses on PM 2.5, where in 2025 the North Sumatra Climatology Station Class 1 (BMKG) will no longer use PM10 sensors.

```
if (!error) {
  pm25 += 3; // Koreksi nilai PM2.5 dengan menambahkan 3
```

Figure 5. Calibration Programming Detection Tool

Based on Figure 5. It is a sensor calibration process with a difference in PM2.5 value of 3 (µg/m³), then a value of 3 is added as a correction to the PM2.5 value in the programming language.

Table 3. Comparison Results of PM2.5 Measurement After the BMKG Calibration Process with the Detection Device

Day	Date	Time (WIB)	Air Quality		Error %	Category
			BMKG	Nova Fitness SDS011 Sensor		
1.	19/03/2025	07.00 AM	46.7 µg/m³	44.90 µg/m³	3.85 %	Moderate
		08.00 AM	61.7 µg/m³	60 µg/m³	2.75%	Unhealthy
		09.00 AM	66.1 µg/m³	66 µg/m³	0.15%	Unhealthy
		10.00 AM	52.9 µg/m³	51.10 µg/m³	3.40%	Moderate
		11.00 AM	48.9 µg/m³	48.69 µg/m³	0.42%	Moderate
		12.00 PM	30.9 µg/m³	30.20 µg/m³	2.26 %	Moderate
		01.00 PM	29 µg/m³	29.50 µg/m³	1.72 %	Moderate
		02.00 PM	19 µg/m³	18.60 µg/m³	2.10 %	Moderate
		03.00 PM	21. µg/m³	20.80 µg/m³	0.95 %	Moderate
		04.00 PM	25.4 µg/m³	25.00 µg/m³	1.57 %	Moderate
		05.00 PM	25 µg/m³	24.90 µg/m³	0.4 %	Moderate
2.	20/03/2025	07.00 AM	36.7 µg/m³	36.30 µg/m³	1.08 %	Moderate
		08.00 AM	39.7 µg/m³	39.20 µg/m³	1.25 %	Moderate
		09.00 AM	30.6 µg/m³	29.50 µg/m³	3,59 %	Moderate
		10.00 AM	27.5 µg/m³	28.30 µg/m³	2.90 %	Moderate
		11.00 AM	25.6 µg/m³	25.00 µg/m³	2.3 %	Moderate
		12.00 PM	28.1 µg/m³	27.50 µg/m³	2.13 %	Moderate
		01.00 PM	31.1 µg/m³	30.20 µg/m³	2.89 %	Moderate
		02.00 PM	34.4 µg/m³	37.70 µg/m³	9.59 %	Moderate
		03.00 PM	25.3 µg/m³	25.60 µg/m³	1.85 %	Moderate
		04.00 PM	18.1 µg/m³	17.70 µg/m³	2.64 %	Moderate
		05.00 PM	20.8 µg/m³	21.50 µg/m³	3.36 %	Moderate
3.	21/03/2025	07.00 AM	49.5 µg/m³	47.80 µg/m³	3.43 %	Moderate
		08.00 AM	52.7 µg/m³	52.70 µg/m³	0 %	Moderate
		09.00 AM	40.3 µg/m³	40.50 µg/m³	0.49 %	Moderate
		10.00 AM	38.4 µg/m³	37.80 µg/m³	1.56 %	Moderate
		11.00 AM	33 µg/m³	32.00 µg/m³	3.03 %	Moderate
		12.00 PM	35 µg/m³	36.51 µg/m³	4.31 %	Moderate
		01.00 PM	31.7 µg/m³	29.60 µg/m³	6.62 %	Moderate
		02.00 PM	36.5 µg/m³	36.10 µg/m³	1.09 %	Moderate
		03.00 PM	34.3 µg/m³	35.70 µg/m³	4.08 %	Moderate
		04.00 PM	34.8 µg/m³	35.70 µg/m³	2.58 %	Moderate
		05.00 PM	37.9 µg/m³	37.70 µg/m³	0.52 %	Moderate

Based on Table 3, the calibration results show a close agreement between the PM2.5 concentration measurements obtained from the developed device using the Nova Fitness SDS011 sensor and those recorded by the Class 1 Climatology Station of North Sumatra (BMKG). This agreement is reflected in a relatively low average error of 2.43%, indicating that the developed device provides a good level of accuracy for PM2.5 measurements.

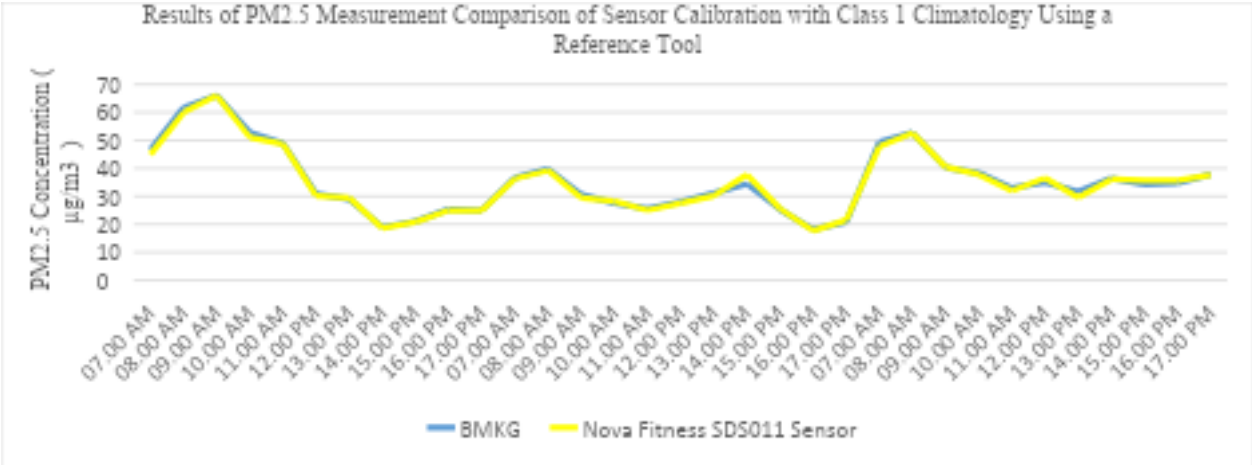


Figure 6. Graph of Comparison Results of PM2.5 Measurement of Class 1 Climatology Station with Detection Device

This result is further supported by Figure 6, which presents a graphical comparison between the PM2.5 measurements obtained from the reference instrument and the developed detection device. The consistency of the trends observed in both datasets confirms the reliability of the SDS011 sensor after calibration. However, although the error value is relatively small, the observed deviation may be influenced by environmental factors such as humidity and temperature, which are known to affect the performance of laser scattering-based sensors. High humidity conditions, in particular, can lead to overestimation of particle concentrations due to the hygroscopic growth of airborne particles. Compared to previous studies, which reported error ranges of approximately 3–10% for similar low-cost particulate matter sensors, the performance of the proposed system can be considered competitive. This indicates that the calibration approach applied in this study contributes to improved measurement accuracy.

Nevertheless, the limitations of the SDS011 sensor under varying environmental conditions remain a challenge. Therefore, further improvements, such as the implementation of environmental compensation algorithms or the integration of additional sensors (e.g., humidity sensors), are recommended to enhance measurement reliability in future developments. In addition to sensor performance, the power consumption (Equation 3) of the device was also evaluated to assess its operational efficiency and the estimated operating time of the device was determined using Equation 4. Using a battery capacity of 6200 mAh (2S2P configuration) and a current of 230 mA, the theoretical operating time of the device is 26.96 hours. However, experimental results show that the device operated for approximately 23 hours before the battery was depleted. During operation, the device consumed approximately 1.15 W of power, calculated using a voltage of 5 V and a current of 0.23 A. The discrepancy between theoretical and experimental results can be attributed to energy losses during voltage conversion. Specifically, the step-down converter reduces the battery voltage from 7.4 V (2S configuration) to 5 V, leading to efficiency losses. This indicates that power management is an important consideration in the design of portable monitoring systems. The performance test was conducted over a period of three days, from March 19 to March 21, 2025, with daily operation from 07:00 to 17:00 WIB.

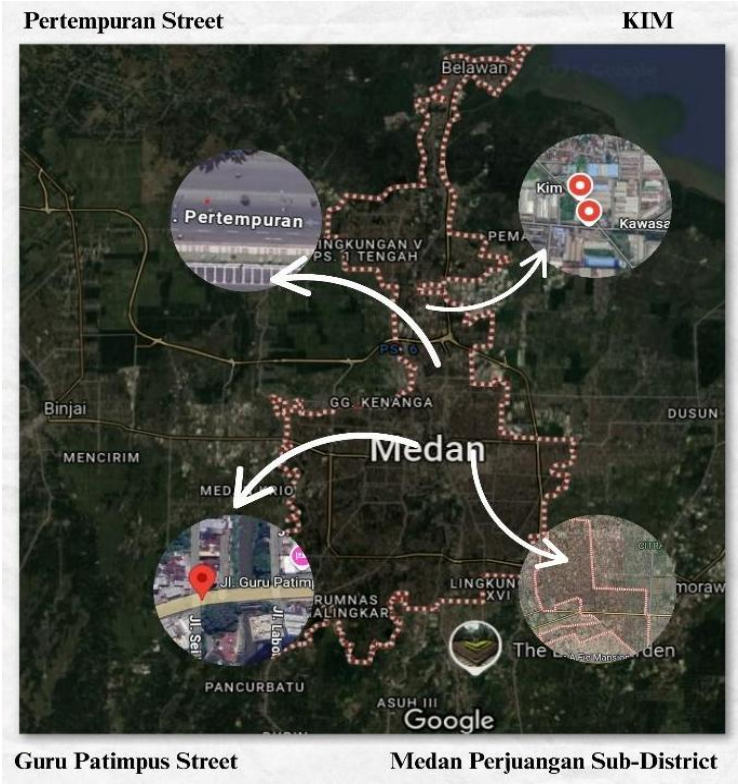


Figure 7. Map of Research Locations in Medan City

Following the validation and calibration stages, field testing was conducted to evaluate the performance of the device under real environmental conditions. As shown in Figure 7, measurements were carried out at several strategic locations in Medan City, including Medan Perjuangan District, Kawasan Industri Medan (KIM), Jalan Pertempuran, and Jalan Guru Patimpus. These locations were selected to represent different environmental characteristics, such as densely populated residential areas, industrial zones, and high-traffic roads. This variation allows for a more comprehensive evaluation of the device's performance under diverse pollution conditions.

Table 4. PM2.5 Measurement in Medan City

No	Date	Location	Time WIB	Air Quality Nova Fitness SDS011 Sensor PM2.5	category
1	24/03/2025	Medan Perjuangan Sub - district	09.00	50.60 µg/m^3	Moderate
			10.00	45.70 µg/m^3	Moderate
			11.00	40.00 µg/m^3	Moderate
2	25/03/2025	Kawasan Industri Medan (KIM)	09.00	75.20 µg/m^3	Unhealthy
			10.00	93.10 µg/m^3	Unhealthy
			11.00	83.20 µg/m^3	Unhealthy
3	27/03/2025	Pertempuran Street	09.00	34.70 µg/m^3	Moderate
			10.00	24.32 µg/m^3	Moderate
			11.00	28.50 µg/m^3	Moderate
4	28/03/2025	Guru Patimpus Street	09.00	8.20 µg/m^3	Good
			10.00	8.30 µg/m^3	Good
			11.00	82.10 µg/m^3	Unhealthy

Based on Table 4, the measurement results indicate significant variations in PM2.5 concentrations across different locations and times, ranging from “Good” to “Unhealthy” categories. Data collection was conducted over four consecutive days, from March 24 to March 28, 2025, between 09:00 and 11:00 WIB. The highest PM2.5 concentrations were observed in industrial and

high-traffic areas, particularly in the Kawasan Industri Medan (KIM), where values reached the "Unhealthy" category. In contrast, lower concentrations were recorded in less congested areas, such as Jalan Guru Patimpus during certain periods. These findings suggest that PM2.5 concentration levels are strongly influenced by local activity patterns, including vehicular emissions, industrial operations, and population density. The spatial variation of PM2.5 concentrations is further illustrated in Figure 8, which provides a comparative visualization of pollutant levels across the selected locations.

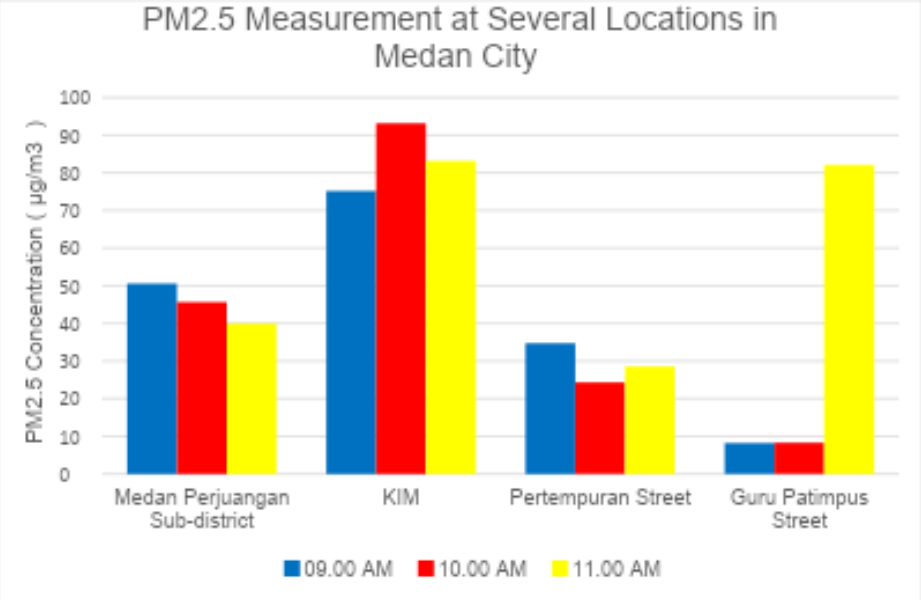


Figure 8. PM2.5 Measurement in Medan City

The calibration results demonstrated a strong agreement between the developed device and the BAM 1020 reference instrument, as indicated by the average error of only 2.43%. This level of accuracy suggests that the SDS011 sensor, when properly calibrated, can provide reliable $PM_{2.5}$ measurements for urban air quality monitoring applications.

The obtained results are comparable to those reported in previous studies on low-cost particulate matter sensors. Badura et al. (2018) reported that the SDS011 sensor showed acceptable performance for ambient $PM_{2.5}$ monitoring after calibration procedures were applied. Similarly, Budde et al. (2018) demonstrated that low-cost $PM_{2.5}$ sensors can achieve satisfactory accuracy under various environmental conditions, although measurement deviations may occur due to temperature and humidity effects.

The performance achieved in this study is also consistent with the principles outlined in SNI 9178:2023 regarding the evaluation and application of low-cost air quality sensors. The relatively small measurement error indicates that the developed device is capable of producing $PM_{2.5}$ data with sufficient accuracy for environmental monitoring activities.

Field measurements conducted at four locations in Medan City revealed noticeable variations in $PM_{2.5}$ concentrations. Higher concentrations were observed in industrial and high-traffic areas, while lower concentrations were recorded in locations with lower levels of anthropogenic activity. These findings are consistent with previous studies showing that transportation emissions, industrial activities, and population density are major contributors to urban particulate pollution (LCDI Indonesia, 2024; WRI Indonesia, 2024).

The observed spatial variations demonstrate the capability of the developed device to capture differences in air quality under real urban conditions. Such information is valuable for supporting environmental monitoring efforts and increasing public awareness of air pollution exposure.

Despite the promising results, several factors may influence measurement accuracy. The SDS011 sensor operates based on the laser light scattering principle, which is known to be affected by environmental conditions such as relative humidity and temperature. High humidity may alter

particle size through hygroscopic growth and consequently affect sensor response (Budde et al., 2018). Nevertheless, the low average error obtained in this study indicates that the applied calibration procedure was effective in minimizing measurement deviations.

4. CONCLUSION

This study successfully developed and validated a portable air quality monitoring device based on the SDS011 sensor with an average error of 2.43%, demonstrating its reliability for PM2.5 measurement. The main contribution of this work lies in integrating a low-cost sensor with real-time monitoring, calibration against a reference instrument, and field deployment in diverse urban environments. Practically, this device can support public awareness and environmental monitoring, particularly in educational and community settings. Future research should focus on improving sensor stability under varying environmental conditions, integrating IoT-based data transmission, and expanding multi-parameter air quality monitoring.

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