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EVALUATION OF LOW-COST $PM_{2.5}$ SENSOR ACCURACY IN COMPARISON WITH GOVERNMENT REFERENCE INSTRUMENT

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Abstract

Air pollution in Jambi City, due to the increasing $PM_{2.5}$, often exceeds the national quality standards. This situation requires a uniform monitoring solution, since the number of government reference stations is limited. An IoT-based monitoring system using low-cost sensors can be an alternative, which are flexible and real-time monitoring. We developed an IoT-based monitoring system using two low-cost sensors (PMS5003 and PMS7003), which were collocated with and validated against the BAM-1020 reference instrument operated by the Meteorology, Climatology, and Geophysics Agency (BMKG) at the Sultan Thaha Jambi Climatology Station. This quantitative study aims to evaluate the accuracy of the two sensors against the reference instrument for the period December 2025 to January 2026. The analysis was carried out using the statistical parameters MBE, MAE, RMSE, the correlation coefficient (r), and the coefficient of determination (R^2), followed by a linear regression-based correction of the sensor readings. The results showed that both sensors were able to follow the pattern of changes in $PM_{2.5}$ concentration quite well (R^2 = 0.60 for PMS5003 and 0.59 for PMS7003), although they tended to produce higher values (overestimate). The PMS7003 sensor showed slightly better accuracy with a lower error rate (MBE=10.46; MAE=12.53; RMSE=18.02 µg/m3) compared to the PMS5003 (MBE=11.84; MAE=13.60; RMSE=19.60 µg/m3). This overestimation is consistent with the influence of high relative humidity and the technical limitation of light-scattering sensors, which cannot distinguish solid particles from water droplets, as reported in previous studies. Overall, both sensors are reliable for real-time monitoring, but still require further calibration.

Keywords: *Air Quality, $PM_{2.5}$, IoT, PMS5003, PMS7003, BMKG Sultan Thaha.*

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1. Introduction

Air pollution has been recognized as one of the major environmental problems affecting human health for centuries, and its primary sources have changed dynamically with industrial development (Handika et al. 2019). Air pollution has become a growing concern, especially in densely populated cities that are frequently exposed to multiple emission sources (Fajar et al. 2026). Air pollution caused by anthropogenic activities, especially $PM_{2.5}$ particles, has become a serious threat to public health. Its ability to penetrate deep into the respiratory system and even enter the bloodstream, makes it a major health concern (Suhartawan and Sarie 2024). Therefore, precise and continuous monitoring of pollutant levels is highly crucial. However, air quality monitoring in Jambi Province is quite limited, relying on only three official monitoring points, including BMKG Sultan Thaha.

The limited number of reference stations means that the spatial coverage is insufficient to represent overall air quality conditions. Data from BMKG Sultan Thaha show high fluctuations in annual average, with concentration of $PM_{2.5}$ 40.03 $\mu g/m^3$ in 2023, decreasing to 25.35 $\mu g/m^3$ in 2024, and slightly change to 25.67 $\mu g/m^3$ in 2025. Although the trend is declining, these concentrations consistently continue to exceed the annual quality standard of 15 $\mu g/m^3$ stipulated in Government Regulation PP Number 22 of 2021. As a solution, the integration of Internet of Things (IoT) technology using low-cost sensors such as the PMS5003 and PMS7003 offers flexible, economical, and real-time monitoring. Based on previous research, this PMS sensor series has been proven to have better reliability compared to similar devices such as the SDS011, ZH03A, and OPC-N2 (Okaem et al. 2022). The accuracy of these sensors in the field still needs to be tested using several statistical parameters such as Mean Bias Error (MBE), Mean Absolute Error (MAE), Root Mean Square Error (RMSE), correlation coefficient (r), and coefficient of determination (R^2), because their performance is susceptible to being influenced by environmental variables such as high temperature and humidity.

The development of low-cost air quality monitoring systems in Jambi city has already been explored in several local undergraduate studies, which have generally focused on IoT-based hardware design such as systems built around the Sharp GP2Y1010AU0F and ZH03B sensors and on the reliability of data transmission to cloud platforms. However, in-depth evaluation of sensor accuracy against official regulatory-grade instruments remains rare in this local context, including for the hardware configuration replicated in the present study (Mutawaqil 2025).

Based on the above description, there is still a limitation in research that specifically evaluates the accuracy and reliability of IoT-based $PM_{2.5}$ sensors. This study was carried out to test and evaluate the IoT system using PMS5003 and PMS7003 sensors, combined with LoRa technology, through direct comparison with the standard instrument belonging to the BMKG Sultan Thaha Jambi Climatology Station. Research conducted by Mutawaqil demonstrated that LoRa technology with a star topology is capable of maintaining stable data transmission across various terrains. Through testing in an airport environment that has its own distinct emission characteristics, the results of this research are expected to serve as a scientific basis for utilizing IoT systems. In this

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way, IoT can be used as a more affordable, efficient, and evenly distributed air quality monitoring tool in urban areas.

2. Method

2.1 Type of Research

This research applies a quantitative method with an experimental and comparative approach to analyze numerical data obtained from measurements by the IoT-based monitoring device. Data collected from the device were compared with reference data from the BMKG Sultan Thaha Jambi Climatology Station to test its accuracy. Performance of the sensor assessed through a series of statistical analyses, including linear regression to model the relationship between variables, calculation of Mean Bias Error (MBE), Mean Absolute Error (MAE), and Root Mean Square Error (RMSE) to measure the level of error, as well as the Pearson correlation coefficient (r) and the coefficient of determination (R^2) to examine the strength of the relationship between the two datasets.

2.2 $PM_{2.5}$ Monitoring Using IoT-Based Sensors

The application of IoT technology has proven effective in providing real-time and accurate $PM_{2.5}$ data. This data is highly important for supporting government policy and increasing public awareness (Alamsyah et al. 2024). Because of its low cost and ease of large-scale development, this system is an appropriate solution for reaching areas that are not yet covered by the official monitoring infrastructure (Wanabil et al. 2024). Various types of sensors are available on the market, such as the ZH03B and SDS011, but the Plantower PMS7003 series is considered more reliable because its results are very close to the reference instrument after calibration (Ali et al. 2024; Badura et al. 2018; Cowell et al. 2024).

Despite being efficient, future development still has to face challenges related to the sensor's accuracy and sensitivity to extreme weather and high humidity. At the international level, peer-reviewed studies have documented the humidity-dependent bias of Plantower PMS-series sensors, which overestimate $PM_{2.5}$ as relative humidity increases due to hygroscopic particle growth (Barkjohn et al. 2021). The U.S. EPA addressed this with a nationwide multilinear regression correction incorporating relative humidity, later refined for warm–humid climates with 16–23% error reduction directly relevant to tropical settings like Jambi (Mathieu-Campbell et al. 2024). Comparable collocation studies report R^2 values consistent with this study's results, ranging from 0.60 to 0.72–0.78, while newer physical correction approaches offer alternatives to statistical models (Lekamge and Oswin 2025). No local Jambi study, however, has yet incorporated a humidity correction or benchmarked against this international literature — a gap this study addresses.

This $PM_{2.5}$ sensor system uses the electronic setup and programming from Mutawaqil (2025), with slight changes to the casing shape to improve airflow and weather protection.

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Figure 1. PMS5003 Sensor

The PMS5003 sensor uses the principle of laser scattering to detect particles ranging in diameter from 0.3 µm to 10 µm, reported as $PM_{1.0}$, $PM_{2.5}$, and PM_{10} mass concentrations in real time (Zulhelman and Wisesa 2021). Due to its compact size and use of a UART interface, this sensor is easy to connect to microcontrollers such as the ESP32 or Arduino. Although its power consumption is low, its accuracy is susceptible to extreme temperatures and high humidity, thus requiring additional calibration to maintain data quality under various environmental conditions.

Figure 2. PMS7003 Sensor

The PMS7003 sensor is a particle detector for sizes ranging from 0.3 to 10 microns that transmits $PM_{1.0}$, $PM_{2.5}$, and PM_{10} data every second via a serial connection (Fatkhurrahman et al. 2019). This instrument is highly suitable for monitoring ambient air due to its durability, portability, and affordability (Okaem et al. 2022). Despite all the advantages, the accuracy of this sensor is still affected by environmental factors, where high humidity and low temperatures can cause concentration readings to be higher than the actual value.

Figure 3. BME280 Sensor

The BME280 sensor was used only for device housekeeping (internal logging of temperature and relative humidity); its readings were not included in the accuracy or correction analysis reported in this study.

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2.3 Description of Device Placement

This research uses a real-time IoT-based air quality monitoring system to measure $PM_{2.5}$ concentrations (µg/m^3) using the PMS5003 and PMS7003 sensors. This device was developed by replicating the configuration, working principle, and data acquisition method from previous research, but with adjustments to the physical design to make it more functional, neat, and easy to operate. The data obtained then processed by a microcontroller, then sent periodically to a web-based platform via a communication module supported by a power supply and continuous storage media. To maintain data accuracy, the device was installed side by side with the BMKG reference instrument in an open area on top of the building at the Sultan Thaha-Jambi Aviation Meteorological Office Station. This location was chosen so that air circulation remains optimal and free from external disturbances such as local emissions, turbulence, or heat reflection. This is important so that the data produced is truly accurate for evaluating sensor performance.

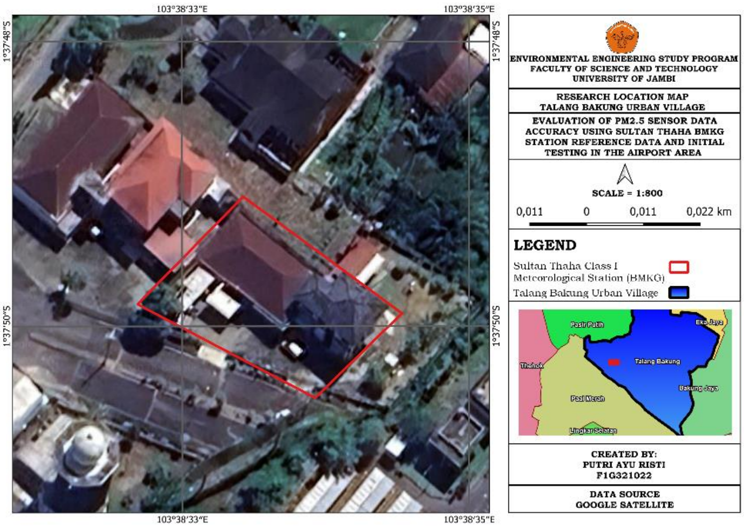

Figure 4. Location of The Research

2.4 Data Collection Techniques

Data collection in this study was carried out to evaluate the performance of the IoT-based air quality monitoring device by comparing two main sources, namely the readings from the PMS7003 and PMS5003 sensors against the reference instrument belonging to the BMKG Sultan Thaha Jambi Station (BAM1020 sensor). Technically, the ESP32 microcontroller receives $PM_{2.5}$ concentration data from the sensors, displays it on an LCD screen, and forwards it periodically to an IoT dashboard. Data from the official BMKG instrument was taken to match the reading time of the IoT sensors in order to avoid bias. Environmental conditions such as temperature, humidity, and the location of the devices were also ensured to be comparable. Subsequently, all the data were statistically analyzed to test the level of accuracy and consistency of the developed monitoring system.

Both sensors reported $PM_{2.5}$ concentrations at one-minute intervals; these readings were averaged to hourly values to match the temporal resolution of the BAM-

1020. Hourly averages were computed only when at least 75% of the one-minute records within the hour were valid.

Table 1. BAM1020 Sensor Data

No	Date	BAM1020 (µg/m³)
1	04 December 2025	27.99
2	05 December 2025	15.25
3	06 December 2025	18.99
4	07 December 2025	16.30
5	08 December 2025	22.79
6	09 December 2025	25.53
7	10 December 2025	17.65
8	11 December 2025	28.02
9	14 December 2025	15.66
10	15 December 2025	12.72
11	16 December 2025	13.98
12	17 December 2025	12.10
13	18 December 2025	14.60
14	19 December 2025	15.57
15	20 December 2025	15.25
16	21 December 2025	23.55
17	22 December 2025	23.34
18	25 December 2025	24.32
19	26 December 2025	20.42
20	27 December 2025	22.23
21	28 December 2025	20.81
22	29 December 2025	15.27
23	30 December 2025	22.60
24	31 December 2025	37.91
25	01 January 2026	23.12
26	02 January 2026	12.80
27	03 January 2026	10.39
28	04 January 2026	24.74

Data availability: the raw and processed datasets supporting this study are available from the corresponding author upon reasonable request.

2.5 Data Analysis Techniques

Evaluation of accuracy and precision is crucial for validating the performance of the $PM_{2.5}$ sensor against BMKG (BAM1020) reference data, which can be observed in Table 1. Accuracy measures how close the results are to the reference value, while precision assesses the consistency of repeated measurements. Given that external factors such as weather greatly affect low-cost sensors, local calibration and field testing through standard deviation are needed to ensure data reliability (Kelly et al. 2017). The assessment is carried out through four main statistical parameters, namely:

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a) Mean Bias Error (MBE)

MBE is used to evaluate whether the IoT device tends to produce readings that are higher or lower compared to the reference sensor. A positive MBE value indicates that the sensor tends to read higher, while a negative value indicates a tendency to read lower compared to the reference.

MBE Formula:

$$\text{MBE} = \frac{1}{n}\sum_{i=1}^{n}(x_i - y_i)$$

Description:

x_i = measurement value from the IoT sensor.

y_i = actual or reference value (e.g., data from the BMKG sensor).

n = total number of data observed.

b) Mean Absolute Error (MAE)

MAE is used to measure the average magnitude of the absolute error between the IoT sensor data and the BMKG data. The smaller the MAE value, the better the sensor's level of accuracy.

$$\text{MAE} = \frac{1}{n}\sum_{i=1}^{n}|x_i - y_i|$$

Description:

x_i = sensor measurement value

y_i = reference value

n = number of data

$| x_i - y_i |$ = absolute difference (without negative sign)

c) Root Mean Square Error (RMSE)

RMSE is used to calculate the level of error between two data sets. RMSE places greater emphasis on large errors, and a lower value indicates a better fit between the data.

$$\text{RMSE} = \sqrt{\frac{\sum_{i=1}^{n}(x_i - y_i)^2}{n}}$$

Description:

x_i = predicted value (IoT sensor),

y_i = actual value (reference sensor),

n = number of data samples.

d) Coefficient of Determination (R^2)

The coefficient of determination is the square of the Pearson correlation value.

$$R^2=r^2$$

while the correlation formula (r):

$$r = \frac{\sum(X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum(X_i - \bar{X})^2\sum(Y_i - \bar{Y})^2}}$$

Description:

X_i= sensor data

Y_i= reference data

$\bar{X}$= mean of sensor

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$\overline{Y}$= mean of reference

3. Result and Discussion

3.1 $PM_{2.5}$ Sensor Measurement Results

$PM_{2.5}$ concentration data (µg/m3) from the PMS5003 and PMS7003 sensors were collected periodically every one hour from December 4, 2025, to January 4, 2026, to describe air quality conditions. To maintain the accuracy of the analysis, empty data (with a value of zero) caused by technical disturbances was removed. The remaining data was then calculated for its daily average and converted into a graph to show the air quality pattern in the Sultan Thaha Airport area. Data from BMKG's air quality monitoring instrument (BAM1020) was then used as the reference in this study. The graph of the $PM_{2.5}$ sensor measurement results can be seen in Figure 5.

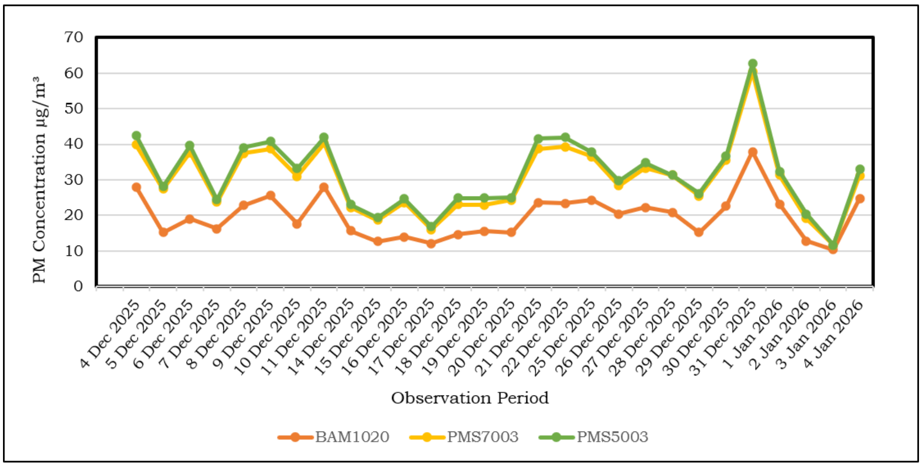

Figure 5. $PM_{2.5}$ Sensor Measurement Result

The daily average graph from the PMS5003 sensor shows that the $PM_{2.5}$ concentration is fluctuating and dynamic, where the daily average values ranged from 23 to 42 µg/m³ from the beginning to the middle of December, then slightly decreases, and rises significantly toward the end of the year until reaching its peak on December 31 due to increased activity related to the year-end transition. Entering early January, the concentration dropped sharply on January 2–3 before rising again on January 4. The consistency of the trend pattern between the PMS5003 and the BAM-1020 indicates that the PMS5003 sensor is capable of capturing short-term variations in air quality. Meanwhile, the PMS7003 sensor shows a dynamic and fluctuating trend in $PM_{2.5}$ concentration through several phases of change. At the beginning of the observation, the graph moves stably within a narrow range, indicating relatively controlled air quality. Entering mid to late December, the graph begins to fluctuate sharply with a gradually increasing tendency until peaking in the form of a prominent spike at the end of the year due to activities that significantly affected particulates. After that, the graph shows a sharp decline in early January before finally gradually moving upward again.

A direct comparative analysis through the daily average graph above shows that the PMS5003 and PMS7003 sensors have a very good level of consistency in recording changes in air quality. Both sensors display very similar trend patterns, with matching timing in every increase and decrease in value, including the relatively stable phase at

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the beginning of the observation period. Although there are slight differences in value on several days due to technical factors and the sensitivity of each device, these differences are still within reasonable limits and do not affect the overall consistency of the data produced by both devices. However, the pattern of change in $PM_{2.5}$ concentration from both sensors tends to align and has a relatively similar rising-falling trend to the BMKG reference data, which indicates the ability of both to follow the dynamics of air quality. Although capable of following the change pattern well, both sensors show a tendency to overestimate result compared to the BAM1020. Therefore, further quantitative analysis using statistical parameters is needed to accurately evaluate the level of error and the strength of the relationship between the data of both sensors and the reference data.

3.2 Statistical Analysis of Sensor Accuracy

Statistical analysis was carried out to evaluate the accuracy, error rate, and quantitative relationship between the sensor data (PMS5003 and PMS7003) and the BAM1020 reference data using the parameters MBE, MAE, RMSE, correlation coefficient (r), and coefficient of determination (R^2). Out of 744 possible hourly records between 00:00 on 4 December 2025 and 23:00 on 4 January 2026, 659 records (88.6%) were retained for analysis; the remaining records were removed during data cleaning because they contained invalid (zero) values caused by technical disturbances.

a) Accuracy of the PMS5003 Sensor Compared to the BAM1020 Sensor

Based on the accuracy evaluation of the PMS5003 sensor against the BAM1020 reference data, an MBE value of 11.84 $\mu g/m^3$ was obtained. This positive MBE value indicates that the PMS5003 sensor consistently produces readings higher than the reference data, reflecting a systematic tendency to overestimate measured concentrations. An MAE value of 13.60 $\mu g/m^3$ reveals that the average absolute deviation between the sensor readings and the reference data is considerably large, suggesting a substantial discrepancy between the two instruments. Meanwhile, an RMSE value of 19.60 $\mu g/m^3$, which exceeds the MAE, points to the presence of several data points with notably large deviations from the reference, as RMSE is inherently more sensitive to extreme error values.

A correlation coefficient (r) of 0.78 indicates a strong and positive relationship between the PMS5003 sensor measurements and the BAM1020 reference data, demonstrating that the sensor is capable of tracking changes in $PM_{2.5}$ concentration reasonably well. The coefficient of determination (R^2) of 0.60 further suggests that approximately 60% of the variance in the reference data can be accounted for by the sensor readings, while the remaining 40% is attributed to other factors beyond the model. Overall, although the PMS5003 sensor is able to capture general trends in $PM_{2.5}$ concentration, the relatively high error values and consistent overestimation indicate that a correction or calibration process is necessary to enhance the sensor's measurement accuracy.

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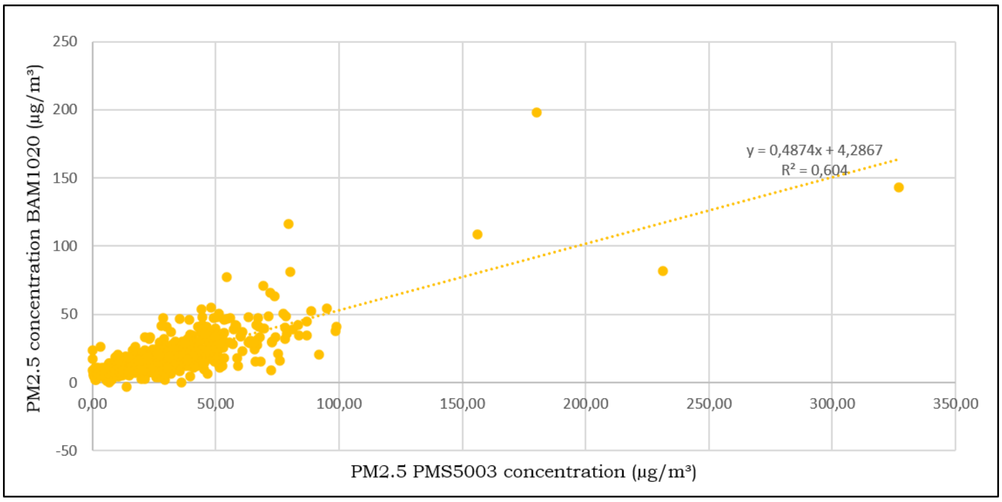

Figure 6. Scatter Plot Graph of the PMS5003 Sensor

Based on the scatter plot graph above and the statistical analysis, the PMS5003 sensor shows a fairly strong positive linear relationship (R^2 0.60) with the BMKG BAM1020 reference instrument, where the sensor is able to follow the pattern of $PM_{2.5}$ changes well at low concentrations. However, this sensor's performance has a fairly significant bias and error rate. The regression equation y = 0.4874x + 4.2867, along with the positive MBE value, confirms a tendency caused by the sensitivity of the optical sensor and the effect of high air humidity that enlarges hygroscopic particles. In addition, the MAE value of 13.60 µg/m³ shows a significant absolute difference, while the larger RMSE value (19.60 µg/m³) indicates the presence of extreme deviations and instability in readings under certain conditions (high concentrations).

b) Accuracy of the PMS7003 Sensor Compared to BAM1020 Data

Based on the accuracy evaluation of the PMS7003 sensor against the BAM1020 reference data, an MBE value of 10.46 µg/m³ was obtained. This positive MBE value indicates that the PMS7003 sensor consistently produces readings higher than the reference data, reflecting a systematic tendency to overestimate measured concentrations. An MAE value of 12.53 µg/m³ reveals that the average absolute deviation between the sensor readings and the reference data is considerably large, suggesting a substantial discrepancy between the two instruments. Meanwhile, an RMSE value of 18.02 µg/m³, which exceeds the MAE, points to the presence of several data points with notably large deviations from the reference, as RMSE is inherently more sensitive to extreme error values.

A correlation coefficient (r) of 0.77 indicates a strong and positive relationship between the PMS7003 sensor measurements and the BAM1020 reference data, demonstrating that the sensor is capable of tracking changes in $PM_{2.5}$ concentration reasonably well. The coefficient of determination (R^2) of 0.59 further suggests that approximately 59% of the variance in the reference data can be accounted for by the sensor readings, while the remaining 41% is attributed to other factors beyond the model. Overall, although the PMS7003 sensor is able to capture general trends in $PM_{2.5}$ concentration, the relatively high error values and consistent overestimation indicate that a correction or calibration process is necessary to enhance the sensor's measurement accuracy.

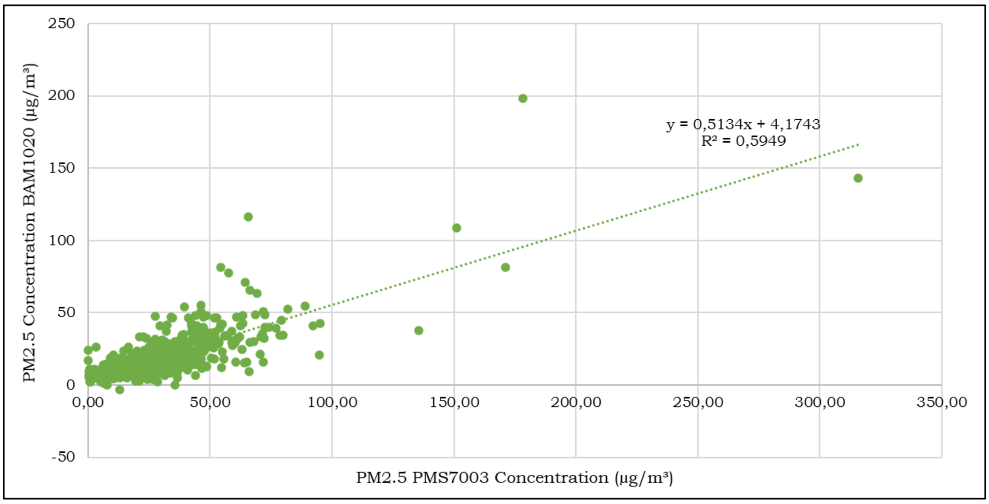

Figure 7. Scatter Plot Graph of the PMS7003 Sensor

Based on the scatter plot graph above and the statistical analysis, the PMS7003 sensor shows a fairly strong positive linear relationship (R^2 = 0.59) with the BAM1020 reference instrument, where the data distribution appears dense and stable at low concentrations but shows deviation at high concentrations. Although reliable for monitoring trends, this sensor has a certain bias and measurement error. The regression equation y = 0.5134x + 4.1743 and the positive MBE value (10.46 µg/m³) confirm a tendency toward higher readings (overestimate). The MAE value of 12.53 µg/m³ and RMSE of 18.02 µg/m³ also indicate the presence of an absolute difference and several fairly large measurement errors under certain conditions. Overall, the level of bias and extreme error in the PMS7003 is lower and more controlled compared to the PMS5003 sensor, although it still requires further calibration to improve the accuracy of its absolute value.

c) Comparison of the Performance of the PMS5003 and PMS7003 Sensors

Table 2. Accuracy Test Result of the PMS5003 and PMS7003 Sensors

Statistical Parameter	PMS5003	PMS7003
MBE (µg/m³)	11.84	10.46
MAE (µg/m³)	13.60	12.53
RMSE (µg/m³)	19.60	18.02
Coefficient of Determination (R^2)	0.60	0.59

The error metrics presented in Table 2 are reported as point estimates. Standard deviations and 95% bootstrap confidence intervals were not calculated because the objective of this study was limited to evaluating sensor performance using point estimates derived from the collocated dataset.

Based on the comparison of the performance of the PMS5003 and PMS7003 sensors above, it shows that both sensors have relatively similar performance and are equally reliable in following the pattern of changes in $PM_{2.5}$ concentration, as proven by the coefficient of determination value (R^2 0.59–0.60) and a linear regression value close

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to 1. However, the main difference between these two light-scattering-based sensors lies in their level of absolute error due to differences in the characteristics and sensitivity of the devices. In general, the pattern-tracking performance of the two sensors is statistically indistinguishable (R^2 = 0.60 vs 0.59), whereas the PMS7003 shows consistently lower absolute errors (MBE, MAE, and RMSE) relative to the BAM-1020 reference instrument and can therefore be considered marginally more accurate in absolute terms.

The R^2 values obtained in this study (0.59–0.60) are within the range reported by previous collocation studies of Plantower sensors under humid ambient conditions, which strengthens the validity of the present evaluation (Magi et al. 2020; Bulot et al. 2019).

3.3 Correction of Sensor Measurement Results Using the Regression Equation

Accuracy evaluation results showed that both the PMS5003 and PMS7003 sensors tend to produce higher readings than the BAM1020 reference data. To correct this, a linear calibration model was fitted with the BAM-1020 concentration as the dependent variable and the sensor reading as the independent variable:

$$C_{ref} = a \cdot C_{sensor} + b$$

This formulation allows the fitted equation to be applied directly as a correction function without algebraic inversion, consistent with standard practice in low-cost sensor calibration. The regression equation for each sensor is shown in Table 3 below.

Table 3. Regression Equation of the PMS5003 and PMS7003 Sensors

Sensor	Regression Equation
PMS5003	y = 0.4874x + 4.2867
PMS7003	y = 0.5134x + 4.1743

The correction equations were then applied to all daily average $PM_{2.5}$ concentration data obtained from the PMS5003 and PMS7003 sensors. The corrected $PM_{2.5}$ concentration results for each sensor are shown in the graphs below:

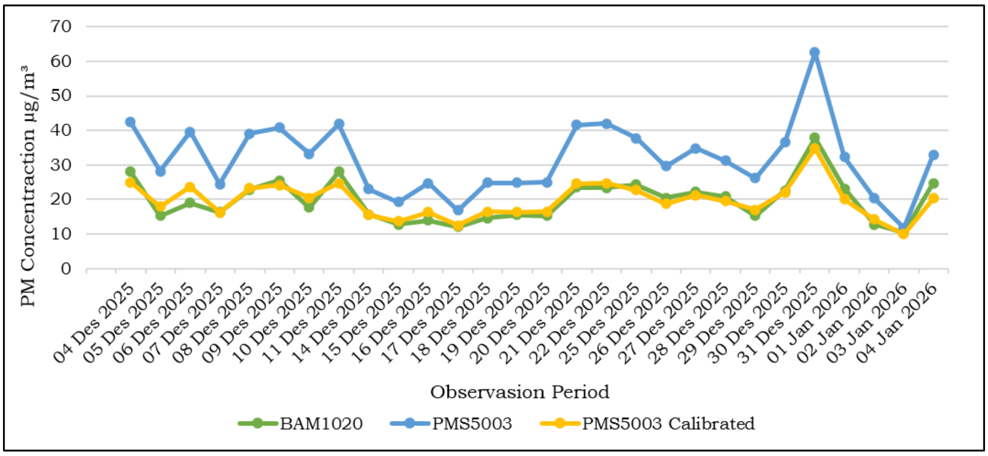

Figure 8. Comparison of $PM_{2.5}$ Concentration of BAM1020 and PMS5003 Before and After Correction

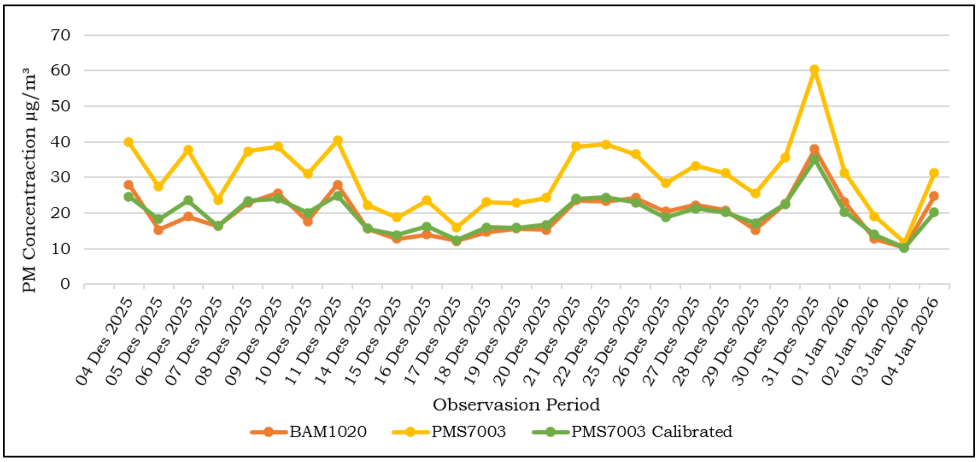

Figure 9. Comparison of $PM_{2.5}$ Concentration of BAM1020 and PMS7003 Before and After Correction

All regression analyses and error metrics (MBE, MAE, and RMSE) were calculated using the hourly collocated dataset (659 observations). Daily averages presented in Figures 8 and 9 were used only to facilitate visualization of temporal trends before and after correction and were not used to derive the regression equations or calculate the error statistics.

Table 4 summarizes the error statistics before and after correction. The correction reduced the MBE from 11.84 to 0.00 µg/m³ (PMS5003) and from 10.46 to -0.67 µg/m³ (PMS7003), with corresponding reductions in MAE and RMSE.

Table 4. Statistical Performance Evaluation Metrics for PMS5003 and PMS7003 Sensors Before and After Calibration

Statistica Parameter	PMS5003	PMS5003 Calibrated	PMS7003	PMS7003 Calibrated
MBE (µg/m³)	11.84	0.00	10.46	-0.67
MAE (µg/m³)	13.60	5.84	12.53	5.81
RMSE (µg/m³)	19.60	9.53	18.02	9.68
Coefficient of Determination (R^2)	0.60	0.60	0.59	0.59

Figure 8 shows that after correction, the PMS5003 readings shifted closer to the BAM1020 reference data, reducing the overestimation seen before correction while preserving the overall concentration pattern. Similarly, Figure 9 shows that the PMS7003 readings, which also tended to overestimate, moved closer to the BAM1020 curve after correction, indicating that the regression equation reduced its positive bias.

After correction, the in-sample error statistics improved from MBE = 11.84 µg/m³ to 0.00 µg/m³, MAE = 13.60 µg/m³ to 5.84 µg/m³, and RMSE = 19.60 µg/m³ to 9.53 µg/m³ for the PMS5003, and from MBE = 10.46 µg/m³ to -0.67 µg/m³, MAE = 12.53 µg/m³ to 5.81 µg/m³, and RMSE = 18.02 µg/m³ to 9.86 µg/m³ for the PMS7003 (Table 4). Because these metrics were computed on the same data used to derive the regression coefficients, they represent the in-sample fit rather than an independent validation; the near-zero MBE is an algebraic property of ordinary least squares and should not be interpreted as evidence of out-of-sample accuracy.

4. Conclusion

This research concludes that the PMS5003 and PMS7003 sensors have a fairly good ability to follow the pattern of changes in $PM_{2.5}$ concentration, with a coefficient of determination value (R^2) of 0.59–0.60. However, both sensors tend to produce higher values (overestimate) compared to the BMKG reference data—indicated by a positive MBE value of 11.84 µg/m³ (PMS5003) and 10.46 µg/m³ (PMS7003)—as well as large MAE and RMSE values, thus requiring calibration for accurate measurement. This inaccuracy is consistent with the known sensitivity of light-scattering sensors to high relative humidity reported in previous studies, although this influence was not statistically tested in the present study. In addition, the characteristics of the sensor, which uses the light scattering method, make it sensitive to particle size, unable to distinguish solid particles from water droplets, and susceptible to a coincidence effect that triggers readings biased higher than actual conditions. Future work should optimize the calibration method by incorporating relative humidity as a covariate, extend the collocation period to capture seasonal variability, and improve the reliability of the IoT data pipeline — including automatic backup or temporary local storage — to prevent data loss caused by technical disturbances.

AI Writing Statement

During the preparation of this manuscript, the authors used Claude (Anthropic, 2026) for English language editing. The authors have reviewed, verified, and edited all AI-assisted content and accept full responsibility for the integrity and accuracy of the manuscript.

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