*Ceddi Journal of Information Systems and Technology (JST)* *ISSN:2829-808X (print)*
*Vol. 4 No. 1 April (2025)* *ISSN:2829-6575 (online)*
https://doi.org/10.56134/jst.v4i1.111

# Internet of Things (IoT) Based Air Pollution Detector for Baby Rooms

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**Abstract**

Indoor air pollution is a leading cause of respiratory illnesses in infants and children, potentially resulting in severe health outcomes, including death. Common sources include dust, cigarette smoke, cleaning chemicals, and hazardous gases such as carbon monoxide (CO) and nitrogen dioxide ($NO_2$), particularly in enclosed, air-conditioned (AC) environments. Due to the difficulty of detecting pollutants like fine particulate matter (PM2.5) and CO, an effective, real-time monitoring solution is crucial. This study aims to design and develop an Internet of Things (IoT)-based device capable of monitoring PM2.5, CO, temperature, and humidity, specifically in infant rooms. The system integrates an ESP32 microcontroller with DSM501a, MQ-7, and DHT22 sensors and features automated alerts via a Telegram bot when pollutant levels exceed predefined thresholds. The device was evaluated through a comparative 24/7 testing method over seven days against commercially available standard instruments. Results show a relative error of 25% for PM2.5, 30% for CO, and significantly lower errors for temperature (2%) and humidity (0%). Sensor data is processed and transmitted to the Thingspeak server for real-time graphical monitoring. The Telegram alert feature demonstrated an average response time of 1.84 seconds across 20 tests. The findings suggest that the proposed device offers a viable, accessible, and responsive solution for indoor pollutant detection, contributing to improved air quality monitoring and early warning systems to protect vulnerable populations, especially infants.

*Keywords:* Indoor Air Pollution; Infant Room Monitoring; Internet of Things (IoT); Real-Time Notification System; PM2.5 and Carbon Monoxide Detection.

Received: 22 December 2024 Revised: 3 February 2025 Accepted: 15 April 2025

## Introduction

Air pollution is a significant environmental problem and can have negative impacts on human health, especially on infants and children who are vulnerable to its adverse effects (Priyana, 2023; Rafsanjani, 2021; Rosyidah, 2018; Yunus, 2004). Indonesia is one of the countries with the worst levels of air pollution in the world (Haryanto, 2018; Yasir, 2021; Nugraha & Bhwana, 2021). WHO even estimates that the life expectancy of Indonesian people can decrease by 5.5 per year due to inhaling air pollution every day (Yuwono, 2008). Indoor air quality pollution is one of the causes of respiratory diseases in infants and children, which results in death (Garmini & Purwana, 2020). Indoor air pollution is a serious threat to health, especially for babies who have a respiratory system that is not yet fully developed (Handayani, 2020; RF & Oktaviani, 2024; Tunashijau, 2024). Nearly two-thirds of the 500,000 recorded infant deaths are linked to indoor air pollution (Mukaromah & Nugroho, 2020; Inscription, 2020; Forbes et al., 2020).

Indoor air pollution can come from sources such as dust, cigarette smoke, chemicals from cleaning products, and harmful gases such as carbon monoxide (CO) or nitrogen dioxide (NO2) produced by household appliances (Fadila & Upahita, 2024; Kav, 2024; Rosário Filho et al., 2021; Mukono, 2011; Saidal Siburian & Mar, 2020; Suhartawan & MT, 2024). In a closed baby room that uses an air conditioning (AC) system, there is the potential for air pollution to be trapped in the room.(Administrator, 2024). Although air conditioning is used to maintain a comfortable temperature in the baby's room, its use does not completely eliminate indoor air pollution (Putri Krislia, 2021). In addition, these gases are colorless, cannot be felt, and have no odor, making them difficult for humans to detect (Azka, 2023; Prasetyo, 2023; Salim, 2023).

Given the difficulty of realizing the presence of pollutants such as fine particles (PM2.5) and carbon monoxide (CO), a tool is needed to detect these pollutants, especially in closed rooms with air conditioning (AC) (Aji, 2024; Prasetyo, 2024). Although there are several air pollution detectors available, most of them are not specifically designed for the baby's room. In addition, most traditional detectors require manual supervision and are often difficult to operate by busy

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parents caring for their babies (Puskomedia, 2024; Taufiqullah, 2024). Therefore, it is necessary to develop an intelligent and easy-to-use air pollution detector for baby rooms based on the Internet of Things (IoT).

Several studies have been conducted on indoor air pollution detectors and the use of IoT technology for air quality monitoring. Such as the creation of an indoor air pollution detector based on the Internet of Things (IoT), where if pollution is detected, the image will be sent and displayed on the Telegram application (Sari & Waliyuddin, 2021). Rivaldi et al. (2022) Creating a detection system for toxic gas pollution, CO, HC, NOx, in a closed room, which is the result of fossil fuel combustion by engines. Next, there is IOT-Based Pollution and Air Quality Monitoring Equipment with ESP-8266, which focuses on the outdoors to detect air pollutants such as CO, CO2, SO2, and NO2 (Lumbangaol et al., 2022). However, the detection and monitoring of air quality in specific rooms of baby rooms has not been carried out.

Therefore, this study aims to fill this gap and provide an effective solution for IoT-based indoor air pollution monitoring in baby rooms (Iglesia et al., 2018). The detector to be developed will measure important parameters such as PM2.5, carbon monoxide, and other parameters relevant to air quality in the baby's room, namely temperature and humidity. This research is a new contribution in the field of air pollution monitoring in the baby's room, which in turn is expected to provide better health protection for babies. Through this research, it is hoped that a solution will be found that can help parents or caregivers of babies take appropriate actions to maintain healthy air quality in closed and air-conditioned baby rooms. With an accurate IoT-based air pollution detector connected to a monitoring system, users can receive real-time information about the level of air pollution in the baby's room through an application or connected device.

## Method

The type of research used in this study is R&D/Research and Development. R&D research is a type of research that functions to produce something new and is continued with testing it (Maydiantoro, 2021; Putra, 2012; Safitri et al., 2020). Then, the research method used is the waterfall method. The reason for using this method is that the waterfall method takes a systematic and sequential approach in building a system (Adminlp2m, 2022; Iqbal, 2023; Tekno, 2021). The waterfall method is when the work on a system is carried out sequentially. The resulting system will be of good quality, because its implementation is gradual, so that it is not focused on a particular stage (Borecky et al., 2016; Meilinaeka, 2023; Senarath, 2021). The stages are needs analysis, system design, implementation, testing, and maintenance.

The data collected is primary data because the data is taken directly from the source without going through an intermediary. The data taken is the number generated by the two sensors installed in units of µgr/m3 (24 hours) for PM2.5 and ppm (8 hours) for carbon monoxide levels. This data is then processed by the ESP32, which is then sent to the Thingspeak server to be displayed in real time, and will send a notification to the Telegram application if the pollutant levels in the room exceed the threshold.

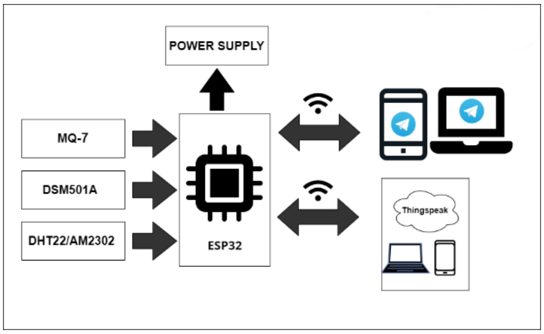


Figure 1. Tool scheme

Figure 1 shows the overall scheme and how the device works. The data detected by the MQ-7, DSM501A, DHT22/AM2302 sensors are carbon monoxide (CO), dust particles (PM2.5), temperature and humidity obtained from the surrounding air which will then be processed by the ESP32, and the wifi module on the microcontroller will send information to the internet. information sent by the ESP32 microcontroller will be sent to the ThingSpeak server.

Thingspeak is an IoT platform that functions to record data from sensors that have been sent by the microcontroller, so that the platform converts input data into output in the form of graphical information in real-time (Ersyandhy, 2024; Nettikadan et al., 2018; Pimprale et al., 2023). Users will access via a web browser to the server so that the results are obtain information about the content of carbon monoxide (CO) and dust particles, which are parameters for measuring air quality. If the level of air pollutants in the air exceeds the threshold, a notification in the form of a warning will be sent to the user via the Telegram application installed on a smartphone or laptop.

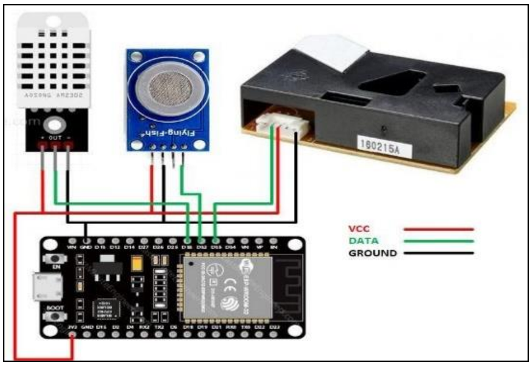


Figure 2. Tool circuit diagram

In Figure 2, the schematic circuit of the device is a circuit that will illustrate the device's function as an input and a processor in the system (Elektronika, 2024; Tagliafico, 2021). The MQ-7 sensor consists of 4-pin legs. The data pin on the MQ-7 sensor is connected to the D32 pin on the ESP32, the Vcc + 3.3V sensor is connected to the 3V3 ESP32, while the GND sensor is connected to the GND pin of the ESP32. On the DSM501A dust sensor, the DATA port is connected to the D35 pin of the ESP32, the GND sensor is connected to the GND pin of the ESP32, and the Vcc + 5V sensor is connected to the 3V3 ESP32. As for the DHT22 sensor, which consists of three legs, namely DATA, which is connected to the D33 pin of the ESP32, GND to the GND pin of the ESP32, and Vcc + 3.3V is connected to the 3V3 pin of the ESP32.

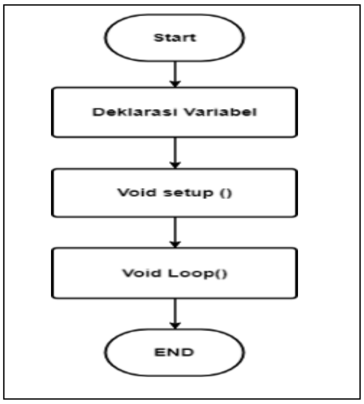


Figure 3. Flowchart of the tool algorithm

In Figure 3, the steps of the tool algorithm are shown to consist of several stages. First, the process begins with Start. Then, a variable declaration is made to define a data storage location whose values can change during program execution, such as the variables “carbon monoxide, “PM2.5,” “temperature,” and “humidity.” Next, in the Void Setup() section, the pin configuration for the MQ-7, DSM501A, and DHT11 sensors is carried out according to Figure 8. After that, the Void Loop() section runs the main program repeatedly, including the retrieval of sensor data, display of pollutant, temperature, and humidity data on Thingspeak, and sending warning notifications to Telegram. This process ends with End.

## Results and Discussion

### Results

The system implementation is the result of designing an IoT-based air pollution detection device in a baby's room that has been designed in the previous chapter. The implementation of this tool circuit is an implementation in terms of physical aspects and the arrangement of each component. The IoT (Internet of Things)-based air pollution detection device in a baby's room is made from a plastic project box. The plastic project box used has dimensions of 12.5 cm x 8.5 cm x 5 cm. which contains an ESP32 microcontroller, DSM501A sensor, MQ-7 sensor, DHT22 sensor. The physical appearance and circuit of the system can be seen in Figure 4.

(i) (ii) (iii)

Figure 4. Tool view (i) Front (ii) Side (iii) Inside

Figure 4 shows that inside the project box, there is an ESP32 microcontroller that functions to process the sensing results from 3 installed sensors. The three sensors are connected to the ESP32 using the existing jumper cables. On the side of the project box, there are 3 types of ports that are used as a power supply to the device and also to carry out the process of uploading code to the ESP32. Testing the performance of the tool in the field, this test is carried out to determine the ability of the tool to detect pollutants in the baby's room. Data taken from the sensor based on daily use for the use of AC (Air Conditioner) in the baby's room is only 8-10 hours per day, which is only during the day. Testing the tool is carried out by comparing the output of the air data obtained with the air quality measuring tool selected as a comparison. The data collection process is carried out every 30 seconds for 24 hours. the results of the performance test of the comparison tool for each parameter can be seen in Table 1.

Table 1. Results of tool performance testing in the field

| **No** | **Datetime** | **Tools Made** | | | | **Beurer HM 16 Thermo Hygrometer** | | **AQM Portable Stock** | **AS8700A Portable** |
|---|---|---|---|---|---|---|---|---|---|
| | | **Temperature** | **Moisture** | **PM2.5** | **CO2 gas** | **Temperature** | **Wetness** | **PM2.5** | **CO2 gas** |
| 1 | 2023-09-12T00:00:00 +07:00 | 24 | 51 | 8.05 | 0.39 | 25.5 | 50 | 8.18 | 0.62 |
| 2 | 2023-09-12T00:00:30 +07:00 | 24.7 | 50 | 8.23 | 0.22 | 25.8 | 50 | 9.44 | 0.56 |
| 3 | 2023-09-12T00:01:00 +07:00 | 23.7 | 51 | 5.83 | 0.27 | 26.7 | 49 | 7.56 | 0.64 |
| 4 | 2023-09-12T00:01:30 +07:00 | 25.9 | 50 | 9.31 | 0.67 | 25.5 | 50 | 6.71 | 0.41 |
| 5 | 2023-09-12T00:02:00 +07:00 | 23.5 | 51 | 9.02 | 0.39 | 27.3 | 49 | 6.67 | 0.42 |
| 6 | 2023-09-12T00:02:30 +07:00 | 24.7 | 50 | 11.1 | 0.52 | 26.5 | 49 | 9.45 | 0.43 |
| 7 | 2023-09-12T00:03:00 +07:00 | 26 | 50 | 7.21 | 0.25 | 25.5 | 50 | 6.67 | 0.53 |

| No | Datetime | Tools Made | | | | Beurer HM 16 Thermo Hygrometer | | AQM Portable Stock | AS8700A Portable |
|---|---|---|---|---|---|---|---|---|---|
| | | Temperature | Moisture | PM2.5 | CO2 gas | Temperature | Wetness | PM2.5 | CO2 gas |
| 8 | 2023-09-12T00:03:30 +07:00 | 25.3 | 50 | 6.2 | 0.27 | 27.3 | 49 | 8.23 | 0.44 |
| 9 | 2023-09-12T00:04:00 +07:00 | 24.3 | 50 | 7.67 | 0.72 | 26 | 49 | 6.7 | 0.44 |
| 10 | 2023-09-12T00:04:30 +07:00 | 25.9 | 50 | 11.88 | 0.38 | 27.3 | 49 | 6.07 | 0.48 |
| . | . | . | . | . | . | . | . | . | . |
| n | n | n | n | n | n | n | n | n | n |
| 17280 | 2023-09-17T23:59:30 +07:00 | 25.7 | 50 | 7.17 | 0.78 | 25.8 | 50 | 7.12 | 0.61 |
| **Average** | | **26.42** | **49.29** | **8.48** | **0.50** | **28.38** | **48.31** | **8.00** | **0.55** |

Table 1 shows the data of the field test results between the tool that has been made and the air quality measuring tool used as a comparison for 24/7 consecutive days. The total data amounted to 17280, which was successfully recorded by the tool that was made. All data that was successfully recorded was then processed by ESP32 and then sent to the Thingspeak server and displayed in graphic form on the Thingspeak website, as in Figure 5.

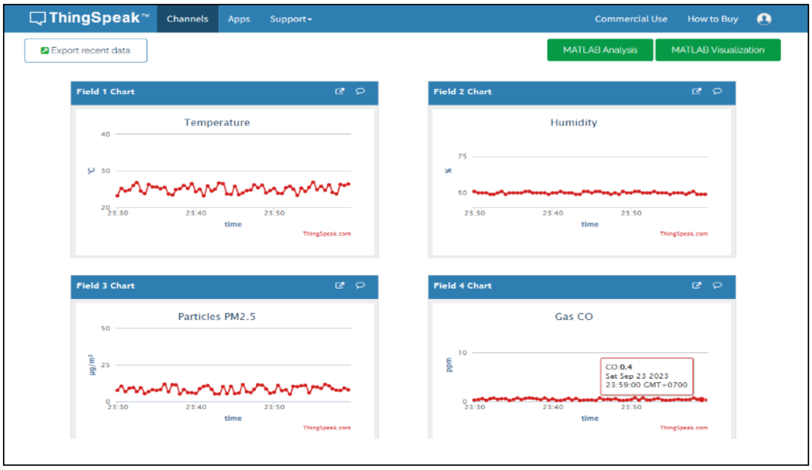
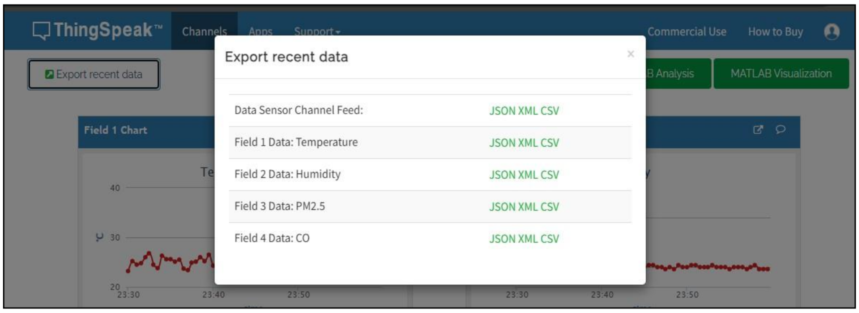


Figure 5. Display of tool test result data on Thingspeak

The test result data displayed on the Thingspeak dashboard can be exported with file extensions in the form of JSON, XML, or CSV, as shown in Figure 6.

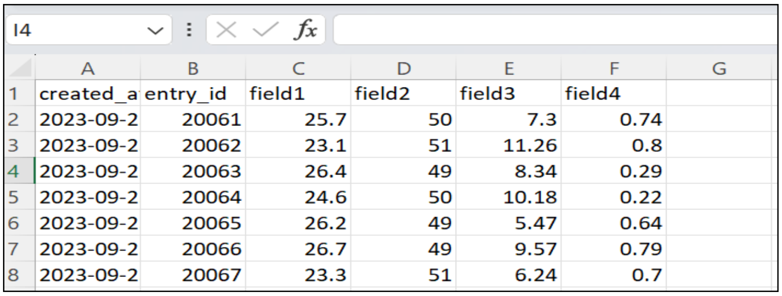


Export recent data

| | |
|---|---|
| Data Sensor Channel Feed: | JSON XML CSV |
| Field 1 Data: Temperature | JSON XML CSV |
| Field 2 Data: Humidity | JSON XML CSV |
| Field 3 Data: PM2.5 | JSON XML CSV |
| Field 4 Data: CO | JSON XML CSV |

Figure 6. Thingspeak data export

The export results for all test parameters, namely temperature, humidity, PM2.5, and CO gas in Comma Separated Value or CSV format, are shown in Figure 7.

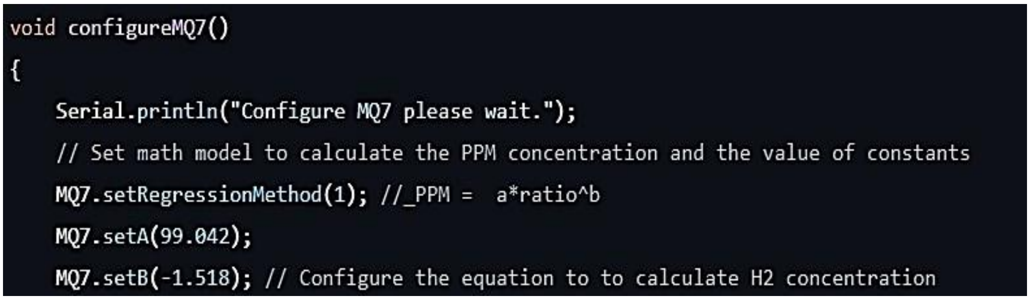


| | A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|
| 1 | created_a | entry_id | field1 | field2 | field3 | field4 | |
| 2 | 2023-09-2 | 20061 | 25.7 | 50 | 7.3 | 0.74 | |
| 3 | 2023-09-2 | 20062 | 23.1 | 51 | 11.26 | 0.8 | |
| 4 | 2023-09-2 | 20063 | 26.4 | 49 | 8.34 | 0.29 | |
| 5 | 2023-09-2 | 20064 | 24.6 | 50 | 10.18 | 0.22 | |
| 6 | 2023-09-2 | 20065 | 26.2 | 49 | 5.47 | 0.64 | |
| 7 | 2023-09-2 | 20066 | 26.7 | 49 | 9.57 | 0.79 | |
| 8 | 2023-09-2 | 20067 | 23.3 | 51 | 6.24 | 0.7 | |

Figure 7. CSV file view

In this research result, algorithm analysis was also conducted on the algorithm used in the implemented air quality measurement system. The algorithm includes steps of converting sensor values into meaningful units, detecting changes in weather conditions, and calculating values for each parameter. The results of CO gas measurements in Table 2 are gas values that have been converted from ADC (Analog to Digital Converter) values into ppm (parts per million) units. The R0 value (sensor resistance in clean conditions) is converted using equation 1 to calculate the CO concentration:

$PPM = a * (ratio \wedge b)$ (Sendari et al., 2019)



```
void configureMQ7()
{
    Serial.println("Configure MQ7 please wait.");
    // Set math model to calculate the PPM concentration and the value of constants
    MQ7.setRegressionMethod(1); //_PPM =  a*ratio^b
    MQ7.setA(99.042);
    MQ7.setB(-1.518); // Configure the equation to to calculate H2 concentration
```

Figure 8. MQ-7 sensor ADC value conversion script

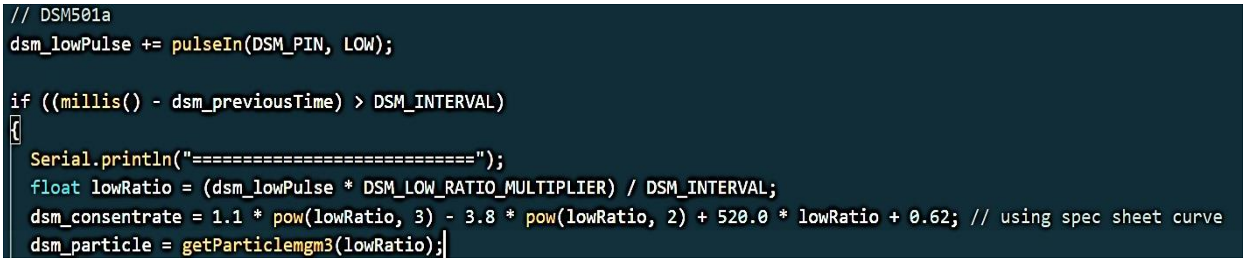
Equation 1 is implemented into the conversion script on the ESP32 as shown in Figure 8 to produce the performance test values of the tool in Table 2.

Table 2. Results of comparative data analysis of CO parameters

| Data to- | Time | CO2 gas | | Correct | Absolute Error Value | Relative Error Value |
|---|---|---|---|---|---|---|
| | | Study | AS8700A Portable | | | |
| 1 | 2023-09-12T00:00:00+07:00 | 0.39 | 0.62 | 0.23 | 0.23 | 37.09677 |
| 2 | 2023-09-12T00:00:30+07:00 | 0.22 | 0.56 | 0.34 | 0.34 | 60.71429 |
| 3 | 2023-09-12T00:01:00+07:00 | 0.27 | 0.64 | 0.37 | 0.37 | 57.8125 |
| 4 | 2023-09-12T00:01:30+07:00 | 0.67 | 0.41 | -0.26 | 0.26 | 63.41463 |
| 5 | 2023-09-12T00:02:00+07:00 | 0.39 | 0.42 | 0.03 | 0.03 | 7.142857 |
| 6 | 2023-09-12T00:02:30+07:00 | 0.52 | 0.43 | -0.09 | 0.09 | 20.93023 |
| 7 | 2023-09-12T00:03:00+07:00 | 0.25 | 0.53 | 0.28 | 0.28 | 52.83019 |
| 8 | 2023-09-12T00:03:30+07:00 | 0.27 | 0.44 | 0.17 | 0.17 | 38.63636 |
| 9 | 2023-09-12T00:04:00+07:00 | 0.72 | 0.44 | -0.28 | 0.28 | 63.63636 |

| Data to- | Time | CO2 gas |  | Correct | Absolute Error Value | Relative Error Value |
|---|---|---|---|---|---|---|
|  |  | **Study** | **AS8700A Portable** |  |  |  |
| 10 | 2023-09-12T00:04:30+07:00 | 0.38 | 0.48 | 0.1 | 0.1 | 20.83333 |
| . | . | . | . | . | . | . |
| n | n | n | n | n | n | n |
| 1780 | 2023-09-17T23:59:30+07:00 | 0.78 | 0.61 | -0.17 | 0.17 | 27.86885 |
| **Average** |  | **0.498** | **0.550** | **0.052** | **0.165** | **30.491201** |

Table 2 shows the CO parameter data with an average correction value for 24/7 days of measurement of 0.052 ppm, which means it tends to give good results. For the average absolute error value, the average difference (Δ) is 0.165 ppm, indicating the consistency and accuracy of the measurement. The average relative error value obtained is 30.491201, indicating that the average measurement results have a difference of about 30% from the actual value.



```
// DSM501a
dsm_lowPulse += pulseIn(DSM_PIN, LOW);

if ((millis() - dsm_previousTime) > DSM_INTERVAL)
{
  Serial.println("============================");
  float lowRatio = (dsm_lowPulse * DSM_LOW_RATIO_MULTIPLIER) / DSM_INTERVAL;
  dsm_consentrate = 1.1 * pow(lowRatio, 3) - 3.8 * pow(lowRatio, 2) + 520.0 * lowRatio + 0.62; // using spec sheet curve
  dsm_particle = getParticlemgm3(lowRatio);
```

Figure 9. DSM501A sensor value conversion script

In Figure 9, the DSM501A sensor value conversion script with the DSM501A sensor output in the form of a PWM (pulse with modulation) signal, so as to convert the PWM value obtained by the sensor and displayed in µg/m3 units. After measurements were carried out for 24/7 days, comparative data were obtained between the tool made by the author and the comparative tool available on the market, as shown in Table 3.

Table 3. Results of comparative data analysis of PM2.5 parameters

| Data to- | Time | PM2.5 |  | Correct | Absolute Error Value | Relative Error Value |
|---|---|---|---|---|---|---|
|  |  | **Study** | **Stock Portable AQM** |  |  |  |
| 1 | 2023-09-12T00:00:00+07:00 | 8.05 | 8.18 | 0.13 | 0.13 | 1.589242 |
| 2 | 2023-09-12T00:00:30+07:00 | 8.23 | 9.44 | 1.21 | 1.21 | 12.8178 |
| 3 | 2023-09-12T00:01:00+07:00 | 5.83 | 7.56 | 1.73 | 1.73 | 22.8836 |
| 4 | 2023-09-12T00:01:30+07:00 | 9.31 | 6.71 | -2.6 | 2.6 | 38.74814 |
| 5 | 2023-09-12T00:02:00+07:00 | 9.02 | 6.67 | -2.35 | 2.35 | 35.23238 |
| 6 | 2023-09-12T00:02:30+07:00 | 11.1 | 9.45 | -1.65 | 1.65 | 17.46032 |
| 7 | 2023-09-12T00:03:00+07:00 | 7.21 | 6.67 | -0.54 | 0.54 | 8.095952 |
| 8 | 2023-09-12T00:03:30+07:00 | 6.2 | 8.23 | 2.03 | 2.03 | 24.66586 |
| 9 | 2023-09-12T00:04:00+07:00 | 7.67 | 6.7 | -0.97 | 0.97 | 14.47761 |
| 10 | 2023-09-12T00:04:30+07:00 | 11.88 | 6.07 | -5.81 | 5.81 | 95.71664 |
| . | . | . | . | . | . | . |
| n | n | n | n | n | n | n |
| 17280 | 2023-09-17T23:59:30+07:00 | 7.17 | 7.12 | -0.05 | 0.05 | 0.702247 |
| **Average** |  | **8.48** | **8.00** | **-0.47** | **1.95** | **25.29** |

Table 3 shows PM2.5 parameter data with an average correction value for 24/7 days of measurement of -0.47 µg/m3 which is slightly lower than the actual value. Despite this tendency, the correction value approaching zero still indicates good measurement results. For the average absolute error value, the average difference (Δ) is 1.95 µg/m3 indicating measurement consistency and accuracy. The average relative error value obtained is 25.29 indicating that the average measurement results have a difference of about 25% from the actual value, although it is still within acceptable tolerance limits, but this relative error percentage requires further research.

Table 4. Results of comparative data analysis of temperature and humidity parameters

| **Data to-** | **Time** | **Tools Made** | | **Thermo Hygrometer Beurer HM 16** | | **Corrct** | | **Absolute Error Value** | | **Relative Error Value** | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Temp.** | **Wetness** | **Temp.** | **Wetness** | **Temp** | **Wetness** | **Temp.** | **Wetness** | **Temp.** | **Wetness** |
| 1 | 2023-09-12T00:00:00 +07:00 | 24 | 51 | 25.5 | 50 | 1.5 | -1 | 1.5 | 1 | 5.882353 | 2 |
| 2 | 2023-09-12T00:00:30 +07:00 | 24.7 | 50 | 25.8 | 50 | 1.1 | 0 | 1.1 | 0 | 4.263566 | 0 |
| 3 | 2023-09-12T00:01:00 +07:00 | 23.7 | 51 | 26.7 | 49 | 3 | -2 | 3 | 2 | 11,23596 | 4.081633 |
| 4 | 2023-09-12T00:01:30 +07:00 | 25.9 | 50 | 25.5 | 50 | -0.4 | 0 | 0.4 | 0 | 1.568627 | 0 |
| 5 | 2023-09-12T00:02:00 +07:00 | 23.5 | 51 | 27.3 | 49 | 3.8 | -2 | 3.8 | 2 | 13,91941 | 4.081633 |
| 6 | 2023-09-12T00:02:30 +07:00 | 24.7 | 50 | 26.5 | 49 | 1.8 | -1 | 1.8 | 1 | 6.792453 | 2.040816 |
| 7 | 2023-09-12T00:03:00 +07:00 | 26 | 50 | 25.5 | 50 | -0.5 | 0 | 0.5 | 0 | 1.960784 | 0 |
| 8 | 2023-09-12T00:03:30 +07:00 | 25.3 | 50 | 27.3 | 49 | 2 | -1 | 2 | 1 | 7.326007 | 2.040816 |
| 9 | 2023-09-12T00:04:00 +07:00 | 24.3 | 50 | 26 | 49 | 1.7 | -1 | 1.7 | 1 | 6.538462 | 2.040816 |
| 10 | 2023-09-12T00:04:30 +07:00 | 25.9 | 50 | 27.3 | 49 | 1.4 | -1 | 1.4 | 1 | 5.128205 | 2.040816 |
| . | . | . | . | . | . | . | . | . | . | . | . |
| n | n | n | n | n | n | n | n | n | n | n | n |
| 1780 | 2023-09-17T23:59:30 +07:00 | 25.7 | 50 | 25.8 | 50 | 0.1 | 0 | 0.1 | 0 | 0.387597 | 0 |

For the DHT sensor value, no conversion is performed because the output value produced by the temperature sensor is already in digital form. Table 4 shows the temperature parameter data with an average correction value for 24/7 days of measurement of 0.1 oC indicating that the temperature measurement results tend to be slightly higher than the actual value. The average absolute error value shows an average difference (Δ) of 0.1 oC. The average relative error value obtained is 0.387597 indicating that the average measurement results have a difference of around 0.39% from the actual value indicating a high level of accuracy in temperature measurement. While the humidity parameter data with an average measurement correction value, absolute error value and relative error value of 0 oC.

Next is the data sending algorithm processed by ESP32 to the Thingspeak and Telegram servers. At this stage, an evaluation is carried out on the time required by the system to send the measurement data to the Thingspeak platform and the Telegram application. The following is a graph of the sending time.

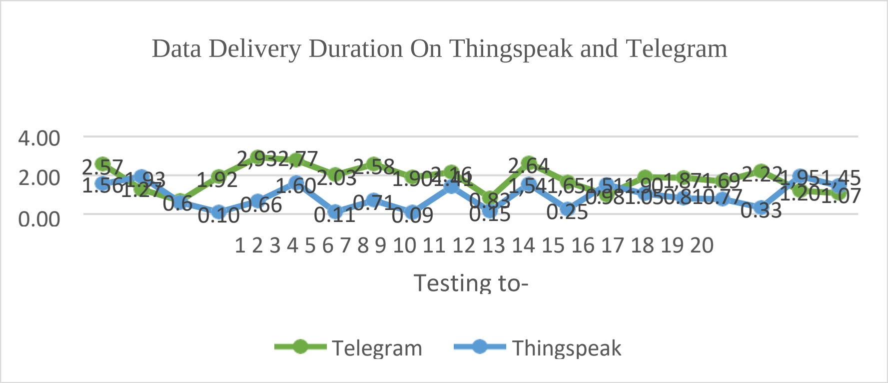


Figure 10. Graph of data delivery duration on Tingspeak and Telegram

Figure 10 is a graph produced from testing data delivery by ESP32 to the Thingspeak server and Telegram's response via a bot created to change in conditions that exceed a predetermined threshold. Out of 20 tests, 100% were successfully sent and displayed to Thingspeak and Telegram. The longest data reception on Thingspeak was 1.95 seconds and the fastest was 0.09 seconds, with an average time of less than 1 second, namely 0.93 seconds. On Telegram, the notification bot displays changes in conditions due to pollutants exceeding the threshold in 20 tests, with the longest duration of 2.93 seconds and the fastest 0.69 seconds, with an average delivery duration of 1.84 seconds. The results of the tool performance testing in the field for 7 days obtained an average of each parameter measured as in Table 5.

Table 5. Average measurement parameters

| Time | Average Temperature (0C) | Average Humidity (%) | Average PM2.5 ( µg/m3) | Average CO gas (ppm) |
|---|---|---|---|---|
| 2023-09-17 | 26.4 | 49 | 8,464 | 0.498 |
| 2023-09-18 | 26.4 | 49 | 8,504 | 0.507 |
| 2023-09-19 | 26.4 | 49 | 8,420 | 0.507 |
| 2023-09-20 | 26.5 | 49 | 8,453 | 0.497 |
| 2023-09-21 | 26.4 | 49 | 8,493 | 0.499 |
| 2023-09-22 | 26.4 | 49 | 8,536 | 0.501 |
| 2023-09-23 | 26.4 | 49 | 8,483 | 0.502 |
| **Total** | **26.4** | **49** | **8,479** | **0.501** |

It can be seen from Table 5 that the average temperature parameter from the first day of testing to the last day did not change, with a total average for 7 days of 26.4 oC. Similar to room humidity, on the first day of testing to the 7th day of testing, the average per day was always the same, which was 49%, with a total average for 7 days of 49% as well. For the PM2.5 parameter, during the 7 days of testing, it had a different daily average with a total average PM2.5 level of 8,479 µg/m3. Meanwhile, for the CO gas parameter during the 7 days of testing, the total average level was calculated at 0.501 ppm.

Based on the results of the field testing of the equipment, there is a possibility of error in the measurement of parameters caused by the DSM501A sensor and the MQ-7 sensor. One source of error is the Ro value on the MQ-7 sensor, which is the sensor resistance related to the concentration of the gas being measured. In this test, the MQ-7 sensor did not go through a calibration process to determine the Ro value at certain gas levels, so the possibility of differences in the Ro value used with the Ro value of the calibrated sensor affects the measurement accuracy. In addition, the position of the sensor to detect PM2.5 and CO which is outside the casing without a fan causes air sampling to be less than optimal. The air detected by the sensor does not fully reflect the concentration of air quality parameters accurately. To overcome this, the proposed solution is to position the sensor inside the casing and add a fan to suck air from various directions to improve measurement accuracy.

## Discussion

This study shows that an IoT-based air pollution detector for a baby's room successfully detects carbon monoxide (CO), PM2.5 fine particles, temperature, and humidity with a reasonable level of accuracy. This finding is significant because it provides a solution to the health risks caused by indoor air pollution, especially for babies who are susceptible to respiratory disorders. Integration with the ThingSpeak IoT platform and real-time notification features via Telegram also provides added value by facilitating remote monitoring of air quality.

The test results indicate that the system provides consistent data for seven consecutive days, although there are relative errors in some parameters, such as CO (30%) and PM2.5 (25%). This finding is in line with previous literature showing that IoT technology has great potential in monitoring air quality effectively, although there are often challenges in sensor accuracy. For example, a study by Lumbangaol et al. (2021) on IoT-based air quality monitoring also underlines the importance of sensor calibration to improve accuracy. However, some limitations need to be acknowledged. The absence of a calibration process for the MQ-7 sensor to determine the base resistance value (R0) can affect the results of CO gas measurements. In addition, the position of the sensor outside the casing without an air suction fan can result in less than optimal air sampling. These limitations lead to recommendations to develop a more efficient physical design of the device and improve the sensor calibration process.

The clinical relevance of this study is significant, as the tool can help parents or caregivers identify unhealthy air quality in their baby's room, allowing for early preventive action against potential health problems. In the future, further developments could include the integration of historical data-based predictive models to provide proactive alerts to users. Further research should also consider the use of more accurate sensors and the development of tools to meet specific air quality standards for baby rooms. This is important to ensure the sustainability and practical impact of this system in improving infant health and comfort in indoor environments.

## Conclusions and Suggestions

### Conclusions

The results of the study on an Internet of Things (IoT)-based air pollution detection device for a baby's room showed that the system is capable of detecting pollutants such as carbon monoxide (CO), fine particles measuring 2.5µm (PM2.5), temperature, and humidity. The device was successfully integrated with the ThingSpeak IoT platform, enabling real-time data transmission to the cloud for remote monitoring and further analysis. The system is also equipped with a notification feature via the Telegram application, which provides a warning if pollutant levels exceed a specified threshold, while also providing information related to temperature and humidity parameters. Tests conducted for seven consecutive days with a simulation of AC use for 8–10 hours per day produced data that reflected daily variations in air quality, thus proving the effectiveness of this system in providing relevant information to users.

### Suggestions

For further research, it is recommended:

1. Re-evaluate the type of sensor used and the calibration settings to ensure the accuracy of the measurement results. The selection of a more sophisticated sensor or a sensor with a higher level of accuracy can also be considered.
2. Use of historical data to develop predictive models that can alert users to possible changes in air quality based on certain conditions, such as the weather or certain activities in the nursery.
3. Further research can be conducted to identify and understand more specific and relevant air quality standards for baby rooms. This will help in determining more accurate thresholds for notifications and alerts.

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