Real-time Air Quality Index monitoring experiments using SDS011 sensors and raspberry pi

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Abstract. This study aims to propose a real-time Air Quality Index (AQI) monitoring using SDS011 sensors and raspberry pi as a server to detect Particulate Matter (PM)2.5 and PM10. To calculate the AQI standard values, we refer to BMKG as the board responsible for regulating it. We collected data on the campus area close to the textile industry area in Purwakarta, West Java, Indonesia for 1440 minutes. From the experiments, the results of the AQI value for PM2.5 are between 66–110 or equivalent to 19.1 to 39.7 μg / m3, while for PM10 between 26–70 or equivalent to 23.1 to 43.9 μg / m3. This value shows the performance of the SDS011 sensor can work well. Furthermore, to be publicly accessible, the AQI and PM values are sent to the web every minute without having to refresh the web page. For further development, it is possible to make a low-cost portable monitoring device using SDS011 sensors and raspberry pi that can be placed in areas considered pollution-prone as a warning system when pollution has passed the permitted threshold.

1. Introduction

Air quality is now a serious concern in various countries in the world. Awareness of the daily levels of air pollution as a one factor in air quality is important not only for citizens [1] but also for animals, plants, oceans, aquatic life worldwide [2]. Based on WHO data, air pollution has the biggest environmental impact on health today. It is estimated that it has caused 4.9 million deaths and 147 million loss of healthy life every year [3].

Various studies related to air quality monitoring have been carried out by previous researchers [4-7], including more specific measurements to detect particles below 2.5μm in various countries [8–11]. Related to that, studies for real-time data monitoring based on IoT and web have been developed, including monitoring sites belonging to IQ Air for global scale, and BMKG for local scale [12-15]. However, IQ Air only displays Particulate Matter (PM)2.5 data and BMKG displays PM2.5 and also PM10 [16,17]. The data is only updated every hour and only in big city areas.

This study aims to fill the gap in monitoring the air quality index that combines PM2.5 and PM10 particles that are sent every minute to the web, especially in small cities in Indonesia. Then, we propose to measure the real-time air quality index using SDS011 sensors [18] and raspberry pi as a low-cost server [19] to detect PM2.5 particles and also PM10. At the time, data is sent to the web every minute without refreshing the web page. We conducted data collection for this paper in the campus area which is close to the textile industry in Purwakarta as one of the small cities in West Java, Indonesia.
2. Method

This research uses an experimental method with duration to collect data around 1440 minutes [20,21]. In the first step, we determine the particulate matter to be measured i.e. PM$_{2.5}$ and PM$_{10}$. Next, we determine the sensor specifications that can detect these particles. Then, we chose high precision sensor SDS011, because this sensor can capture particle concentrations between 0.3 to 10μm in the air [22]. Data from the sensor is sent serially through the ttyUSB0 raspberry pi port with a baud rate value 9600. Furthermore, the incoming data is processed using the python instruction and stored using the *.PY extension [23]. Furthermore, the data is sent and stored in *.JSON and *.JS format and displayed via HTML file, so it can be accessed through a web browser and automatically refreshes every minute. To make the display more attractive, we added the CSS file. All files are stored in the /var/www/html/ folder as localhost in Raspberry pi using Lighttpd server [24]. To access data from the localhost then we use IP address based on the network given to raspberry pi. Figure 1 explains the block diagram of this experiment.

![Figure 1. Block diagram of real-time air quality monitoring using SDS011 sensor and raspberry pi.](image)

To differentiate AQI levels, we classify the AQI display colors based on BMKG regulations such as table 1. Referring to BMKG, the threshold value for PM$_{10}$ is 150 μgram/m$^3$, while PM$_{2.5}$ is 65 μgram/m$^3$. For countries outside Indonesia, the classification of AQI values may be different i.e. Following the EPA as described in table 2. Because BMKG only provides a scale of PM$_{10}$ conversion to AQI values, in this study, the scale of PM$_{2.5}$ conversion to AQI values were adopted to the EPA scale [25].

![Table 1. Classification of Air Quality Index (AQI) refers to BMKG.](image)

| (AQI) Values | PM$_{2.5}$ (μgram/m$^3$) | PM$_{10}$ (μgram/m$^3$) | Level of Health Concern | Color |
|--------------|--------------------------|--------------------------|-------------------------|-------|
| 0-50         | 0-12                     | 0-50                     | Good                    | Green |
| 51-100       | 12.1-35.4                | 51-150                   | Moderate                | Blue  |
| 101-200      | 35.5-150.4              | 151-350                  | Unhealthy               | Yellow|
| 201-300      | 150.5-250.4            | 351-420                  | Very Unhealthy          | Red   |
| 301-500      | 250.5-250.5              | >420                     | Hazardous               | Maroon|
Table 2. Classification of Air Quality Index (AQI) refers to EPA.

| (AQI) Values | PM$_{2.5}$ (µgram/m$^3$) | Level of Health Concern | Color |
|--------------|--------------------------|-------------------------|-------|
| 0 - 50       | 0 - 12                   | Good                    | Green |
| 51 - 100     | 12.1 - 35.4              | Moderate                | Yellow|
| 101 - 150    | 35.5 - 55.4              | Unhealthy for Sensitive Groups | Orange |
| 151 - 200    | 55.5 - 150.4             | Unhealthy               | Red   |
| 201 - 300    | 150.5 - 250.4            | Very Unhealthy          | Purple|
| 301 - 400    | 250.5 - 350.4            | Hazardous               | Maroon|
| 400 - 500    | 350.5 - 500              | Hazardous               | Maroon|

3. Result and discussion

To access data from the server, we tried using a different browser on a mobile, tablet or PC and the data display is quite good. In this experiment, we used the IP address 192.168.1.8 on browser or localhost on raspberry pi. Figure 2 shows the data view using the chrome browser and figure 3 show the display of data from sensor on raspberry pi.

A comparison chart of AQI for PM$_{2.5}$ versus AQI for PM$_{10}$ can be seen in figures 4 and 5. The results of the AQI value for PM$_{2.5}$ are between 66 - 110 or equivalent to 19.1 to 39.7 µg / m$^3$, while for PM$_{10}$ between 26 - 70 or equivalent to 23.1 to 43.9 µg / m$^3$. From the graph it can be analyzed that the increase in particulate matter (PM)$_{2.5}$ is always directly proportional to the increase in particulate matter (PM)$_{10}$.

![Figure 2. Real-time AQI display of PM$_{2.5}$ and PM$_{10}$ using the chrome browser.](image)

![Figure 3. PM$_{2.5}$ and PM$_{10}$ data display in raspberry pi](image)

![Figure 4. Data performance of AQI vs PM2.5](image)
In this experimental study, the testing phase of the SDS11 sensor and raspberry as server performance has been well achieved. However, the appearance in the web browser is still limited to AQI and particulate matter (PM) values, not yet displayed in real-time charts. We also do not calibrate the sensor, but only follow the sensor specifications specified by the manufacturer.

4. Conclusion
SDS011 sensor has a good level of precision in detecting particulate matter 2.5 and 10 in the air. From this research, we can add real time charts on the web for further development. So, it is possible to make a low-cost portable monitoring device based on the SDS011 sensor and raspberry pi which can be placed in places that are considered pollution-prone. Then, it becomes a warning system when pollution has passed the permitted threshold.

Acknowledgment
We want to show our gratitude to the LPPM Politeknik Enjinering Indorama and the YPI Board for supporting this research funding. We are also very grateful to Zefanza and friend for sharing the source code associated with this research.

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