Monitoring and calculation of the air pollution standard index (APSI) of Bandung Regency

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Abstract. Air pollution is directly proportional to the rate of economic growth. With the growing economic life, more people will use high-tech materials, which can cause air pollution. The main problem of this pollution is decreasing air quality. This decrease in air quality is caused by many things, including excessive environmental exploitations, industrial activity, energy use, and vehicles exhaust emissions, all of which trigger pollution problems. Bandung Regency is surrounded by many industries, i.e., textile, garment, metal, printing, metal, food, furniture, and plastic. Thus, monitoring air pollution is imperative. The air parameters measured were Carbon monoxide and Nitrogen dioxide. The measurement duration is every 14 days, from June to July 2021. The sample location is divided into four regions, Margahayu, Kopo Katapang, Baleendah, and Dayeuh Kolot. The method used was the MCU 6814 sensor which has been calibrated by IQAir. Carbon monoxide measurements were taken every 8 hours, while nitrogen dioxide was measured every hour of the day. The average measurement for the four areas in the morning and evening was relatively good, 3-5 g/m³ for CO in the morning and 10-14 g/m³ at peak activity during the day. These results indicated the unhealthy air category.

Keywords: Air pollution index; air quality; Bandung Regency; CO; NO₂

1. Introduction
In the ecosystems of big cities, air pollution is becoming a critical concern. There are several activities to engage in large cities to expend off energy. Human life can be harmed by mismanaged energy. Motor vehicles and industry activities are two examples of human activities that produce heat and gas. Exhaust gases have a negative impact on human respiratory health. Air pollution has been repeatedly related to significant health consequences in developed and developing countries. [1].

The air pollution index (API) is commonly used to report the level of severity of air pollution to the public [2]. The air pollution index is calculated from the concentration of carbon monoxide (CO) and nitrogen dioxide (NO₂) gases in the air. Both gases are classified as hazardous gases for human health [3].

Bandung Regency is surrounded by many industries, including textile, garment, metal, printing, metal, food, furniture, and plastic industries, and has the hypothesis of producing very high air pollution. In this research, we calculated and monitored the air pollution index using 15 points of CO and NO₂ gas sensors; data collection was carried out. Data were collected and stored on the internet of things.
application server [3]. The collected data will be used to calculate the standard air pollution index of Bandung city.

2. Materials and Methods

2.1. Materials

The materials used in this research are as follows: Microcontroller using ESP8266 and air quality sensor using MICS 6814. MICS 6814 can detect Carbon Monoxide gas CO (1-1000 ppm), NO₂ (0.05 – 10 ppm), Ammonia NH₃ (1 – 500 ppm).

The sensitivity factor is defined as Rs in air divided by Rs at 60 ppm CO. Test conditions are 23 ± 5 °C and 50 ± 10% RH. Indicative values only. The sensitivity factor is defined as Rs at 0.25 ppm NO₂, divided by Rs in air. Test conditions are 23 ± 5°C and ≤ 5% RH. Sensor data was collected on the internet of things server using the HTTP communication protocol.

2.2. Methods

This research method is the data acquisition and data processing. A control system for CO and NO₂ gas sensor readings was made using a microcontroller and sensors for the data acquisition section. While for the data processing section, the sensor data output was processed and calculated using excel software.

The sensitive material of the MQ135 gas sensor is SnO₂, which with lower conductivity in clean air. Therefore, when target pollution gas exists, the sensor’s conductivity increases, and the gas concentration rises. Users can convert the change of conductivity to correspond output signal of gas concentration through a simple circuit [4]. The detection limit of this sensor was 10 - 1000 ppm, sensitivity sensor was Rs in air/Rs in 4000 ppm CO and NO₂ ≥ 5 [3].

Microcontroller system design using esp8266, and the sensor used was MICS 6814 (Figure 1). Sensor data was collected on the internet of things server using the HTTP communication protocol. The stored gas sensor data would be processed and calculated to obtain the air pollution standard index value [4].

Air sampling was conducted in four areas in Bandung Regency, namely Margahayu, Kopo Katapang, Baleendah, and Dayeuh Kolot. CO data measurements were done every 8 hours in one day, while NO₂ data was taken every hour of the day. Measurements of CO and NO₂ lasted for two weeks.

![Figure 1. Design of the system.](image-url)
The internet of things server used was thingspeak. This server was accessible and had large storage for database usage. Data collection and storage were carried out in real-time and can be accessed by users anytime and anywhere. To calculate the air pollution index of Bandung Regency, the equation below was used [5]:

\[ I_P = \frac{I_{HI} - I_{LO}}{BP_{HI} - BP_{LO}} (C_P - BP_{LO}) + I_{LO} \]  

(1)

Where \( I_P \) is calculated index standards, \( I_{HI} \) is index standard upper threshold, \( I_{LO} \) is index standard lower threshold, \( BP_{HI} \) is upper limit ambient concentration, \( BP_{LO} \) is lower limit ambient concentration, and \( C_P \) is concentration of ambient measurement results.

The CO and NO\textsubscript{2} gas sensor data were entered and calculated using equation (1) to obtain the air pollution standard index value.

3. Results and Discussion

The first part of this research was the data acquisition of CO and NO\textsubscript{2} gas sensors, while the final part was to calculate the standard air pollution index using equation (1). Data acquisition of CO and NO\textsubscript{2} gas were carried out for 14 days; in one day, measurements were taken three times, namely at 06.00 am, 02.00 pm, and 10.00 pm.

![Figure 2. Graphic display of sensor data CO.](image)

Figure 2 depicts the results of data collection of CO gas concentrations at various periods throughout a 14-day period. The blue graph describes the morning reading of CO gas concentration data, the orange graph explains the daytime reading of CO gas concentration data, and the gray graph explains the nighttime reading of CO gas concentration data. Because there is still minimal human activity in the morning, the CO gas concentration reading is very low. Due to very active human activities, such as the number of motorized cars and manufacturing gas exhaust activities, CO gas concentrations are relatively high during the day. Meanwhile, due to the lack of industry activity and decrease in motorized vehicles number at night, the CO gas concentration readings decrease again. The final step in this study is to use equation (1) to calculate the standard air pollution index. Table 1 shows the results of the air pollution standard index calculation for CO.

Table 1 shows the weekly average value of CO gas concentration readings. For example, in the first week the average value of CO gas concentration in the morning is 4.29 g/m\textsuperscript{3}; for the day, it is 11.29 g/m\textsuperscript{3} and at night is 6.57 g/m\textsuperscript{3}. In the second week, the average value of CO gas concentration in the morning is 4.14 g/m\textsuperscript{3}, for the day it is 11.29 g/m\textsuperscript{3} and at night is 6.57 g/m\textsuperscript{3}, respectively.
Table 1. Calculation of CO gas air pollution standard index.

| Carbon monoxide | 8 hours CO (µg/m³) |
|-----------------|-------------------|
| Time            | 06:00:00 | 14:00:00 | 22:00:00 |
| 4               | 14       | 9        |
| 5               | 13       | 7        |
| 4               | 13       | 7        |
| 5               | 11       | 5        |
| 3               | 9        | 6        |
| 4               | 10       | 7        |
| 5               | 9        | 5        |
| Week Average I  | 4.29     | 11.29    | 6.57     |
| 5               | 9        | 5        |
| 5               | 11       | 6        |
| 4               | 12       | 7        |
| 4               | 12       | 8        |
| 5               | 14       | 8        |
| 3               | 9        | 5        |
| 3               | 8        | 8        |
| Week Average II | 4.14     | 10.71    | 6.71     |
| Color description | Good | Moderate | Unhealthy | No index can be reported at low concentrations with a long-term short exposure |

The air pollution standard index is a measure of how polluted the air is CO gas was calculated, and it was discovered that the weekly average real data gas concentration in the morning was 4.29 g/m³, which is classified as good (green colour) based on calculations using equation (1). We can deduce from the results of these calculations that the gas concentration in the morning is good. It is 11.29 g/m³ for the day, which is considered harmful (red colour), and 6.57 g/m³ at night, which is deemed to be moderate (orange colour).

The CO air pollution standard index findings are classified into three categories: good, moderate, and unhealthy. When the industrial activity has not lasted as long as it should, the good and moderate categories appear, whereas the unhealthy category appears when activity is at its highest. Because no index may be provided at low concentrations with long-term brief exposure, the air pollution standard index findings are not included in the index category for NO₂ [6].

Figure 3 depicts the data acquisition results of NO₂ gas concentrations at various periods throughout a 14-day period. The blue graph describes the morning reading of NO₂ gas concentration data. The orange graph explains the daytime reading of NO₂ gas concentration data. The gray graph illustrates the nighttime reading of NO₂ gas concentration data. Because there is still minimal human activity in the morning, the NO₂ gas concentration reading is very low. However, due to very active human activities, such as the number of motorized vehicles and factory gas exhaust activities, the reading of NO₂ gas concentration is
very high during the day. Meanwhile, due to the lack of factory activity and the number of motorized vehicles at night, the reading of NO\textsubscript{2} gas concentration decreases again.

![Graphical display of sensor data NO\textsubscript{2}.](image)

**Figure 3.** Graphic display of sensor data NO\textsubscript{2}.

**Table 2.** Calculation of NO\textsubscript{2} gas air pollution standard index.

| Nitrogen Dioxide | 1 hour NO\textsubscript{2} (µg/m\textsuperscript{3}) |
|------------------|---------------------------------|
| Time             | 06:00:00 | 14:00:00 | 22:00:00 |
| 104              | 120      | 99       |
| 105              | 180      | 78       |
| 104              | 150      | 77       |
| 105              | 155      | 75       |
| 103              | 187      | 76       |
| 104              | 180      | 77       |
| 105              | 185      | 75       |
| Week Average I   | 104.29   | 165.29   | 79.57    |
| 105              | 120      | 75       |
| 105              | 110      | 86       |
| 104              | 120      | 87       |
| 104              | 125      | 78       |
| 105              | 148      | 78       |
| 103              | 122      | 75       |
| 103              | 150      | 78       |
| Week Average II  | 104.14   | 127.86   | 79.57    |

**Color description**

No index can be reported at low concentrations with a long-term short exposure
Table 2 shows the weekly average value of NO2 gas concentration readings. In the first week, the average value of NO2 gas concentration in the morning is 104.29 g/m³; for the day, it is 165.29 g/m³ and 79.57 g/m³ at night, respectively. In the second week, the average value of NO2 gas concentration in the morning is 104.14 g/m³; for the day, it is 127.86 g/m³ and at night is 79.57 g/m³. For NO2, the air pollution standard index results are not included in the index category because no index can be reported at low concentrations with long-term short exposure [6].

These findings are in line with the findings of the following study: At the beginning of the week, sampling site 4 had the highest average carbon monoxide concentrations (5.21 g/m³) with a maximum value of 8.19 g/m³, whereas sampling site 1 had the lowest average concentrations (4.16 g/m³) with a maximum value of 8.27 g/m³ [7]. The propensity for rising CO and NO2 gas concentrations is attributable to increased human activity [8]. The Bandung Regency is known for its industrial districts, which emit daily exhaust emissions into the atmosphere [9]. When it comes to respiratory health, Bandung Regency's air quality falls into the intermediate category, yet it has no negative impact on human health. [10]

4. Conclusions
In conclusion, CO and NO2 gas monitoring and air pollution standard index calculation systems have been successfully developed. The weekly average actual data gas concentration in the morning was 4.29 g/m³, classified as good by the air quality standard index calculation (green color). When factory activity has not lasted as long as it should, the good and moderate categories appear. In contrast, the harmful category appears when activity is at its highest of the day. Because no index may be provided at low concentrations with brief long-term exposure, the air pollution standard index findings are not included in the index category for NO2.

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