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Air Quality Assessment Based on Real-Time Continuous Monitoring: Particulate and Nitrogen Dioxide Concentrations in South Tangerang

Penilaian Kualitas Udara Berdasarkan Pemantauan Kontinu secara Real-Time: Konsentrasi Partikulat dan Nitrogen Dioksida di Tangerang Selatan

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ABSTRAK

Meningkatnya konsentrasi $PM_{2,5}$, PM_{10}, dan NO_2 di perkotaan akan berdampak pada kesehatan manusia. Pengukuran dan penghitungan konsentrasi $PM_{2,5}$, PM_{10}, dan NO_2 merupakan salah satu upaya pengendalian pencemaran karena dapat diperoleh informasi mengenai status atau kategori zat pencemar udara tersebut. Oleh karena itu, penelitian ini bertujuan untuk menganalisis kualitas udara, termasuk partikulat $PM_{2.5}$, PM_{10}, dan NO_2 yang dihitung berdasarkan Indeks Standar Pencemar Udara (ISPU). Pengukuran zat pencemar dilakukan secara kontinyu dan real-time selama 24 jam. Pengukuran zat pencemar menggunakan alat continuous dichotomous aerosol chemical speciation analyzer (ACSA-14) yang ditempatkan di Kawasan Sains dan Teknologi BJ Habibie, Serpong, Tangerang Selatan. Analisis konsentrasi $PM_{2,5}$, PM_{10}, dan NO_2 dilakukan untuk mendapatkan rata-rata konsentrasi harian selama periode pengukuran, serta metode ISPU yang diatur dalam Peraturan Menteri Lingkungan Hidup dan Kehutanan Nomor 14 Tahun 2020. Selama periode pengukuran, rata-rata harian konsentrasi $PM_{2,5}$, PM_{10}, dan NO_2 masing-masing sebesar 40,0 µg/m³, 60,4 µg/m³, dan 37,4 µg/m³, dengan konsentrasi tertinggi masing-masing sebesar 170,8 µg/m³, 336,0 µg/m³, 647,5 µg/m³. Kategori sedang dan tidak sehat mendominasi hasil analisis ISPU $PM_{2,5}$ selama periode pengukuran masing-masing sebesar 55,5% dan 23,0%. Kategori baik dan sedang mendominasi hasil analisis ISPU PM_{10} dan NO_2, yaitu masing-masing sebesar 38.0% dan 52,2% untuk PM_{10}, dan 82,5% dan 7,5% untuk NO_2.

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ABSTRACT

The increasing concentration of $PM_{2.5}$, PM_{10}, and NO_2 in urban areas will impact human health. Measuring and calculating the concentration of $PM_{2.5}$, PM_{10}, and NO_2 is one of the efforts to control pollution because it can obtain information on the status or category of these air pollutants. Therefore, this study aims to analyze air quality, including $PM_{2.5}$, PM_{10}, and NO_2 particulates calculated based on the Air Quality Index. Pollutant measurements are carried out continuously and in real-time for 24 hours. Pollutant measurements use a continuous dichotomous aerosol chemical speciation analyzer (ACSA-14) tool placed in the BJ Habibie Science and Technology Area, Serpong, South Tangerang. Analysis of $PM_{2.5}$, PM_{10}, and NO_2 concentrations were analyzed to obtain the average daily concentration during the measurement period and the ISPU method was regulated in the Regulation of the Minister of Environment and Forestry Number 14 of 2020. During the measurement period, the daily average concentrations of $PM_{2.5}$, PM_{10}, and NO_2 were 40.0 µg/m³, 60.4 µg/m³, and 37.4 µg/m³, respectively, with the highest concentrations of 170.8 µg/m³, 336.0 µg/m³, 647.5 µg/m³. The moderate and unhealthy categories dominated the results of the ISPU $PM_{2.5}$ analysis during the measurement period, respectively, at 55.5% and 23.0%. The good and moderate categories dominate the ISPU PM_{10} and NO_2 analysis results, namely 38.0% and 52.2% for PM_{10} and 82.5% and 7.5% for NO_2, respectively.

1. INTRODUCTION

1.1 Background

Air pollution can be a health threat, for instance, with high fine particulate matter (PM) concentrations in big cities such as Jakarta, which has Indonesia's highest annual average value (Syuhada et al., 2023; Tritamtama et al., 2023). Several factors influence the concentration level of pollutants in the atmosphere in a region, such as human activity, meteorological parameters, and the region's topography (Ihsan et al., 2023). Human activities such as transportation, industry, construction and the like can cause pollutants.

Air quality in South Tangerang City and its surroundings has become a hot topic in mid-2023. Based on the IQAir website, in July and August 2023, South Tangerang City had the highest pollution in Indonesia. Increased transportation and industrial activities harm on the air quality in South Tangerang. Air quality in South Tangerang is also influenced by pollutants in surrounding areas, such as the Jakarta Megacity. As a satellite city of Jakarta, South Tangerang City can potentially receive pollutants carried by the wind from Jakarta or other surrounding cities. Wind direction can determine the distribution of contaminants, while wind speed can influence the dilution and dispersion of pollutants from emission sources. Kim et al., (2015) concluded that there is a weak to moderate relationship between PM concentration and wind speed, while wind direction will significantly impact PM concentration but only locally. The other weather parameters, such as rainfall, can clean pollutants in the air and bring them back to the ground surface.

Air quality conditions can be analyzed using the Air Quality Index, which describes the ambient air quality conditions in specific locations, including South Tangerang City. The government has issued regulations related to ISPU, namely Minister of Environment and Forestry Regulation Number 14 of 2020. This regulation has determined seven ISPU parameters, including particulates ($PM_{2.5}$ and PM_{10}), SO_2, NO_2, CO, O_3, and HC. Particulate matter, a pollutant from human activities in urban areas, can impact human health, especially the respiratory, cardiovascular and nervous systems (Prasad et al., 2023). The presence of particulates can increase human morbidity and mortality levels (Xing et al., 2016). In addition, particulates in the atmosphere can reduce cognitive abilities, affect human psychology (Lavy et al., 2014; Pun et al., 2017), and even affect human height growth (Tan-Soo & Pattanayak, 2019). Nitrogen dioxide (NO_2) is also a pollutant that harms human health. Short-term and long-term exposure to NO_2 can cause premature death in the respiratory and circulatory systems, cause asthma and bronchitis, and worsen people's health, especially those with a history of respiratory and cardiovascular diseases (Krzyzanowski, 2023). The main source of NO_2 comes from transportation, particularly in areas with high transportation activity (Environmental Protection Agency, 2018).

It is essential to carry out studies regarding PM and NO_2 and their impact on health. Research on the health effects increased significantly during the 2009–2018, focusing on respiratory and cardiovascular diseases (Lee et al., 2021). Ambient air quality conditions from exposure to particulates and NO_2 in an area like South Tangerang must be described or analyzed. One method to describe it is using the Air Quality Index. The ISPU calculations in this research were not only carried out when it became a hot issue in mid-2023 but also analyzed the results of particulate concentration measurements several months earlier. Continuous measurement and calculation of particulate and NO_2 concentrations, especially using ISPU analysis, is one of the control efforts that can be carried out to obtain information regarding the status or condition of ambient air quality in urban areas.

1.2 Research Objective

This research aims to analyze air quality in South Tangerang, including particulate matter ($PM_{2.5}$ and PM_{10}) and nitrogen dioxide (NO_2) which are calculated based on the Air Quality Index.

2. METHODS

2.1 Time and Location

Particulate matter ($PM_{2.5}$, PM10) and nitrogen dioxide (NO_2) concentration measurements were carried out in the BJ Habibie Science Technology Area (KST), Serpong, South Tangerang, from January 2023 to December 2023. Figure 1 shows that the monitoring location was in the city's suburbs.

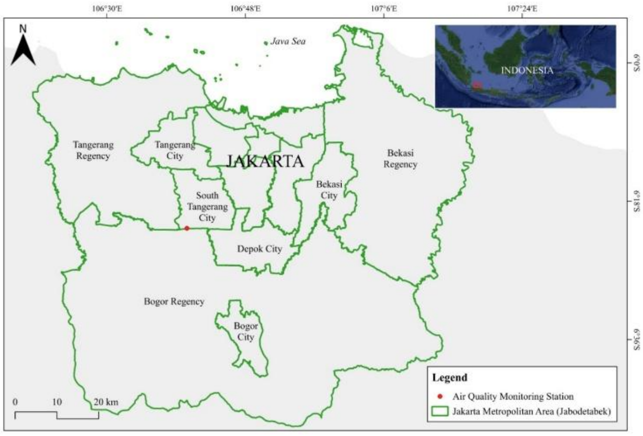


Figure 1. Location of greenhouse gases and air quality monitoring site in Serpong

2.2 Pollutant Concentration Measurement

The concentrations of PM and NO_2 were measured continuously and in real time for 24 hours using a continuous dichotomous aerosol chemical speciation analyzer (Model ACSA-14, Kimoto Electric, Ltd., Japan) and NOx analyzer (Model 42i-TL, Thermo Scientific, USA). The measured $PM_{2.5}$ and PM_{10} concentrations result from the average concentration every three hours, while the NO_2 concentration is the average result of measurements every minute. This observation was conducted as part of the monitoring system of greenhouse gases and air pollutants (Nishihashi et al., 2019).

2.3 Data Analysis

This research uses average $PM_{2.5}$ and PM_{10} concentration data every 3 hours and average NO_2 concentration data every minute during the research period. The $PM_{2.5}$ values were calculated with dry corrections. The PM_{10} values were calculated as a sum of $PM_{2.5\text{-dry}}$ and $PM_{2.5\text{-}10}$. Statistical analysis of the data using R software.

The ISPU analysis with $PM_{2.5}$, PM_{10}, and NO_2 concentration parameters based on the ISPU method in Minister of Environment and Forestry Regulation Number 14 of 2020. Equation 1 to calculate ISPU (Ministry of Environment and Forestry, 2020).

$$I = \frac{I_a - I_b}{X_a - X_b}(X_x - X_b) + I_b \quad (1)$$

where:

I = calculated ISPU
Ia = upper limit ISPU
Ib = lower limit ISPU
Xa = upper limit ambient (μg/m^3)
Xb = lower limit ambient (μg/m^3)
Xx = real ambient level measurement results (μg/m^3)

The ISPU calculation results are converted into ISPU range number categories as in Table 1.

Table 1. Air Quality Index

Range	$PM_{2.5}$ (μg/m^3)	PM_{10} (μg/m^3)	NO_2 (μg/m^3)	Category
1–50	15.5	50	80	Good
51–100	55.4	150	200	Moderate
101–200	150.4	350	1130	Unhealthy
201–300	250.4	420	2260	Very Unhealthy
≥ 301	500	500	3000	Hazardous

3. RESULTS AND DISCUSSION

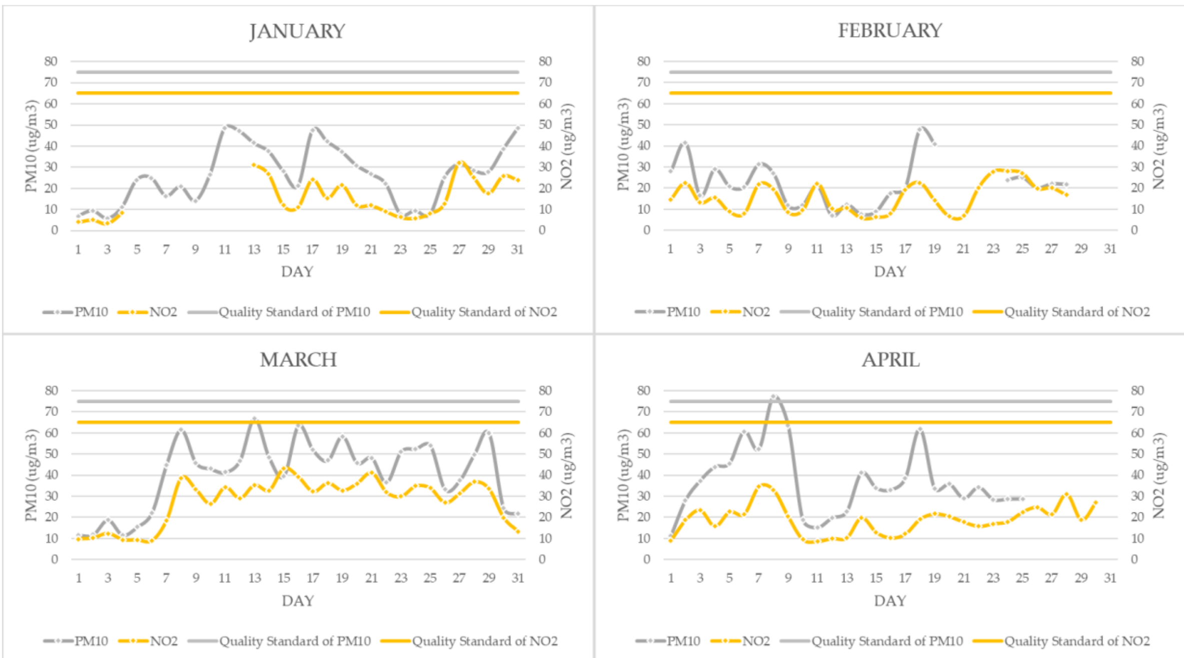
During the measurement period from January 2023 to December 2023, the average concentrations of PM_{10} and NO_2 were 60.4 μg/m^3 and 37.4 μg/m^3, respectively. At the same measurement location in the BJ Habibie Science Technology Area (KST), Serpong, the average concentration of $PM_{2.5}$ is 40.0 μg/m^3, according to research results by Istiqomah (2024). The concentration ratio of $PM_{2.5}$ and PM_{10} was 0.7. Table 2 shows the highest concentrations of $PM_{2.5}$, PM_{10}, and NO_2 during the research period.

Table 2. Descriptive statistical $PM_{2.5}$, PM_{10}, NO_2

Parameter	$PM_{2.5}$ (μg/m^3)	PM_{10} (μg/m^3)	NO_2 (μg/m^3)
Mean	40.0	60.4	37.4
Max	170.8	336.0	647.5
Min	0.4	1.2	0.1

*Istiqomah (2024)

In October and May, the highest concentrations of PM2.5 and PM10 were 170.8 μg/m3 and 336.0 μg/m3, respectively the highest concentration of NO_2 was 647.5 μg/m^3 in March. The smallest concentrations of $PM_{2.5}$ and PM_{10} occurred in January at 0.4 μg/m^3 and 1.2 μg/m^3, and NO_2 occurred in April at 0.1 μg/m^3.



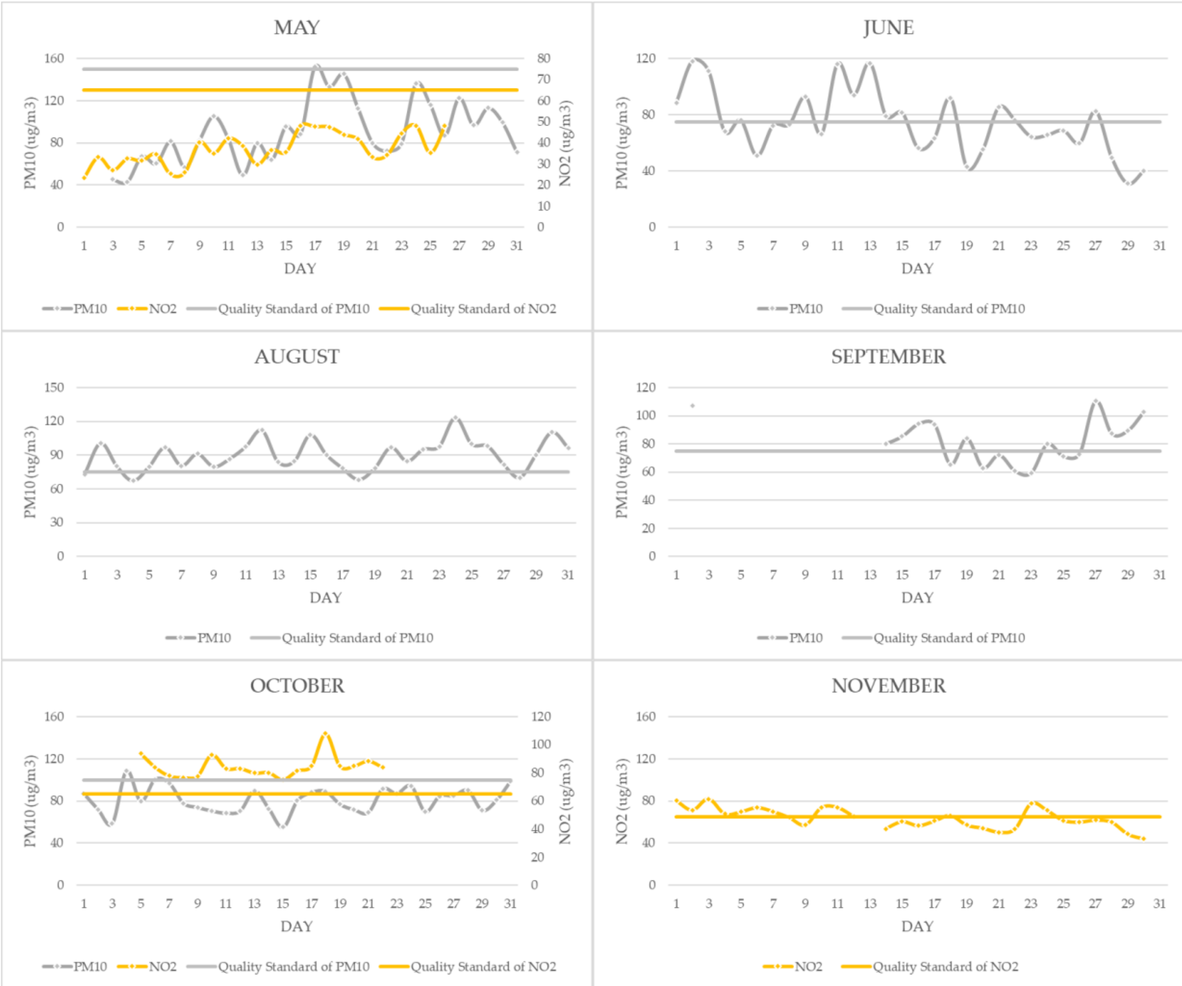
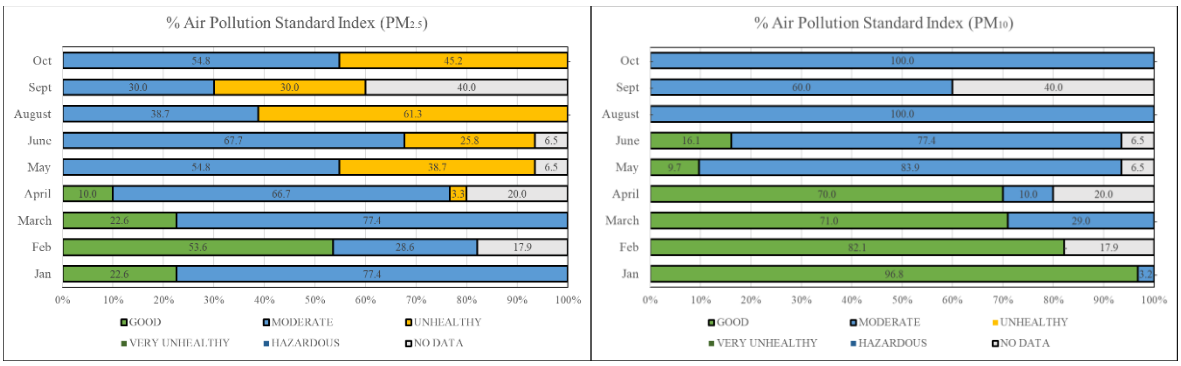


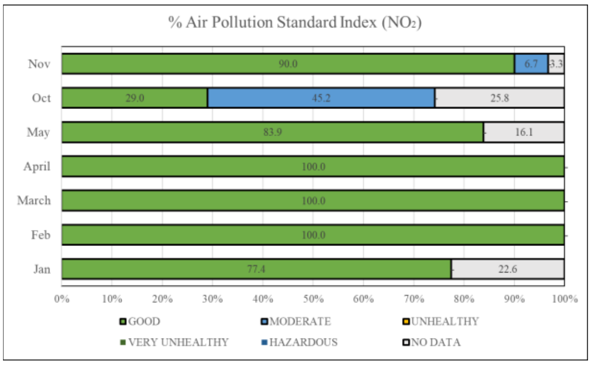
Figure 2. Average daily concentrations of PM_{10} and NO_2

Figure 2 shows the pattern of PM_{10} and NO_2 concentrations during the measurement period. In January and Feburary, which is the wet season period, the average pollutant concentration is relatively low, namely 23.4 μg/m³ $PM_{2.5}$ (Istiqomah, 2024), 26.3 μg/m³ PM_{10} and 15.4 μg/m³ NO_2, and 15.8 μg/m³ $PM_{2.5}$ (Istiqomah, 2024), 22.3 μg/m³ PM_{10}, and 15.5 μg/m³ NO_2. Pollutants increased in the following months, where the highest monthly average $PM_{2.5}$ concentration was in August at 57.6 μg/m³ (Istiqomah, 2024), 90.4 μg/m³ PM_{10} in May, and 63.7 μg/m³ NO_2 in November. In this research period, there were gaps in data in July, November, and December 2023; this was due to maintenance of the measurement equipment so that no data was recorded.

The research results also show that the daily average concentration of $PM_{2.5}$, PM_{10}, and NO_2 in January, February, and March did not exceed the quality standards in Government Regulation Number 22 of 2021 (Ministry of Environment and Forestry, 2021). The ambient air quality standard for 24-hour measurements for $PM_{2.5}$ was 55 μg/m³, PM_{10} was 75 μg/m³, and NO_2 was 65 μg/m³. Meanwhile, the ambient air quality standards set by WHO for 24-hour measurements are 15 μg/m³ $PM_{2.5}$, 45 μg/m³ PM_{10}, and 25 μg/m³ NO_2 (World Health Organization, 2021). So, if this research uses air quality standards from WHO, the number of polluted days will be more than shown in Figure 2.



(a) (b)

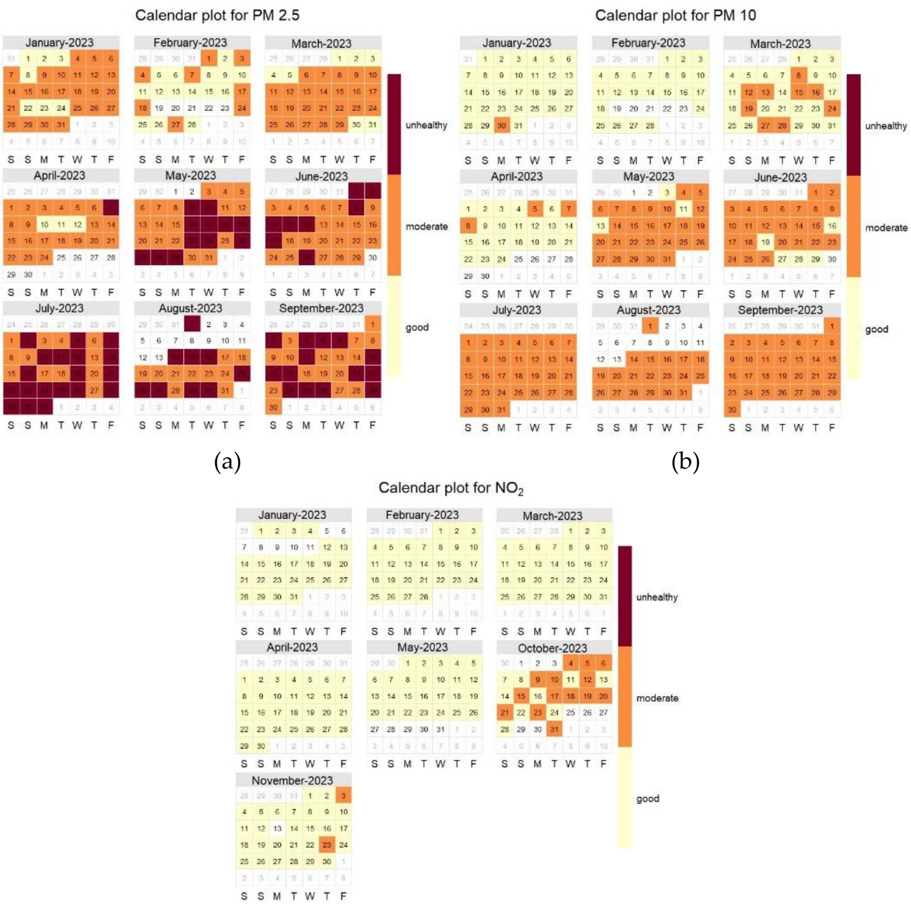


(c)

Figure 3. Monthly ISPU analysis in 2023, (a) $PM_{2.5}$ parameter; (b) PM_{10} parameter; (c) NO_2 parameter

In the following months, the concentration of pollutants increased so that the daily average of pollutants exceeded the quality standards, especially in May, June, and August. The reason is that these months are included in the dry season in the study area according to the rainfall classification (Aldrian & Susanto, 2003). Hence, there is less rainfall to dissolve pollution in the atmosphere.

Figures 3 shows the results of ISPU calculations for $PM_{2.5}$ and PM_{10} particulates from January 2023 to September 2023. The measured concentrations of $PM_{2.5}$ and PM_{10} will determine the ISPU category at the measurement location. Five ISPU categories are defined in the Minister of Environment and Forestry Regulation No. 14 of 2020: good, moderate, unhealthy, very unhealthy, and dangerous. The monthly ISPU value from the measurement results shows that the air quality at the measurement location is in the "moderate" category for $PM_{2.5}$ pollutants and good and moderate categories for PM_{10} pollutants. Based on the measurements and analysis results, 11.7% of $PM_{2.5}$ was in the good category, 55.5% was in the moderate category, and 23.0% of $PM_{2.5}$ was in the unhealthy category. For PM_{10}, 38.0% was in the good category, and 52.2% was in the moderate category. Meanwhile, good and moderate categories for NO_2 were 82.5% and 7.5% respectively.



(c)

Figure 4. Calendar plot of ISPU (a) $PM_{2.5}$ parameter; (b) PM_{10} parameter; (c) NO_2 parameter

In January, most ISPU $PM_{2.5}$ categories were good and moderate. The $PM_{2.5}$ particulate washout process influences the low pollutant concentrations measured. The washout process during rain has a direct impact on reducing the concentration of pollutant substances in the atmosphere (Kwak et al., 2017). The good and moderate ISPU categories also generally occur in February, March, and April. In June, August, September, and October, $PM_{2.5}$ concentrations increased. Due to February and March being included in the wet season, intense rainfall can suppress the concentration of pollution in the atmosphere. However, according to Aldrian & Susanto (2003), August and September are included in the dry season, while October is a transition period, so the small amount of rainfall in the dry season causes higher pollutant concentrations in the area. The calculation results show that June to October has moderate and unhealthy ISPU categories or an ISPU value range of 51–100 and 101–200. Based on $PM_{2.5}$ measurement, the June–October period has a concentration range of 25.8–80.9 μg/m^3. The unhealthy ISPU category is detrimental to living things, so sensitive community groups are recommended to reduce outdoor physical activity. Several studies have explained that exposure to $PM_{2.5}$ can damage the respiratory system (Croft et al., 2018; Jung et al., 2019; Wu et al., 2021), cardiovascular system (Gallo et al., 2020; Yang et al., 2020), nervous system (Kioumourtzoglou et al., 2016; Younan et al., 2020), renal system (Bo et al., 2021; Bowe et al., 2018), digestive system (Liu et al., 2021; Weinmayr et al., 2018), and the reproductive system (Guo et al., 2021; Percy et al., 2019).

The analysis results show that the ISPU PM_{10} values are generally in the "good" and "moderate" categories, with 38.0 and 52.2% percentages. In contrast to $PM_{2.5}$, the presence of PM_{10} in the atmosphere did not indicate an unhealthy category during the measurement period. Although only 1 day showed a moderate category for PM_{10}, the washout process can generally influence the low concentration of PM_{10} in January. In the following months, especially in August and October, the PM_{10} concentration increased, affecting the increasing number of days with the "moderate" ISPU category. The "moderate" category indicates that the quality of PM_{10} is still acceptable for human health. However, it is recommended to reduce activities that are too long or strenuous outdoors for sensitive groups. Exposure to PM_{10} will have an impact on worsening the respiratory system, including asthma and chronic obstructive pulmonary disease.

During the research period, 82.5% of NO_2 had a good category, and 7.5% had a moderate category. From January to May, NO_2 pollutants were in good condition. Figure 2 also shows that the daily average NO_2 concentration is still below the quality standard. In contrast, when the pollutant concentration is above the quality standard in October and November, NO_2 has a moderate ISPU category of 45.2% in October and 6.7% in November.

4. CONCLUSION

During the measurement period, the good category (11.7%) of $PM_{2.5}$ pollutants occurred in January, February, March, and April. In May, June, August, September and October, the $PM_{2.5}$ ISPU category was dominated by the moderate (55.5%) and unhealthy (23.0%) categories, which was in line with the increase in $PM_{2.5}$ concentrations. PM_{10} and NO_2 pollutants are in the good and moderate categories, with respective percentages of 38.0% PM_{10}, 52.2% PM_{10}, 82.5% NO_2, and 7.5% NO_2. The highest average daily concentrations of $PM_{2.5}$, PM_{10}, and NO_2 occurred in August (57.6 μg/m^3 $PM_{2.5}$), May (90.4 μg/m^3 PM_{10}), and November (63.7 μg/m^3 NO_2), respectively.

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