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Analysis of the Influence of Temperature as a Meteorological Factor on Ambient PM $_{2.5}$ Concentration in Jambi City

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Abstract
Introduction: *Air pollution, especially particulate matter with a diameter of less than 2.5 µm (PM2.5), is a major environmental and public health problem in Indonesia. Meteorological conditions, especially temperature, significantly affect fluctuations in PM2.5 levels. This study aims to analyze the relationship between air temperature and ambient PM2.5 concentrations in Jambi City during the dry and rainy seasons in 2023.* ***Methods:*** *The research employed a quantitative correlation approach using secondary data from the Sultan Thaha Class I Meteorological Station, Jambi. Statistical analysis utilized Pearson and Spearman correlation tests to determine the strength and direction of the relationship.* ***Results and Discussion:*** *Findings show that the average PM2.5 concentration was higher during the dry season (20–110 µg/m³) than in the rainy season (10–50 µg/m³). The Pearson correlation coefficient during the dry season was 0.523 and the Spearman coefficient was 0.547, indicating a moderate positive correlation between temperature and PM2.5 concentration. In contrast, the rainy season showed a weaker correlation (Pearson = 0.285; Spearman = 0.335). The relationship was statistically significant (p < 0.05).* ***Conclusion:*** *Air temperature is positively correlated with PM2.5 concentration in Jambi City, especially during the dry season.*

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Introduction

Air pollution represents a critical environmental challenge in Indonesia, fundamentally compromising public health and diminishing quality of life across the nation. Among various air quality parameters, Particulate Matter 2.5 (PM2.5)—comprising solid particles and liquid droplets smaller than 2.5 µm—poses the most severe health threat due to its ability to penetrate deep into the human respiratory system (Qonita et al., 2025). The sustained exposure to PM2.5 has been linked to serious health consequences, including impaired lung function, exacerbated cardiovascular conditions, and elevated cancer risk, making its monitoring and control a public health imperative (Maksum & Tarigan, 2022).

The global burden of PM2.5 pollution remains alarming, with over 90% of the world's population residing in areas where concentrations exceed recommended safety thresholds (Hammer et al., 2020). This widespread exposure directly undermines progress toward multiple Sustainable Development Goals, particularly those addressing health equity, environmental sustainability, and urban development. Indonesia's position among the world's most polluted nations—ranking 13th and 15th in 2023 and 2024 respectively—reflects the urgency of this crisis. The country's annual average PM2.5 concentrations of 37.1 and 35.5 µg/m³ substantially exceed both WHO guidelines (5 µg/m³) and national standards (15 µg/m³), indicating a systemic failure in air quality management (IQAir, 2023).

Jambi Province exemplifies the complex intersection of anthropogenic and natural factors driving air pollution in Indonesia. The province experiences recurrent episodes of hazardous air quality, primarily attributable to seasonal forest and land fires that dramatically elevate PM2.5 levels during dry periods (Hasan, 2024) . Based on data from the 2022 and 2023 performance reports of the Directorate of Air Pollution Control, the annual average PM2.5 concentration in Jambi City was more than 20 µg/m³ in 2018, more than 45 µg/m³ in 2019, more than 25 µg/m³ in 2021, and more than 17 µg/m³ in 2023. These values exceed the national quality standard set by Government Regulation No. 22 of 2021, which is above 15 µg/m³ per year. Therefore, it can be concluded that the air in Jambi City in those years was polluted and unhealthy.

Some conditions that can affect the high average annual concentration of $PM_{2.5}$ are sources of pollution around the monitoring location such as human activities, transportation activities, as well as natural conditions that can also affect the increase in the concentration of dust parameters (particulates in the air) for example forest and land fires, long dry seasons. In addition to being influenced by direct emission sources such as forest and land fires, the concentration of $PM_{2.5}$ in the atmosphere is also very dependent on meteorological factors, one of which is temperature which has an important role in determining daily and seasonal fluctuations of $PM_{2.5}$ concentrations.(Direktorat Pengendalian Pencemaran Udara, 2024).

Temporal changes in meteorological conditions, both daily and seasonal, can cause significant fluctuations in air pollution levels, including fine particulate matter $PM_{2.5}$ various studies have shown that the relationship between $PM_{2.5}$ and meteorological parameters is complex and can vary depending on regional characteristics, seasons, and local and regional emission sources (Novichri et al., 2024). Cold air temperatures in an area can trap pollutants in the atmosphere. This causes the pollutant content in the area to increase. The sudden movement of cold air into an area can cause a temperature reversal. In other words, cold air is trapped and cannot leave the area and tends to trap pollutants in the earth's surface layer, as a result the pollutant content will increase (Sukmawati & Dhevi Warisaura, 2023).

According to previous research (Nuryanto & Melinda, 2023) In general, the increase in $PM_{2.5}$ concentration in Sorong City occurs in two peaks per day, namely in the morning and evening. Meteorological factors such as temperature influence the decrease and increase in $PM_{2.5}$ The distribution of $PM_{2.5}$ pollutants using hysplit shows that the pollutants originate from the Maluku Sea towards Sorong. The results of other research conducted by (Alviani et al., 2022) also stated that temperature influences the increase in $PM_{2.5}$ using the Graz Lagrangian Model Software. Based on this background, research needs to be conducted in-depth study of the relationship between meteorological factors and the increase in $PM_{2.5}$ in Jambi City is important. Therefore, this research is expected to provide insight in efforts to control air pollution, as well as in designing more effective mitigation policies to protect public health from exposure to dangerous $PM_{2.5}$.

Method

This study uses a quantitative approach with a correlation analysis method. This study focuses on the Sultan Thaha Class I Meteorological Station located in Jambi City. This station can be used as a representative in reflecting air quality conditions, especially $PM_{2.5}$ concentrations in Jambi City. BMKG Sultan Thaha Class I Meteorological Station uses a Beta Attenuation Monitor (BAM)-1020 to measure $PM_{2.5}$ particles. This equipment is a statistical and automatic observation instrument that works continuously, recording $PM_{2.5}$ concentrations every hour for 24 hours. The type of data used in this study is secondary data. The data and data sources used in this study are $PM_{2.5}$ concentration data (µg/m³) per hour in 2023 sourced from BMKG Sultan Thaha Jambi Class I Meteorological Station. This data is used to see the temporal pattern of $PM_{2.5}$ concentrations in Jambi City and meteorological data, namely the average daily air temperature (°C).

Results and Discussion

The relationship between $PM_{2.5}$ concentration and air temperature in this study will be visualized using a scatter plot graph in Figure 1 and Figure 2 is a visualization of the relationship between $PM_{2.5}$ and air temperature during the rainy and dry seasons in 2023.

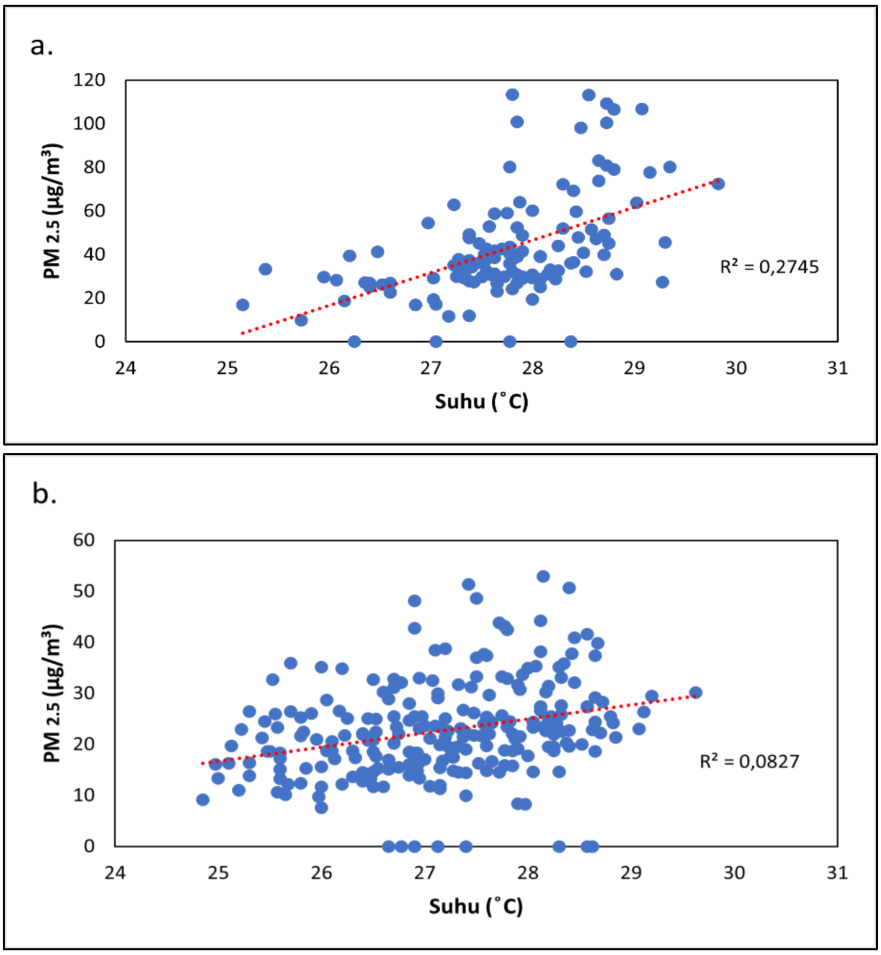

Figure 1. Scatter Plot Graph of the Relationship between PM2.5 Concentration and Air Temperature in the Dry (a) and Rainy (b) Seasons of 2023

Figure 1 above shows a scatterplot that visually illustrates the relationship between $PM_{2.5}$ concentration and air temperature during the dry (a) and rainy (b) seasons of 2023. The dots on the scatterplot represent daily data. Visually, it can be seen that, in general, during the dry season, the average daily PM2.5 concentration ranged between 20 and 110 µg/m3. Meanwhile, during the rainy season, the average daily $PM_{2.5}$ concentration ranged between 10 and 50 µg/m3. Furthermore, the average daily air temperature during the dry season ranged between 26 and 30°C, while during the rainy season it ranged between 25 and 29°C. This indicates that $PM_{2.5}$ concentration and air temperature were higher in the dry season than in the rainy season.

Figure 1 also shows a red dotted line depicting a trend indicating the direction of the relationship between the two variables. The upward slope of the trendline indicates a positive relationship between temperature and $PM_{2.5}$ concentration. This means that as air temperature increases, $PM_{2.5}$ concentration tends to increase as well. The graph also shows that the relationship between air temperature and $PM_{2.5}$ concentration has a small

R2 value, presumably because this relationship only looks at the relationship between $PM_{2.5}$ concentration and temperature variables separately. This scatter plot graph provides an initial indication of a positive correlation between temperature and $PM_{2.5}$ in the dry and rainy seasons of 2023, which can then be strengthened by the Pearson and Spearman correlation statistical tests in Table 1 below.

Table 1

Correlation Statistics of PM2.5 Concentratio and Air Temperature in the Dry and Rainy Seasons of 2023 and 2024

Year	Season	Types of Correlation	Correlation Coefficient (r)	*P-Value*	Description Relationship
2023	Rain	*Pearson*	0.285	0.000	Weak Positive
		Spearman	0.335	0.000	Weak Positive
	Drought	*Pearson*	0.523	0.000	Moderate Positive
		Spearman	0.547	0.000	Moderate Positive

Based on Table 1, during the 2023 dry season, the Pearson correlation coefficient was 0.523 and the Spearman correlation coefficient was 0.547, indicating a moderate positive relationship between temperature and $PM_{2.5}$ concentration. Then, in the 2024 dry season, the relationship weakened, with a Pearson correlation coefficient of 0.341 and a Spearman correlation coefficient of 0.333, indicating a weak positive relationship. During the rainy season, the relationship between $PM_{2.5}$ and temperature tended to be weaker, although still showing a positive correlation. In 2023, the Pearson correlation coefficient was 0.285 and the Spearman correlation coefficient was 0.335.

The statistical analysis results are consistent with the scatterplot results, which show a positive and statistically significant relationship (p-value <0.05) between air temperature and $PM_{2.5}$, with the strongest relationship occurring during the 2023 dry season. This relationship indicates that increasing air temperature tends to be accompanied by an increase in $PM_{2.5}$ particle concentrations in the air.

The results of this study demonstrate a positive and statistically significant correlation between air temperature and PM2.5 concentration, consistent with previous findings across various regions in Indonesia. According to Qonita et al. (2025), fluctuations in PM2.5 levels in Pontianak were strongly influenced by temperature and humidity, indicating that higher temperatures can increase particle suspension and reduce atmospheric dispersion efficiency. Similarly, Alviani et al. (2022) found that higher temperatures during the dry season tend to coincide with elevated PM2.5 concentrations in Jambi City due to more intense photochemical reactions and reduced humidity. The present study supports this, as during Jambi's dry season, PM2.5 levels reached over 100 µg/m³, far exceeding the WHO limit of 5 µg/m³ and the national standard of 15 µg/m³ (Government Regulation No. 22 of 2021).

Temperature plays an indirect role in air pollution dynamics. When surface temperature rises, it promotes vertical mixing in the atmosphere, dispersing particles; however, during prolonged dry and stagnant air conditions, high temperatures can enhance secondary aerosol formation, thus increasing PM2.5 (Sukmawati & Dhevi Warisaura, 2023). In contrast, during the rainy season, frequent precipitation helps remove particulates through wet deposition, leading to lower PM2.5 levels (Novichri et al., 2024).

The moderate correlation during the dry season (r = 0.523) suggests that temperature alone is not the sole determinant of PM2.5 variability. Other meteorological parameters such as humidity, rainfall, and wind speed also interact to modulate pollutant dispersion and accumulation (Nuryanto & Melinda, 2023). The lower correlation during the rainy season further supports the hypothesis that rainfall mitigates particulate accumulation through scavenging mechanisms.

Based on the research results that have been conducted, further research is needed using the BAM-1020 filter to determine the chemical components in the ambient air of Jambi City in order to contribute, support and encourage the government to make appropriate and targeted policies in an effort to improve air quality in Jambi City so that greater health problems can be avoided. The relevant agencies can conduct periodic analysis of the trajectory of PM2.5 particles to identify provinces that are contributors to PM2.5 pollution.

Conclusion

Based on research conducted on the influence of temperature as a meteorological factor on ambient $PM_{2.5}$ concentrations in Jambi City, it can be concluded that the average $PM_{2.5}$ concentration is higher in the dry season compared to the rainy season. Furthermore, $PM_{2.5}$ concentrations are higher at night (7:00 PM - 6:00 AM WIB) compared to during the day (7:00 AM - 6:00 PM WIB).

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