Proceedings Academic Universitas Jambi
Volume 2, Issue 2, Juli, 2026

Analysis of Air Quality in Jambi City Based on Air Pollution Standard Index (ISPU)

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Abstract

Background: Air quality deterioration caused by particulate pollution remains a major environmental and public health concern in urban areas vulnerable to forest and land fires. **Objective:** This study aimed to analyze air quality in Jambi City using the Air Pollution Standard Index (ISPU), particularly for PM10 and PM2.5 during 2023-2024. **Methods:** A descriptive quantitative approach was applied using secondary data from the Air Quality Monitoring System (AQMS), which were converted into ISPU values according to Ministry of Environment and Forestry Regulation No. 14/2020 and analyzed using the Wilcoxon signed-rank test. **Results:** Air quality in 2024 improved compared with 2023, particularly for PM10, which remained in the good category, while PM2.5 still showed many moderate days but no longer reached the unhealthy levels recorded during the 2023 pollution episode. **Conclusion:** The findings support strengthened pollution-control policy and the development of data-driven early warning systems for particulate pollution in Jambi City.

Keywords: air quality; PM10; PM2.5; ISPU; Jambi City; particulate matter; air pollution

Cite This Article

Tyas Hanifatunnisa, Arifin Abdullah, Bambang Irawan, Rizki Andre Handika. (2026). Analysis of Air Quality in Jambi City Based on Air Pollution Standard Index (ISPU). Proceedings Academic Universitas Jambi, 2(2): e55592. DOI: 10.22437/proca.v2i2.55592

Editor

Kevin Waldo, M.Pd

Article info

Received: Mei 15, 2026 · Revised: Juli 06, 2026 · Accepted: Juli 11, 2026

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INTRODUCTION

Air quality is closely linked to the Earth's climate and ecosystems worldwide. Polluted air has become part of the triple planetary crisis, together with climate change and biodiversity loss, which poses a global challenge for the future. It has also become one of the leading causes of disease and premature death worldwide, causing up to 4.2 million premature deaths in 2019 [1]. The World Health Organization (WHO) estimates that 92% of the world's population lives in areas with annual average $PM_{2.5}$ levels greater than 10 μg/m³, exceeding the WHO air quality guidelines for $PM_{2.5}$ exposure [2].

In Indonesia, the main sources of air pollution in urban areas are transportation, residential activities, waste disposal, and industrial activities [3]. However, increases in PM_{10} and $PM_{2.5}$ concentrations are not only caused by local transportation and industrial emissions, but are also exacerbated by annual forest and land fires (karhutla), especially in Sumatra and Kalimantan [4]. Jambi City, as the capital of Jambi Province and one of the centers of economic growth and population activity on Sumatra Island, is not free from air quality degradation. Based on concentration data published by the Government of Jambi City, air quality conditions often show significant fluctuations, especially for PM_{10} and $PM_{2.5}$. During September-October 2023, $PM_{2.5}$ concentrations reached 130-174 μg/m³, causing the index to enter the “unhealthy” and potentially hazardous categories for public health during the long dry season [5].

High PM_{10} and $PM_{2.5}$ concentrations are a serious concern. According to Handika et al. [6], exposure to PM_{10} can cause carcinogenic and non-carcinogenic health risks. These conditions may generate broad impacts, including increased cases of acute respiratory infections (ARI), decreased work and learning productivity, and disruption to tourism and the local economy. The Air Pollutant Standard Index (ISPU) facilitates public understanding of air quality because it converts pollutant concentration data into air quality categories based on their impacts on human health and other living organisms [7]. Based on the Minister of Environment and Forestry Regulation No. 14 of 2020, PM_{10} and $PM_{2.5}$ are among the main indicators determining air quality categories in urban areas. Therefore, this study aimed to analyze air quality in Jambi City over the last two years based on ISPU values for PM_{10} and $PM_{2.5}$, providing scientific information for regional air quality control strategies.

METHODS

Research Design and Data Collection Techniques

This study analyzed air quality conditions in Jambi City, the capital of Jambi Province, located in the central part of Sumatra Island. A descriptive quantitative approach was used to describe air quality conditions based on the Air Pollutant Standard Index (ISPU), specifically for the PM_{10} and $PM_{2.5}$ parameters, during 2023-2024 as a recent period reflecting post-pandemic air quality dynamics. PM_{10} and $PM_{2.5}$ were selected because they represent urban air conditions and have major implications for public health. The study used secondary data obtained from the Ambient Air Quality Monitoring Station in Jambi City, located on Jl. Jenderal Basuki Rahmat, Paal Lima, Kota Baru District, Jambi City. The monitoring station is strategically located and represents average urban air quality conditions by considering various surrounding emission sources. Monitoring was carried out using the Air Quality Monitoring System (AQMS), which measures several air compounds and pollutants, including PM_{10}, $PM_{2.5}$, SO_2, NO_x, O_3, NO_2, and CO.

Data Analysis Technique

The PM_{10} and $PM_{2.5}$ concentration data were collected as time-based concentration data using measurement instruments at the air monitoring station (Figure 1). The results were visualized as monthly trend graphs for each parameter. Inferential statistical tests were then performed to compare two measurements taken on the same subjects, namely the average ISPU values for the same periods in 2023 and 2024.

Figure 1. Location of the Air Quality Monitoring System (AQMS) station in Jambi City.

Concentration data from the station were converted into ISPU values using the equation stipulated in the Minister of Environment and Forestry Regulation Number 14 of 2020 concerning the Air Pollution Standard Index [7]. The ISPU value was calculated using the following equation:

$$\mathrm{I} = \frac{(Ia - Ib)}{(Xa - Xb)}(Xx - Xb) + Ib \ldots\ldots\ldots (1)$$

Notes:

I = calculated ISPU

Ia = upper ISPU limit

Ib = lower ISPU limit

Xa = upper ambient concentration limit (µg/m³)

Xb = lower ambient concentration limit (µg/m³)

Xx = actual measured ambient concentration (µg/m³)

The following ISPU ranges are defined in several categories:

Table 1. ISPU range categories.

ISPU	24 Hour PM10 µg/m3	24 Hour PM2.5 µg/m3	Category	Colors	Description
0-50	50	15.5	Good	Green	Very good air quality; no adverse effects on humans, animals, or plants.
51-100	150	55.4	Moderate	Blue	Acceptable air quality for human, animal, and plant health.
101-200	350	150.4	Unhealthy	Yellow	Air quality may be detrimental to humans, animals, and plants.
201-300	420	250.4	Very Unhealthy	Red	Air quality increases health risks for exposed populations.

>301	500	500	Hazardous	Black	Air quality can seriously harm health and requires immediate action.

Source: Ministerial Regulation of the Environment and Forestry No. 14 of 2020 [7].

Statistical Analysis

Daily PM_{10} and $PM_{2.5}$ concentration values were converted into ISPU values and summarized by category. The normality assumption for paired comparisons was checked before inferential analysis. Because the paired data were not normally distributed, differences in ISPU values between 2023 and 2024 were tested using the Wilcoxon signed-rank test as a non-parametric alternative to the paired sample t-test. Statistical significance was interpreted at $p < 0.05$.

RESULTS

Concentrations of PM_{10} and $PM_{2.5}$ for the 2023-2024 Period

The main analysis was carried out by comparing daily particulate concentrations with the applicable PM_{10} and $PM_{2.5}$ quality standards based on Government Regulation Number 22 of 2021, namely PM_{10} = 75 µg/m³ and $PM_{2.5}$ = 55 µg/m³ [8]. Figure 2 shows the trend in PM_{10} and $PM_{2.5}$ concentrations for 2023-2024. $PM_{2.5}$ concentrations in 2023 showed sharp fluctuations, with several significant peaks around the 260th to 300th day, reaching more than 140 µg/m³ and exceeding the daily quality standard of 55 µg/m³. This condition indicates relatively high fine particle pollution during that period. Meanwhile, PM_{10} in 2023 also increased during the same period, although most values remained below the quality standard of 75 µg/m³. In 2024, both PM_{10} and $PM_{2.5}$ concentrations showed a relatively more stable pattern and were lower than the previous year, without extreme spikes, although several days still exceeded the $PM_{2.5}$ threshold.

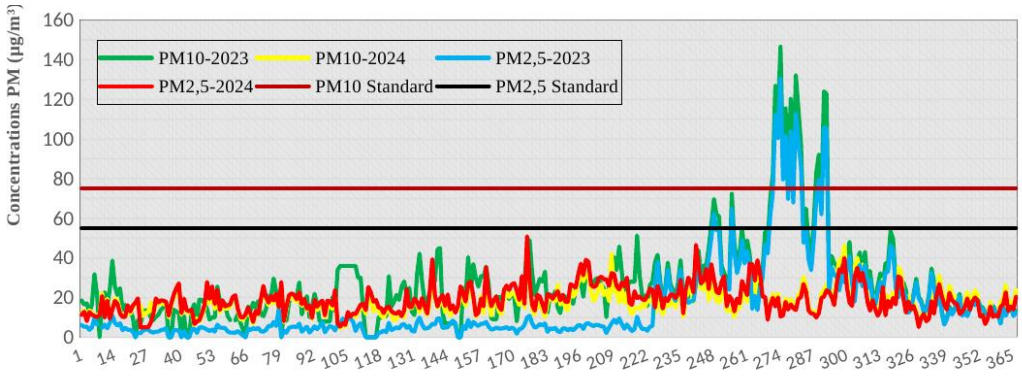

Figure 2. PM_{10} and $PM_{2.5}$ concentration trends for 2023-2024.

Conversion of Concentration Data to ISPU

Concentration data of PM_{10} and $PM_{2.5}$ pollutants are measured in technical units such as µg/m³, which are not easily understood by the public. Therefore, air quality data presentation needs to be converted into the Air Pollutant Standard Index (ISPU). The ISPU values were calculated from PM_{10} and $PM_{2.5}$ concentrations obtained from the AQMS managed by the Jambi City Environmental Agency. The ISPU values indicate daily air quality categories, namely good, moderate, unhealthy, very unhealthy, and hazardous, during 2023-2024. The category distribution for PM_{10} and $PM_{2.5}$ is presented in Table 2. In general, air quality categories in Jambi City in 2023 ranged from good to unhealthy, while in 2024 the categories

narrowed to good and moderate for both pollutants. However, parameter-specific analysis remains important because the health impact varies according to index range, pollutant type, and population sensitivity [9].

Table 2. Number of days with air quality categories by ISPU in Jambi City in 2023 and 2024.

Year	Category	PM_{10}	$PM_{2.5}$
2023	Good	321	236
2023	Moderate	28	93
2023	Unhealthy	0	20
2023	Very Unhealthy	0	0
2023	Hazardous	0	0
2023	Blank Data	16	16
2024	Good	365	124
2024	Moderate	0	244
2024	Unhealthy	0	0
2024	Very Unhealthy	0	0
2024	Hazardous	0	0
2024	Blank Data	1	0

The 2023 ISPU PM_{10} data showed air quality dominated by the good category for 321 days, followed by the moderate category for 28 days. There were no days with PM10 conditions categorized as unhealthy, very unhealthy, or hazardous, and 16 days had blank data. Based on Indonesian ISPU calculation guidelines, the good category (ISPU 0-50) indicates air quality that is safe for outdoor activities. The transition to 2024 showed an improvement, with all 365 recorded days in the good category. All categories above good recorded zero days, with only one blank data point, indicating stable air quality and better data consistency.

Meanwhile, the 2023 ISPU $PM_{2.5}$ data showed 236 days in the good category and 93 days in the moderate category. There were 20 days in the unhealthy category, indicating periods when pollution could negatively affect health. Sixteen blank data points in 2023 could not be analyzed and should be considered when interpreting the category proportions. In 2024, the distribution changed substantially: 124 days were categorized as good, 244 days were categorized as moderate, and no days were recorded as unhealthy or worse. Although the unhealthy category decreased to zero, the sharp increase in moderate days indicates that fine particulate pollution remained an important issue.

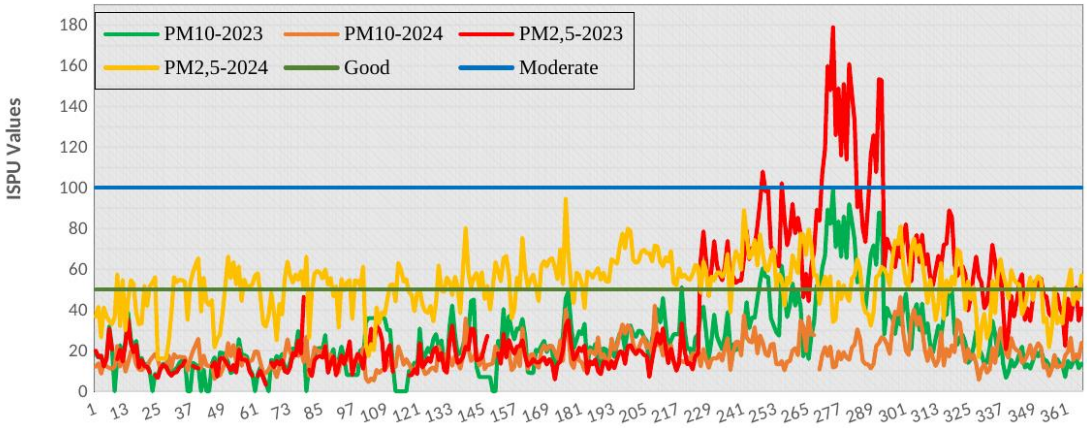

Figure 3. Daily trends in PM10 and PM2.5 ISPU values for 2023-2024.

Based on Figure 3, Jambi City air quality in 2023-2024 showed different dynamics for PM_{10} and $PM_{2.5}$. The 2023 PM_{10} ISPU generally showed air quality in the good to moderate category for most months, with an ISPU value range of 4-99.26. In 2024, PM_{10} ISPU values showed a more controlled and stable pattern, with values remaining in the good category throughout the year and ranging from 4.56 to 46.45. This indicates an improvement in air quality compared with the previous year, possibly due to reduced emission sources, favorable meteorological conditions for pollutant dispersion, and more effective air pollution control policies.

Meanwhile, PM2.5 ISPU in 2023 experienced a significant spike, peaking at 179, which falls into the unhealthy category. This spike coincided with the dry season and is strongly suspected to have been influenced by open burning or land fires around Jambi City. In 2024, no $PM_{2.5}$ ISPU spike reached the unhealthy category, with values ranging from 15.79 to 94.57. However, frequent fluctuations in the moderate category indicate that fine particulate pollution remained unresolved, although its intensity was more controlled than in 2023. The difference between PM_{10} and $PM_{2.5}$ trends indicates that $PM_{2.5}$ remains a critical issue because it is more sensitive to fine combustion sources. Technically, $PM_{2.5}$ is difficult to control because it originates from incomplete combustion and secondary chemical reactions [10]. This is consistent with findings showing that $PM_{2.5}$ can remain high even when PM_{10} decreases [11,12].

Significance Test of Changes in ISPU Values Using the Wilcoxon Signed-Rank Method

Inferential statistical analysis was conducted to compare two measurements taken from the same observation periods, namely the difference in average ISPU values between 2023 and 2024. The paired comparison requires a normality test as a prerequisite for parametric testing. Because the data distribution was not normal, the parametric paired sample t-test was replaced with a non-parametric test. Non-parametric statistics are used when population parameters or data distribution assumptions do not follow a particular distribution model. The Wilcoxon signed-rank test was used as an alternative to the paired sample t-test because it has higher statistical power and is more sensitive than the sign test [17].

Table 3. Wilcoxon signed-rank test.

Test statistic	ISPU PM_{10} value 2024 - 2023	ISPU $PM_{2.5}$ value 2024 - 2023
Z	-8.144	-8.371
Asymp. Sig. (2-tailed)	<0.001	<0.001

The test results showed a Z value of -8.144 for ISPU PM10 and -8.371 for ISPU PM2.5, with $p < 0.001$ for both parameters. These results indicate statistically significant differences in ISPU values between 2023 and 2024. The use of the Wilcoxon signed-rank test strengthens the validity of the analysis under non-normal data conditions. Overall, the results support the conclusion that air quality changed significantly between 2023 and 2024 for both PM_{10} and $PM_{2.5}$. The large magnitude of the Z values indicates that differences in one direction, particularly the reduction of extreme pollution values, were more dominant than the opposite direction. Further interpretation involving meteorological conditions, emission activity, and temporal factors is needed to clarify the causes of these changes.

DISCUSSION

The analysis revealed differences in PM_{10} and $PM_{2.5}$ ISPU values in 2023-2024, raising important questions about air quality control in Jambi City. Although both pollutants can originate from similar sources, including vehicle emissions, industrial activities, and open burning [18], the stronger improvement in PM_{10} compared with $PM_{2.5}$ suggests that existing control measures may be more effective for coarse particulate matter than for fine particulate matter. The spike in ISPU values during September-October 2023 was influenced by external factors such as forest and land fires, which frequently occur during the dry season in Sumatra, including Jambi. Airflow may transport $PM_{2.5}$ pollutants from fire-affected areas in Sumatra to Jambi City, increasing local $PM_{2.5}$ concentrations [19].

Jambi City ISPU data for $PM_{2.5}$ in 2023 recorded approximately 20 days under unhealthy conditions, indicating that air quality at that time was detrimental to humans, animals, and plants. In the unhealthy category, sensitive groups are advised to reduce outdoor activity, take frequent breaks, and monitor symptoms such as coughing or shortness of breath. People with asthma should follow asthma management guidelines and keep medication available. Heart disease patients should be aware of symptoms such as palpitations, shortness of breath, and unusual fatigue. Particles smaller than 2.5 μm can penetrate deep into the lungs and cardiovascular system, causing acute respiratory infections, lung cancer, cardiovascular disease, and even premature death [13].

The increase in $PM_{2.5}$ during the forest and land fire period can also be understood through local land preparation patterns. Farmers in Jambi Province generally begin slashing in March and burn in July and August [14]. Anthropogenic ignition is therefore an important driver of fire hotspot occurrence and contributes to deteriorating air quality in surrounding areas. Fire produces haze containing aerosols dominated by fine particulate matter, especially $PM_{2.5}$, from biomass burning.

Compared with Palangka Raya, a similar pattern emerges: air quality monitoring is often reactive to forest and land fire episodes and seasonal fluctuations, while integration of monitoring data into long-term prevention policies remains limited [15]. In contrast, Bangkok has developed real-time air quality sensor networks and big data systems to monitor air pollution and support the development of vehicle emission control policies and urban transportation planning [16]. Therefore, Jambi City needs to shift from a data-informed approach to a more data-driven approach by strengthening cross-sector integration and community behavior change so that air pollution control policies become more preventive, adaptive, and sustainable.

CONCLUSIONS

Jambi City air quality based on ISPU values generally ranged from good to moderate in 2023, with a peak PM_{10} value of 99.26 in the moderate category. In 2024, PM_{10} ISPU values showed greater stability and remained in the good category throughout the year, with a peak value of 46.45. However, $PM_{2.5}$ experienced a major spike in 2023, with 20 days in the unhealthy category and the highest ISPU value reaching 179. In 2024, no $PM_{2.5}$ values reached the unhealthy category, although the number of moderate days increased from 93 to 244, with the highest daily value reaching 94.57. This indicates that although extreme pollution decreased, Jambi City air quality has not consistently returned to the good category throughout the year.

An early warning system for pollution can be developed by using historical ISPU trends as the basis for a machine learning-based predictive model to estimate potential increases in

monitored pollutant concentrations over the following days. Such a system would enable automatic alert-level determination and allow city governments to prepare mitigation measures when predictions indicate worsening air quality. Further research is recommended to expand air quality indicators beyond PM_{10} and $PM_{2.5}$ to include NO_2, SO_2, CO, and O_3, providing a more comprehensive picture of air quality dynamics in Jambi City.

CONFLICT OF INTEREST

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

FUNDING

This study did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

ACKNOWLEDGMENT

The authors thank the Jambi City Environmental Agency (DLH) for permission to use the data and for the information and valuable assistance provided during this study.

AUTHOR CONTRIBUTIONS

Conceptualization, T.H. and R.A.H.; data collection, T.H. and A.A.; data analysis, T.H. and R.A.H.; manuscript writing, T.H.; manuscript review and editing, T.H., A.A., R.A.H., and B.I.; supervision, R.A.H. and B.I. All authors have read and approved the final version of the manuscript.

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