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Assessing Long-Term Trends in Air Quality and Climate Variables in Peninsular Malaysia: A Descriptive Statistical Analysis

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KEYWORDS

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ABSTRACT

This paper investigates long-term trends in air quality and climate variables in Peninsular Malaysia using descriptive statistical methods, addressing the need for understanding environmental changes and their implications. The objective is to analyze these trends using descriptive statistical methods, providing an overview of data variations. The analysis highlights significant regional disparities, with urban areas like Klang and Seberang Jaya showing higher levels of PM_{10} and CO, driven by industrial and vehicular emissions, while ozone (O_3) levels remain consistently low. Missing data, particularly for CO and O_3, reveal gaps in monitoring infrastructure. These findings provide valuable insights into pollution hotspots, data gaps, and episodic pollution events emphasizing the importance of sustained monitoring and targeted interventions to mitigate air pollution and adapt to climate variability in the region.

1. INTRODUCTION

Air quality and climate variability are critical components of environmental health, influencing ecosystems, human well-being, and sustainable development [1]. In recent years, the rising levels of air pollutants have become a significant concern worldwide, particularly in regions experiencing rapid industrialization and urbanization [2]. These pollutants are closely tied to various human activities and natural processes, necessitating ongoing monitoring and analysis to identify trends and devise effective mitigation strategies [3,4].

In Peninsular Malaysia, air quality management has become increasingly important due to the economic growth and its vulnerability to transboundary pollution from neighboring countries [5]. Seasonal phenomena, such as haze events caused by biomass burning, further exacerbate air pollution levels [3]. Alongside these concerns, climate variability which is characterized by fluctuations in weather parameters plays a crucial role in shaping air quality patterns, influencing pollutant dispersion and concentration [6].

This study aims to analyze the long-term trends of air quality and climate variables in Peninsular Malaysia using descriptive statistical methods. By examining spatial and temporal variations across monitoring stations, the research seeks to identify key patterns, gaps, and areas requiring policy attention. These insights are expected to contribute to a deeper understanding of the environmental challenges, providing a foundation for data-driven interventions and sustainable management strategies. Additionally, ensuring the quality and completeness of the dataset before proceeding with modeling will enhance the reliability and accuracy of future predictive analyses [7].

2. EXPERIMENTAL PROCEDURE

This study employed a systematic approach to analyze the long-term trends of air quality and climate variables in Peninsular Malaysia. The methodology included data preparation and descriptive statistical analysis using SPSS.

The data comprised air quality parameters, including particulate matter (PM_{10}), carbon monoxide (CO) and ozone (O_3) collected from 10 monitoring stations across Peninsular Malaysia. The dataset was obtained from the Department of Environment (DoE), spanning from 2003 to 2022. Initial sorting involved organizing the data by location and parameter, ensuring consistency in format and structure.

Descriptive statistics were computed using SPSS to summarize the central tendency and variability of the data for each location and parameter. Table 1 shows the location of the monitoring stations for this study.

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Table 1 Location of Study Area

Monitoring Station	Category
Kangar	Sub-Urban
Alor Setar	Sub-Urban
Sg.Petani	Sub-Urban
Seberang Jaya	Urban
Tasek Ipoh	Urban
Klang	Sub-Urban
Putrajaya	Sub-Urban
Kuala Selangor	Rural
Seremban	Urban
Bandaraya Melaka	Urban

3. RESULTS AND DISCUSSION

The analysis of air quality parameters, including particulate matter (PM_{10}), carbon monoxide (CO), and ozone (O_3), across various locations in Peninsular Malaysia provides significant insights into regional air quality trends and monitoring challenges.

3.1 Particulate Matter (PM_{10})

PM_{10} levels demonstrated considerable variation across the regions analyzed. Locations such as Klang and Seberang Jaya exhibited the highest mean concentrations (56.57 µg/m³ and 46.57 µg/m³, respectively), indicating potential hotspots of air pollution. These elevated levels may be attributed to urban density, industrial activities, and vehicular emissions [8]. Conversely, areas like Alor Setar and Kangar recorded lower mean concentrations (31.57 µg/m³ and 34.83 µg/m³, respectively), likely benefiting from lower urbanization and less industrial activity.

The data also revealed high skewness values in several locations (e.g., Klang: 4.168), suggesting the presence of extreme outliers or irregular pollution events. These events could reflect episodic sources of pollution, such as haze episodes [9]. Furthermore, missing values were minimal across most locations, except for areas like Tasek Ipoh, where 447 data points were missing, indicating a need to strengthen data collection infrastructure in these areas.

3.2 Carbon Monoxide (CO)

CO levels were relatively low across the analyzed locations, with mean values ranging from 0.416 ppm (Alor Setar) to 0.944 ppm (Klang). Elevated CO levels at Klang are indicative of heavy traffic and industrial contributions [10]. The standard deviations and ranges highlight variability, with Klang showing a maximum concentration of 5.91 ppm, far exceeding other areas. This variability warrants further investigation into localized sources of CO emissions [11].

Several locations, including Seberang Perai, exhibited significant data gaps, with missing values accounting for approximately 29% of the total observations. Such inconsistencies highlight areas for improving monitoring reliability to support long-term air quality assessments [12].

3.3 Ozone (O_3)

Ozone concentrations across the regions were uniformly low, with mean values ranging from 0.015 ppm (Seberang Jaya) to 0.020 ppm (Sg. Petani). The relatively low variance suggests stable ozone levels, potentially due to consistent meteorological conditions or the efficacy of regional regulatory measures. However, skewness values and ranges indicate localized fluctuations that may be influenced by photochemical reactions involving nitrogen oxides and volatile organic compounds under specific conditions.

The findings highlight several critical insights into air quality trends in Peninsular Malaysia. Urban and industrialized regions, such as Klang and Seberang Jaya, recorded the highest concentrations of particulate matter (PM_{10}) and carbon monoxide (CO), indicating significant pollution challenges in these areas. In contrast, ozone (O_3) concentrations were consistently low across all locations, suggesting effective control measures for ozone precursors, though localized fluctuations highlight the importance of sustained monitoring efforts.

The analysis also revealed notable data gaps, particularly for CO and O_3, in certain regions, underscoring the need to strengthen monitoring networks to ensure comprehensive and reliable environmental assessments. Additionally, the temporal and regional variability observed in PM_{10} and CO, characterized by high skewness and the presence of

outliers, points to episodic pollution events likely linked to specific human activities or seasonal factors. Addressing these episodic sources can significantly improve air quality.

4. CONCLUSION

As a conclusion, the findings highlight significant regional disparities, areas such as Klang and Seberang Jaya exhibiting higher concentrations of pollutants like PM_{10} and CO, indicating substantial air quality challenges. In contrast, consistently low ozone levels across all regions suggest effective control measures, although localized variability emphasizes the need for ongoing monitoring. The presence of data gaps, particularly for CO and O_3, underscores the importance of strengthening monitoring networks to ensure accurate and comprehensive assessments. Additionally, the observed temporal variability and episodic pollution events reveal the influence of specific anthropogenic activities and seasonal factors on air quality, calling for targeted mitigation strategies.

This study provides a foundational analysis of air quality conditions in Peninsular Malaysia, focusing on long-term trends and spatial variability across key parameters such as PM_{10}, CO, and O_3. By employing descriptive statistical methods, the study offering insights into the current state of air quality and identifying regional hotspots and temporal variability. The findings establish a baseline for understanding pollution dynamics, highlighting significant disparities between monitoring stations areas, as well as data gaps in monitoring systems that need to be addressed. Building on these results, future research can advance towards developing predictive models to inform policy and promote sustainable environmental practices in the region.

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