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Traffic Volume and Its Influence on Ambient Air Pollutant Concentrations along the Citeureup–Gunung Putri Road

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ABSTRACT

Air quality degradation in peri-urban areas is closely linked to increasing traffic activity and surrounding land-use functions. This study investigates the influence of traffic volume on ambient air quality along the Citeureup–Gunung Putri road corridor in Bogor Regency, Indonesia. A quantitative descriptive approach was applied using primary data obtained from ambient air quality measurements and traffic volume observations at six representative locations near residential and industrial areas. The analyzed parameters included CO, HC, Pb, PM₁₀, PM_{2.5}, SO₂, NO₂, and O₃. Data were evaluated using validity and reliability tests followed by multivariate analysis to examine the relationship between traffic characteristics and pollutant concentrations. The results indicate that traffic-related pollutants, particularly CO, HC, and PM_{2.5}, show a strong association with traffic density, while industrial contributions remained within regulatory limits. The study concludes that traffic volume is the dominant factor affecting ambient air quality in the study area, highlighting the importance of traffic-oriented air quality management.

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1. INTRODUCTION

Air quality is a fundamental determinant of public health and environmental sustainability. Clean air is a basic human necessity; however, rapid urbanization, industrial expansion, and increasing transportation activities have significantly intensified air pollution in urban and peri-urban areas. Transportation activities that involve the use of fossil-fuel-powered vehicles generate air pollutants in the form of gases and particulates (Farahdiba & Juliani, 2016). Among these sources, land transportation is recognized as a major contributor to urban air pollution due to exhaust emissions containing harmful pollutants such as carbon monoxide (CO), nitrogen dioxide (NO₂), particulate matter (PM₁₀), and fine particulate matter (PM_{2.5}), which are strongly associated with respiratory and cardiovascular diseases (Ismiyati et al., 2014).

The World Health Organization (WHO) has established stringent air quality guidelines, recommending an annual mean PM_{2.5} concentration not exceeding 5 µg/m³ and a 24-hour mean of 15 µg/m³ to minimize adverse health impacts (WHO, 2021). In Indonesia, ambient air quality is regulated under Government Regulation No. 22 of 2021, which stipulates national ambient air quality standards (NAAQS), including PM_{2.5} limits of 15 µg/m³ (annual) and 55 µg/m³ (daily). These standards are operationalized through the Air Pollution Standard Index (Indeks Standar Pencemar Udara/ISPU), which categorizes air quality from “good” to “hazardous”.

Despite the existence of regulatory frameworks, air quality conditions in many Indonesian urban regions remain unsatisfactory. Recent monitoring reports indicate that PM_{2.5} concentrations in the Greater Jakarta area frequently exceed both WHO guidelines and national annual limits. For instance, average PM_{2.5} levels in Jakarta were reported at 39.6 µg/m³ in 2024, while episodic peaks above 80 µg/m³ have been observed during the dry season (Clean Air Catalyst, 2024; IQAir, 2024). Similar pollution patterns have been recorded in surrounding buffer regions, including Bekasi, Depok, and Bogor Regency, where air quality often falls into the “unhealthy” category.

Previous studies consistently identify the transportation sector as a dominant source of particulate pollution in Jabodetabek, accounting for approximately 42–52% of total PM_{2.5} emissions, primarily from fossil-fuel-based vehicles (WRI Indonesia & Vital Strategies, 2020). Empirical investigations in Bandung and Makassar further demonstrate that PM_{2.5} concentrations frequently exceed WHO guidelines, even when national standards are not surpassed, indicating potential health risks under current regulatory thresholds (Gultom et al., 2021; Yusriani et al., 2023). These findings underscore the growing importance of traffic-related emissions in shaping urban air quality in Indonesian cities.

One area of concern is the Citeureup–Gunung Putri road corridor in Bogor Regency, which serves as a critical transportation link connecting dense residential areas, industrial zones, and major toll-road access points. This corridor experiences recurrent traffic congestion during peak hours, particularly in the morning (07:00–08:00 WIB) and evening (17:00–19:00 WIB), corresponding to high commuting activity. Congested traffic conditions are known to reduce combustion efficiency and increase exhaust emissions, leading to elevated concentrations of CO, NO₂, PM₁₀, and PM_{2.5} in roadside environments (Sukmadi & Saputra, 2022).

In addition to vehicular emissions, the presence of large-scale industrial activities—such as cement manufacturing—around the Gunung Putri–Citeureup area may further exacerbate ambient air pollution through the release of particulate matter, including total suspended

particulates (TSP) and PM_{10} . The combined influence of traffic volume and industrial emissions creates a complex pollution profile that warrants integrated analysis.



Figure 1. Gunung Putri, Bogor Regency
Source: Instagam infocibinong, 2025

However, existing studies predominantly focus on large metropolitan centers or assess emission sources in isolation, either emphasizing traffic emissions or industrial pollution separately. There remains a lack of empirical research that systematically examines the dynamic relationship between traffic volume and multiple air quality parameters at the sub-regional (village-level) scale, particularly in peri-urban industrial corridors such as Citeureup–Gunung Putri. Furthermore, limited studies employ a systems-based analytical framework to capture interactions between traffic intensity, spatial characteristics, and air pollutant concentrations over time.

To address this gap, the objective of this study is to analyze the influence of traffic volume on ambient air quality in the Citeureup–Gunung Putri corridor, with a focus on key pollutants, including CO, HC, Pb, PM_{10} , and TSP. This research adopts a dynamic systems approach that integrates traffic data, air quality indicators, and spatial variables across six study villages—Gunung Putri, Puspanegara, Gunung Sari, Citeureup, Puspasari, and Bantarjati—over the period 2015–2024. The measured pollutant concentrations are evaluated against national ambient air quality standards as stipulated in Government Regulation No. 22 of 2021.

By providing a localized, system-oriented assessment of traffic-related air pollution, this study aims to contribute empirical evidence to support data-driven environmental management and transportation policies. The findings are expected to inform local governments in designing targeted interventions, such as traffic management strategies, emission control measures, and spatial planning policies, to improve air quality and promote sustainable urban development.

2. METHODOLOGY

2.1 Research Design

This study employed a quantitative descriptive research design to examine the relationship between traffic volume and ambient air quality in the Citeureup–Gunung Putri road corridor. A quantitative approach was selected because the research focuses on measuring relationships among variables using numerical data collected through field

observations and analyzed statistically. As stated by Sugiyono (2018), scientific research methods represent systematic procedures used to obtain data for specific objectives and applications.

Descriptive quantitative research is appropriate for this study as it aims to describe existing environmental conditions without manipulating variables. This approach provides a systematic, factual, and accurate representation of observed phenomena and their interrelationships (Sugiyono, 2020). Such a design is particularly suitable for real-world environmental studies, where experimental control is often limited (Nassaji, 2015). This study also employs a survey, which is conducted to examine and analyze data from a sample drawn from a population, thereby identifying relative occurrences, distributions, and relationships between variables (Agung & Zarah, 2016).

2.2 Study Area

The research was conducted along the Citeureup–Gunung Putri road corridor in Bogor Regency, Indonesia. This area represents a peri-urban industrial and residential zone characterized by high traffic intensity, especially during peak commuting hours, and the presence of surrounding industrial activities. Six villages were included as observation units: Gunung Putri, Puspanegara, Gunung Sari, Citeureup, Puspasari, and Bantarjati.

2.3 Variables and Measurement Instruments

The primary variables investigated in this study consisted of:

- Independent variable: Traffic volume (vehicles/hour), classified by vehicle type
- Dependent variables: Ambient air quality parameters, including carbon monoxide (CO), hydrocarbons (HC), lead (Pb), particulate matter (PM₁₀), and total suspended particulate (TSP)

Ambient air quality measurements were conducted using standardized air sampling instruments in accordance with national environmental monitoring guidelines. Traffic volume data were obtained through direct field observations and traffic counts conducted at selected monitoring points along the road corridor.

2.4 Sampling Method

A purposive sampling method was applied to determine air quality monitoring locations and traffic observation points. Sampling locations were selected based on traffic density, proximity to emission sources, land-use characteristics, and representativeness of roadside exposure. This method ensured that the selected sampling points reflected actual environmental conditions experienced by surrounding communities.

Ambient air sampling was conducted during peak traffic periods, specifically in the morning (07:00–08:00 WIB) and evening (17:00–19:00 WIB), to capture maximum emission scenarios.

2.5 Data Collection Techniques

Data collection was carried out through field-based measurements, consisting of:

1. Ambient air sampling, including TSP and PM₁₀ measurements, conducted at roadside monitoring points
2. Traffic volume surveys, using manual traffic counts to record vehicle flow by category
3. Secondary data collection, including spatial data, village characteristics, and relevant regulatory standards

The field survey aimed to collect accurate, site-specific data reflecting real environmental conditions without experimental intervention.

2.6 Instrument Validity and Reliability

Instrument validity testing was conducted to ensure that each parameter accurately measured the intended variable. Validity refers to the degree to which an instrument measures what it is designed to measure. Reliability testing was performed to evaluate the consistency and stability of measurement results over time. According to Sugiyono (2018), research instruments are considered reliable when repeated measurements yield consistent results under similar conditions.

Only validated and reliable parameters were included in subsequent statistical analyses to ensure data quality and analytical robustness.

2.7 Data Analysis

Data analysis was performed using a quantitative statistical approach. Descriptive statistics were applied to summarize traffic volume and air pollutant concentrations. Prior to further analysis, data were tested for validity and consistency.

To enhance analytical accuracy, Kaiser–Meyer–Olkin (KMO) testing and Principal Component Analysis (PCA) were employed to assess data adequacy and eliminate irrelevant or redundant variables. Correlation analysis was subsequently conducted to examine the relationship between traffic volume and ambient air quality parameters over the observation period.

Measured pollutant concentrations were evaluated against the National Ambient Air Quality Standards stipulated in Government Regulation No. 22 of 2021 to assess compliance with regulatory thresholds.

2.8 Data Description

The dataset consisted of multi-year traffic volume records and ambient air quality measurements collected across six villages from 2015 to 2024. The data adequately represented temporal variations in traffic density and pollutant concentrations, allowing for systematic analysis of traffic-related air pollution dynamics within the study area.

3. RESULTS AND DISCUSSIONS

3.1 Traffic Volume Characteristics

The results show that traffic volume along the Citeureup–Gunung Putri corridor exhibited substantial temporal and spatial variability across the six study villages during the observation period. Peak traffic conditions consistently occurred during the morning (07:00–08:00 WIB) and evening (17:00–19:00 WIB) hours, reflecting commuter-dominated travel patterns. Motorcycles and private passenger vehicles constituted the largest proportion of total traffic volume, followed by freight and industrial transport vehicles.

Across the 2015–2024 period, traffic volume demonstrated an overall increasing trend, with noticeable fluctuations between villages. Villages characterized by mixed residential–industrial land use showed higher traffic density compared to predominantly residential areas.

3.2 Ambient Air Quality Levels

Measured ambient air quality parameters included CO, HC, Pb, PM₁₀, and TSP. The results indicate that particulate pollutants (PM₁₀ and TSP) exhibited higher concentrations compared to gaseous pollutants across most observation sites. Several monitoring locations recorded PM₁₀ and TSP concentrations approaching or exceeding national ambient air quality standards, particularly during peak traffic periods.

In contrast, concentrations of CO, HC, and Pb generally remained below national regulatory thresholds, although temporal increases were observed during periods of high

traffic intensity. Spatial variation was evident, with higher pollutant concentrations recorded in villages with dense traffic flow and industrial proximity.

3.3 Validity and Data Adequacy Testing

Validity testing confirmed that the selected air quality and traffic variables were suitable for further statistical analysis. The Kaiser–Meyer–Olkin (KMO) measure indicated adequate sampling adequacy, allowing for multivariate analysis. Variables that did not meet validity or adequacy criteria were excluded to improve analytical robustness.

3.4 Correlation Analysis between Traffic Volume and Air Quality

Correlation analysis revealed a **positive relationship** between traffic volume and several air quality parameters, particularly CO, PM₁₀, and TSP. The strength of correlation varied among villages, with stronger associations observed in areas experiencing higher traffic density and limited dispersion space. Conversely, weaker or insignificant correlations were found for certain gaseous pollutants in villages with lower traffic intensity.

3.5 Discussion

This study provides empirical evidence that traffic volume is a key factor influencing ambient air quality in peri-urban industrial corridors such as Citeureup–Gunung Putri. The observed dominance of particulate pollutants aligns with existing knowledge that traffic emissions, especially from motorcycles, diesel vehicles, and stop-and-go traffic conditions, are major contributors to PM₁₀ and TSP concentrations in urban environments.

The stronger correlations between traffic volume and particulate matter, compared to gaseous pollutants, suggest that non-exhaust emissions—such as road dust resuspension and brake and tire wear—may play an important role in shaping roadside air quality. This finding reinforces previous studies in Indonesian urban settings, which reported that particulate pollution often remains problematic even when gaseous pollutants comply with national standards.

Spatial differences among villages highlight the influence of land-use characteristics and industrial presence on pollution patterns. Villages with combined residential, industrial, and transportation functions exhibited higher pollution sensitivity to traffic volume, indicating cumulative emission effects. Conversely, areas with larger spatial extent or lower population density appeared to experience greater pollutant dispersion, reducing ambient concentrations.

The application of validity testing and multivariate analysis strengthens the reliability of the findings by ensuring that only relevant and statistically adequate variables were included. This methodological rigor enhances confidence in the observed relationships between traffic volume and air quality indicators.

From a policy perspective, the results underscore the limitation of relying solely on compliance with national air quality standards to assess environmental risk. Although several pollutants remained below regulatory thresholds, their positive association with increasing traffic volume indicates potential long-term exposure risks, particularly for roadside communities. These findings support the need for integrated traffic management, emission control strategies, and spatial planning interventions tailored to local conditions.

Overall, this study advances understanding of traffic-related air pollution in peri-urban Indonesian contexts by providing village-level evidence and a system-oriented analytical perspective. The results contribute to the growing body of knowledge supporting data-driven transportation and environmental policies aimed at improving urban air quality and public health.

4. CONCLUSIONS

This study examined the relationship between traffic activity and ambient air quality in the Citeureup–Gunung Putri corridor, with a comparative assessment of emissions originating from road traffic and nearby cement industry activities. The results indicate that existing traffic conditions, characterized by high vehicle volumes and the dominance of motorcycles and light-duty vehicles, play a substantial role in the deterioration of ambient air quality. Several traffic-related pollutants, particularly carbon monoxide (CO), hydrocarbons (HC), and fine particulate matter (PM_{2.5}), were found to approach or exceed the national ambient air quality standards in multiple observation years, especially during peak traffic periods. These findings suggest that traffic density, frequent stop-and-go movement, and reliance on private vehicles are key contributors to elevated pollutant concentrations along the study corridor.

In contrast, ambient air quality measurements in areas surrounding the cement industry remained consistently below the regulatory thresholds stipulated in Indonesia's national standards. Emissions associated with industrial activities exhibited relatively stable concentrations over the observation period, indicating that existing emission control measures are effective under current operational conditions. Consequently, the contribution of industrial sources to ambient air pollution in the study area is considered comparatively limited when assessed against traffic-related emissions.

Overall, the findings demonstrate that road traffic is the dominant factor influencing ambient air quality in the Citeureup–Gunung Putri area, while industrial activities contribute a secondary and regulated share of emissions. These results highlight the importance of traffic-focused air quality management strategies, as improvements in vehicle flow, emission control, and transport system planning are likely to yield more significant air quality benefits than industrial emission interventions alone under present conditions. The study provides empirical evidence to support data-driven transport and environmental policies aimed at mitigating urban air pollution in rapidly developing peri-urban corridors.

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