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Air Quality at Urban Transportation Nodes: A Case Study of SO_2, NO_2, and CO Concentrations in Palembang City

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Abstract: This study aimed to analyze variations in sulfur oxide (SO_2), nitrogen oxide (NO_2), and carbon monoxide (CO) concentrations at eight major intersections in Palembang City.This study analyzed ambient air quality at eight major traffic nodes in Palembang City using SO_2, NO_2, and CO parameters. Measurements were carried out at a height of 2–3 meters according to US-EPA and WHO standards. SO_2 was determined using the West–Gaeke method, NO_2 with the Griess–Saltzman and chemiluminescence analyzer, while CO was measured using the Non-Dispersive Infrared (NDIR) method. All procedures were accompanied by recording of meteorological factors and instrument quality control. The results showed a significant difference between morning and afternoon, with higher average concentrations in the afternoon (SO_2: $p = 0.014$; NO_2: $p = 0.000$; CO: $p = 0.003$), which was influenced by traffic density and meteorological conditions. Pollutant concentrations tended to increase during rush hour at intersections with high vehicle flow. In contrast, inter-location analysis showed variations in pollutant concentrations, but they were not statistically significant ($p > 0.05$), indicating a relatively homogeneous distribution of traffic emissions in urban areas. Exposure to SO_2, NO_2, and CO has the potential to cause serious health impacts, including respiratory and cardiovascular disorders, as well as liver dysfunction due to oxidative stress and hypoxia. These findings emphasize the need for continuous air quality monitoring and transportation emission control policies in Palembang.

Keywords: Air qualit; urban pollution; sulfur oxides (SO_2); nitrogen oxides (NO_2); carbon monoxide (CO)

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INTRODUCTION

Rapid urban development has driven an increase in transportation and industrial activities, both of which have become major contributors to air pollution in urban areas (Kumar et al., 2017). This phenomenon occurs not only globally but also in Indonesia, where major cities, including Palembang, have experienced a significant rise in the number of motorized vehicles (Putri & Santoso, 2020). The growing number of vehicles directly affects air quality by worsening traffic congestion and increasing exhaust emissions that contain harmful pollutants (Rahmawati et al., 2019). As a metropolitan city in South Sumatra, Palembang faces considerable challenges in managing air pollution, particularly in areas with heavy traffic flow (Yuliana et al., 2021).

The primary source of urban air pollution is motorized vehicles, especially at road intersections. At these points, vehicles frequently stop, accelerate, and become trapped in congestion, which significantly increases pollutant concentrations (Rizky & Hidayat, 2019). Pollutants tend to accumulate during peak hours, resulting in higher emissions compared to straight roads with smoother traffic flow (Wijayanti et al., 2022). Previous studies have shown that pollutant levels are consistently higher at intersections due to prolonged idling and repeated stop-and-go vehicle movements (Utami et al., 2018; Kurniawan et al., 2020).

The dominant pollutants emitted by motor vehicles include sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and carbon monoxide (CO), each of which poses serious threats to both the environment and human health (WHO, 2021). SO_2 is known to cause respiratory irritation and contribute to the formation of acid rain, which harms ecosystems (Li et al., 2019). NO_2 serves as a major precursor for tropospheric ozone and secondary particulate matter, both of which are highly detrimental to health (Sharma et al., 2020). Meanwhile, CO has a high affinity for hemoglobin, disrupting oxygen transport in the human body and potentially leading to poisoning (Lai et al., 2021). Exposure to these pollutants has been linked to respiratory illnesses, cardiovascular diseases, and organ damage through oxidative stress (Zhang et al., 2019).

Beyond traffic volume, meteorological conditions also influence air pollutant concentrations. Variables such as wind direction, wind speed, temperature, and humidity can exacerbate pollutant accumulation, especially in urban areas with poor ventilation (Chen et al., 2020; Haryanto et al., 2019). Under such conditions, pollutants tend to become trapped near the ground, thereby increasing public exposure. This highlights the importance of monitoring air quality at major intersections to better understand the local distribution of pollutants (Sun et al., 2022).

Although numerous studies have been conducted in other cities and countries, detailed investigations of SO_2, NO_2, and CO concentrations at busy intersections in Palembang remain limited. A more localized analysis is necessary, as traffic nodes play a critical role in shaping emission patterns in urban settings. Therefore, this study aims to analyze SO_2, NO_2, and CO concentrations at several key intersections in Palembang City. The findings are expected to provide a clearer understanding of ambient air quality conditions and serve as a foundation for developing effective air pollution control policies.

METHOD

Study Design

This study used a comparative-observational approach, focusing on analyzing differences in air pollutant concentrations across two observation time periods: morning and afternoon.

Research Location and Time

Air quality measurements were conducted at eight strategic points (figure 1) representing dense traffic areas in Palembang City, namely point 1 at the Simpang 4 Polda Police Post, point 2 at the Sekip Simpang 4, point 3 at the Charitas Hospital Roundabout, point 4 at the Ampera Fountain, point 5 at the Nilakandi Simpang 4, point 6 at the Prameswara Simpang 4, point 7 at Jalan Soekarno Hatta, and point 8 at the Jakabaring Flyover. Each point was chosen because it has dense traffic characteristics and is considered to contribute significantly to motor vehicle emissions.

Measurements were conducted over two time periods: mornings from 8:00–9:00 AM and afternoons from 3:00-4:00 PM. These observation times were chosen based on the generally dense traffic conditions during commute and return hours, thus representing peak vehicle emission variations. In addition, measurements were carried out on consecutive working days with relatively similar weather conditions to minimize the influence of meteorological factors on the research results.

Figure 1. Sampling side point

Sampling Technique

Ambient air sampling for sulfur oxides (SO_2), nitrogen oxides (NO_2), and carbon monoxide (CO) in this study was conducted using standard methods referring to US-EPA and WHO procedures. All sampling was conducted at a height of 2–3 meters above ground level, as recommended by WHO (2005), to represent human breathable air. Furthermore, each measurement was accompanied by recording meteorological factors such as temperature, humidity, pressure, and wind direction and speed, as these parameters can affect pollutant dispersion (Seinfeld & Pandis, 2016).

For SO_2 measurement, the West–Gaeke method was used. In this method, air is sucked using a low-flow suction pump (0.5–1.0 L/min) through an impinger containing a sodium tetrachloromercurate (TCM) absorbent solution. The SO_2 gas then reacts to form a stable complex, followed by the addition of pararosaniline and formaldehyde reagents, producing a magenta color that can be measured at a wavelength of 560 nm with a spectrophotometer. The final concentration is calculated based on a standard calibration curve, after correction for temperature and air pressure (West & Gaeke, 1956; WHO, 2010).

For nitrogen oxide (NO), sampling is performed using two approaches. In the manual method, the Griess–Saltzman method is used to measure NO_2 concentration. The gas is drawn through a triethanolamine (TEA) absorbent solution, then colorimetric analysis is performed in the laboratory with sulfanilamide and N-(1-naphthyl) ethylenediamine (NEDA) reagents, producing a pink azo compound that can be measured with a spectrophotometer at a wavelength of 540 nm (US-EPA, 2017; Seinfeld & Pandis, 2016).

CO measurements were conducted using the Non-Dispersive Infrared (NDIR) method, using either portable equipment or fixed monitoring stations. This method utilizes the property of CO to absorb infrared radiation at specific wavelengths, so the measured absorption intensity is directly proportional to the CO concentration in the air (US-EPA, 2012).

Statistical Analysis

Data analysis was conducted using two main approaches. First, to examine differences in pollutant concentrations between morning and evening, a paired t-test was used because the data came from the same measurement point at two different times. Second, to compare pollutant concentrations across the eight measurement points, a one-way analysis of variance (ANOVA) was used.

RESULT AND DISCUSSION

Air quality analysis results show differences in the concentrations of key pollutants, namely sulfur oxide (SO_2), nitrogen oxide (NO_2), and carbon monoxide (CO) between morning and afternoon at the study location. These concentration variations are closely related to traffic activity, meteorological conditions, and vehicle density levels at specific times. To provide a clearer picture, a comparison of the concentrations of each pollutant parameter at the two observation times is presented in Table 1.

Table 1. Results of the analysis of comparison of SO_2, NO_2, and CO concentrations in the morning and afternoon

Parameter	Waktu Pengukuran	N	Mean	Std. Deviation	Std. Error Mean	P Value
SO	Morning (08.00-09.00)	8	43.9125	5.01745	1.77394	0,014
	Afternoon (15.00-16.00)	8	53.6313	8.41508	2.97518	
NO	Morning (08.00-09.00)	8	56.7438	3.96335	1.40126	0,000
	Afternoon (15.00-16.00)	8	71.0938	5.32235	1.88174	
CO	Morning (08.00-09.00)	8	3435.7500	865.91665	306.14777	0,003
	Afternoon (15.00-16.00)	8	5296.6250	1214.45590	429.37500	

Based on the analysis results, it was found that the concentration of air pollutants experienced a significant difference between morning and afternoon. In the sulfur oxide (SO) parameter, the average concentration was recorded at 43.91 µg/m³ (SD = 5.01) in the morning, while in the afternoon it increased to 53.63 µg/m³ (SD = 8.41). Statistical tests showed a p value = 0.014, which indicated a significant difference between SO concentrations at both measurement times. The increase in SO levels in the afternoon is generally influenced by heavier traffic intensity, the use of fossil fuels, and meteorological conditions that tend to retain pollutants in the lower air layers (Rizwan et al., 2018; Kurniawan & Schmidt, 2019). From a health perspective, SO exposure can cause irritation to the respiratory tract, worsen asthma, and increase the risk of chronic obstructive pulmonary disease (COD) (WHO, 2016; Kim et al., 2015). Furthermore, long-term exposure to SO_2 is also associated with oxidative stress and systemic inflammation, which can affect liver function through hepatocyte damage and increase the risk of chronic liver disease (Zhang et al., 2019).

For nitrogen oxide (NO), the average concentration in the morning was 56.74 µg/m³ (SD = 3.96) and increased in the afternoon to 71.09 µg/m³ (SD = 5.32). The p-value obtained was 0.000, indicating that the difference in NO concentration between morning and afternoon was highly significant. The increase in NO concentration in the afternoon is closely related to motor vehicle emissions, primarily due to incomplete combustion and increased transportation activity during the post-work hour (Manisalidis et al., 2020; Dewi et al., 2017). From a health perspective, NO exposure is associated with an increased risk of respiratory tract infections, decreased lung function, and triggers inflammation, which can worsen conditions in people with asthma and cardiovascular disease (Faustini et al., 2014; WHO, 2016). Furthermore, several studies have shown that chronic exposure to NO_2 can increase liver enzymes (ALT, AST, GGT) in the blood, indicating hepatocellular damage due to inflammatory mechanisms and liver metabolic dysfunction (Liu et al., 2021).

Meanwhile, for carbon monoxide (CO), the average concentration in the morning was 3435.75 µg/m³ (SD = 865.91) and increased in the afternoon to 5296.63 µg/m³

(SD = 1214.46). The test results showed a p-value of 0.003, confirming a significant difference between the two measurement times. High CO levels in the afternoon are primarily influenced by increased vehicle volume and limited air circulation in dense urban areas, which tends to trap pollutants in the lower atmosphere (WHO, 2016; Susanto et al., 2020). From a health perspective, CO exposure is highly dangerous because it binds to hemoglobin more strongly than oxygen, reducing the blood's capacity to transport oxygen to body tissues (Prockop & Chichkova, 2007). The resulting chronic hypoxia not only impacts the respiratory and cardiovascular systems but can also lead to liver metabolic disorders, hepatocellular necrosis, and decreased liver detoxification function (Wu et al., 2016; Yang et al., 2019).

Overall, these results indicate that the increase in afternoon concentrations of SO2, NO2, and CO2 is not only driven by anthropogenic factors such as transportation and energy use, but is also influenced by local meteorological conditions such as wind speed, humidity, and temperature inversions, which can exacerbate pollutant accumulation (Baklanov et al., 2016; Lestari & Maulana, 2018). From a public health perspective, exposure to these pollutants not only increases the risk of respiratory and cardiovascular diseases but also has the potential to affect liver function through mechanisms of oxidative stress, hypoxia, and systemic inflammation. This underscores the need for continuous air quality monitoring to minimize long-term impacts on urban public health (Guttikunda & Goel, 2013; WHO, 2016; Liu et al., 2021).

Table 2. Results of comparative analysis of SO2, NO2, and CO2 concentrations at eight sampling points

Parameter	Sampling point	Mean	Std, Deviation	95% Confidence Interval		P value
				Lower Bound	Upper Bound	
SO	Police Post Simpang 4 Polda	51,45	7,85	-19,07	121,97	0,283
	Police Post Simpang 4 Sekip	40,65	3,32	10,79	70,51	
	Police Post Bundaran RS Charitas	54,68	5,83	2,26	107,09	
	Police Post Air Mancur Ampera	45,30	5,37	-2,98	93,58	
	Police Post Simpang 4 Nilakandi	55,80	11,95	-51,57	163,17	
	Police Post Simpang 4 Prameswara	53,35	11,24	-47,66	154,36	
	Police Post Simpang 4 Soekarno Hatta	50,50	5,37	2,22	98,78	
	Police Post Fly Over Jakabaring	38,45	4,03	2,24	74,66	
	Total	48,77	8,37	44,31	53,23	
NO	Police Post Simpang 4 Polda	65,70	9,69	-21,34	152,74	0,891
	Police Post Simpang 4 Sekip	58,48	10,85	-39,05	156,00	
	Police Post Bundaran RS Charitas	62,95	12,02	-45,05	170,95	
	Police Post Air Mancur Ampera	64,28	8,45	-11,64	140,19	
	Police Post Simpang 4 Nilakandi	71,88	13,61	-50,42	194,17	
	Police Post Simpang 4 Prameswara	65,68	8,38	-9,61	140,96	
	Police Post Simpang 4 Soekarno Hatta	64,78	10,22	-27,03	156,58	
	Police Post Fly Over Jakabaring	57,63	7,95	-13,85	129,10	
	Total	63,92	8,69	59,29	68,55	
CO	Police Post Simpang 4 Polda	5726,00	1619,27	-8822,60	20274,60	0,449
	Police Post Simpang 4 Sekip	3435,50	1619,98	-11119,46	17990,46	
	Police Post Bundaran RS Charitas	4581,00	1619,27	-9967,60	19129,60	
	Police Post Air Mancur Ampera	4008,50	809,64	-3265,80	11282,80	
	Police Post Simpang 4 Nilakandi	5726,00	1619,27	-8822,60	20274,60	
	Police Post Simpang 4 Prameswara	4581,00	1619,27	-9967,60	19129,60	
	Police Post Simpang 4 Soekarno Hatta	4008,50	809,64	-3265,80	11282,80	
	Police Post Fly Over Jakabaring	2863,00	810,34	-4417,66	10143,66	
	Total	4366,19	1400,58	3619,87	5112,50	

Based on descriptive analysis of air pollutant concentrations at several measurement points, the average values of sulfur oxide (SO), nitrogen oxide (NO), and carbon monoxide (CO) varied between locations, although the differences were not statistically significant ($p > 0.05$). This indicates that pollutant distribution in urban areas tends to be influenced by relatively homogeneous emission sources, primarily from traffic activity (Rizwan et al., 2018).

For the SO parameter, the lowest average concentration was recorded at the Jakabaring Flyover Police Post, at 38.45 µg/m³, while the highest value was at the Nilakandi Intersection 4 Police Post, at 55.80 µg/m³. This difference can be attributed to traffic density and vehicle volume in the surrounding areas. The Nilakandi area is a busy intersection with high mobility, while the Jakabaring Flyover has a smoother vehicle flow (Kurniawan & Schmidt, 2019). Overall, the average SO2 concentration across all locations was 48.77 µg/m³, with a 95% confidence interval of 44.31–53.23. Statistical tests showed a p-value of 0.283, indicating that the variation in SO2 concentration between locations was not significant, likely due to meteorological factors such as wind speed and relatively uniform atmospheric dispersion at the time of measurement (Baklanov et al., 2016).

For the NO2 parameter, the lowest average concentration was found at the Jakabaring Flyover Police Post (57.63 µg/m³) and the highest at the Nilakandi Simpang 4 Police Post (71.88 µg/m³). These concentration variations are generally influenced by motorized vehicle activity, particularly gasoline- and diesel-powered cars and motorcycles, which are the main sources of NO2 emissions in urban areas (Sharma et al., 2020). The overall mean NO was 63.92 µg/m³, with a 95% confidence interval of 59.29–68.55. A statistical test yielded a p-value of 0.891, indicating no significant difference between measurement points. This indicates that the contribution of NO emissions is relatively even across all observation locations, supported by dense traffic patterns at most of the city's major intersections (Manisalidis et al., 2020).

Meanwhile, for CO, the lowest mean value was found at the Jakabaring Flyover Police Post (2,863.00 µg/m³), while the highest values were found at the Simpang 4 Polda Police Post and the Nilakandi Simpang 4 Police Post (5,726.00 µg/m³). These differences in CO concentrations can be explained by differences in congestion levels and the duration of vehicle idling at each intersection. Locations such as the Polda Intersection and Nilakandi tend to have longer vehicle waiting times, increasing the accumulation of CO emissions due to incomplete fuel combustion (Susanto et al., 2020). Overall, the average CO concentration was 4366.19 µg/m³ with a 95% confidence interval of 3619.87–5112.50. The test results showed a p-value of 0.449, reaffirming the lack of significant differences between locations. This may occur because CO distribution patterns are strongly influenced by local meteorological factors, such as wind direction and speed, which play a role in distributing pollutants throughout the region (Lestari & Maulana, 2018).

Thus, although the analysis results indicate variations in average values between locations, these differences are not statistically significant. This confirms that the main sources of air pollution in urban areas are more influenced by traffic activities which are evenly distributed, while differences between points are more influenced by local variations such as traffic density, intersection design, and meteorological conditions at the time of measurement (Guttikunda & Goel, 2013; WHO, 2016).

CONCULSION

Based on the research results, it can be concluded that (1) The concentrations of air pollutants (SO_2, NO_2, and CO) in Palembang City showed significant differences between morning and afternoon, with higher concentrations recorded in the afternoon. This pattern was mainly influenced by traffic density, fossil fuel consumption, and local meteorological conditions that facilitate pollutant accumulation; (2) From a health perspective, exposure to SO_2, NO_2, and CO has the potential to cause respiratory and cardiovascular disorders, as well as liver dysfunction through mechanisms of oxidative stress, hypoxia, and systemic inflammation; (3) Inter-location analysis revealed variations in average pollutant concentrations, but these differences were not statistically significant ($p > 0.05$). This indicates that pollutant distribution in urban areas tends to be relatively homogeneous because the dominant source of pollution is motor vehicle emissions; (4) Continuous air quality monitoring and effective control of transportation emissions are essential to safeguard public health in urban areas.

RECOMMENDATION

For Future research on air quality at urban transportation nodes should expand beyond SO_2, NO_2, and CO by incorporating additional pollutants such as particulate matter ($PM_{2.5}$ and PM_{10}), ozone (O_3), and volatile organic compounds (VOCs) to provide a more comprehensive picture of urban air pollution. Long-term and seasonal monitoring is also recommended to capture temporal variations and better understand pollutant dynamics under different weather patterns. Furthermore, integrating advanced modeling approaches, remote sensing, and Geographic Information System (GIS)-based spatial analysis can help identify pollution hotspots and predict dispersion patterns. Finally, studies linking measured pollutant concentrations with epidemiological data on respiratory, cardiovascular, and other health outcomes in Palembang would strengthen the evidence base for policy-making and urban air quality management.

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