VOL. 20, NO. 1, JANUARY 2025 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

ANALYSIS OF THE IMPACT OF VEHICLE DENSITY ON CARBON MONOXIDE CONCENTRATION IN THE VICINITY OF THE TELLO DIESEL POWER PLANT IN MAKASSAR, INDONESIA

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ABSTRACT

The mobilization of individuals from one location to another using transportation has become increasingly essential for human life. However, the transportation sector is the largest contributor to emissions, primarily due to the rising use of motor vehicles each year. This study aims to assess air quality about vehicle density by utilizing a gas sampling device known as a midget impinger to collect carbon monoxide (CO) samples. The air samples were subsequently analyzed in the laboratory using a non-dispersive infrared CO detector. Air sampling was conducted concurrently with data collection on the number of vehicles at three designated sampling locations: Urip Sumoharjo Street west of the Diesel Power Plant (A), Leimena Street to the north (B), and Leimena Street to the east (C), with a one-hour interval for data collection. The findings indicate that the concentration of CO gas at the three research locations surrounding the Tello Diesel Power Plant in Makassar remains within safe limits, according to the National Ambient Air Quality Standards. The highest average vehicle density was observed on Urip Sumoharjo Street, while the lowest average vehicle count was noted on the eastern section of Leimena Street near the Tello Diesel Power Plant. Furthermore, the results reveal a significant relationship between vehicle density and CO concentration in the vicinity of the Tello Power Plant, with an average coefficient of determination for CO of 90.3%.

Keywords: vehicle density, air quality, impinger, CO.

Manuscript Received 13 October 2024; Revised 3 January 2025; Published 10 February 2025

INTRODUCTION

The mobilization of individuals from one place to another using transportation has become increasingly essential for human life. However, the transportation sector is the largest contributor to exhaust emissions, primarily due to a significant increase in the use of motor vehicles. [1], [2]. Therefore, with the rise in the trend of motor vehicle growth, it is the responsibility of each individual to use motor vehicles more judiciously. Additionally, the involvement of relevant agencies, such as the Ministry of Industry and Trade, is essential to enforce and tighten policies regarding automotive production. [3], [4]

The use of fossil fuels in the engines of motor vehicles is one of the primary sources of carbon monoxide emissions. Approximately 75% of the carbon monoxide released into the atmosphere originates from the transportation sector. [5], [6]. Urban areas are increasingly susceptible to rising pollutant levels. The higher levels of activity in cities compared to rural areas, It has been reported that dense urban areas with developments impact the environment [7], [8], particularly in terms of transportation and industry-both significant contributors to pollution-are critical factors in this trend. Makassar is one of Indonesia's four main growth centers, along with other cities. Covering an area of 175.77 km² and with a population exceeding 1.5 million, Makassar ranks as the seventh largest city in Indonesia. [9], [10], [11]. According to data from the Central Bureau of Statistics, the number of motor vehicles recorded includes the following: motorcycles of various brands total 115,023,039 units, passenger cars total 15,797,746 units, buses total 233,261 units, and freight vehicles total 5,083,405 units.

Emissions are substances, energy, and/or other components produced by an activity that are released into or introduced into the ambient air, with or without the potential to act as pollutants. Transportation emissions refer to the release of exhaust gases originating from the transportation sector. These exhaust gases come from motor vehicles and are emitted or released into the ambient air [12].

Motor vehicle exhaust emissions are measured in grams per vehicle per kilometer of travel and are influenced by several factors such as vehicle type, vehicle age, temperature thresholds, and altitude. Vehicles of varying ages and fuel types will produce different emission levels. Emission sources from the fuel combustion process produce exhaust gases that theoretically contain elements such as H2O (water), HC (hydrocarbons), CO (carbon monoxide), CO2 (carbon dioxide), NOx (nitrogen oxides), NO2 (nitrogen dioxide), SO2 (sulfur dioxide), and particulate matter, including lead (Pb) [13], [14], [15], [16]. Motor vehicles can also increase particulate matter levels, originating from road surfaces, tire components, and brake systems. [17].

 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

Carbon monoxide is a gas naturally present in the environment, produced as the final result of incomplete combustion. It is characterized by being tasteless, colorless, and odorless. The concentration of carbon monoxide in the air is significantly influenced by other factors such as emission rates, dispersion rates, and the removal of CO from the air. Dispersion rates, in turn, are affected by several meteorological factors, which include air turbulence, atmospheric stability, and wind direction and speed. In urban areas, meteorological factors lead to limited air movement due to the high density of vehicles, increasing the potential for carbon monoxide accumulation (13).

This study aims to explore the relationship between vehicle density and CO concentration around the Tello Diesel Power Plant (PLTD) with the hope of providing useful information for air quality management and transportation planning in the city of Makassar. The results of this study are expected to offer recommendations to authorities in efforts to control air pollution and protect public health.

2. MATERIALS AND METHODS

2.1 Sampling Site Description

The Province of South Sulawesi is one of the 34 provinces in Indonesia, with Makassar City serving as its capital. Geographically, Makassar City is bordered to the north by Maros Regency, to the south by Gowa Regency, to the west by the Makassar Strait, and to the east by Maros Regency. The total area of Makassar City is 175.77 square kilometers, comprising 15 districts. It is one of Indonesia's most densely populated cities with significant urban activity and is one of the fastest-growing cities outside of Java. As of 2022, the population of Makassar City was 1, 598, 154 people, consisting of 756,951 males and 841,203 females. Compared to 2021, the population growth rate of Makassar City was 1.29%, with male population growth at 1.43% and female population growth at 1.36%. The number of industries in Makassar is 145, including sectors such as basic metals, fabricated metal products, chemicals and chemical products, food and beverages, textiles and garments, wood and wood products, and others. The number of vehicles operating in Makassar by October 2022 reached 1,563,608 units, including 1,156,759 motorcycles, 213,985 passenger cars, 74,603 freight vehicles, 17,306 buses, and 403 special vehicles. The rapid urbanization and industrialization in Makassar City have led to traffic congestion on nearly all roads, contributing to unhealthy air conditions, which may affect the city's residents. In this study, the research was conducted around the Tello Diesel Power Plant in Makassar City. The sampling points for measuring ambient air carbon monoxide were taken from Urip Sumoharjo Street (A), Leimena Street (B), and Leimena Street (C). These sampling locations are illustrated in Figure-1. The selected areas are two heavily congested routes with continuous traffic jams.

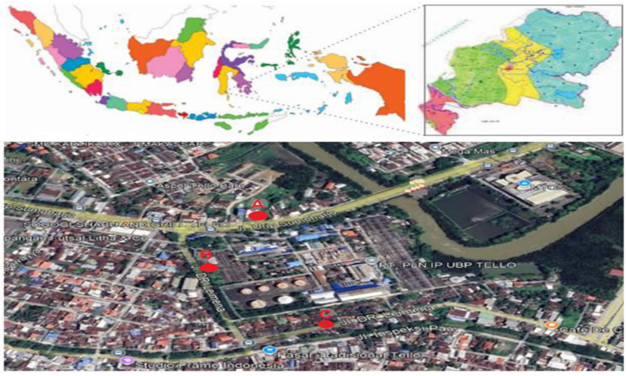

Figure-1. The sampling site is at Tello, Makassar City.

2.2 Methods

Carbon monoxide sampling was conducted twice a week over three months, from June to September 2024, around the Tello Diesel Power Plant in Makassar City. On sampling days, air samples were collected three times a day: in the morning (07:30–08:30 WITA), midday (11:30–12:30), and in the afternoon (15:30–16:30). The air samples were collected using Tedlar bags and a vacuum pump and the carbon monoxide samples were then analyzed using the Non-Dispersive Infrared (NDIR) method. The entire sampling procedure and the final concentration analysis followed the Indonesian National Standard (SNI) for measuring CO levels in ambient air [19]. Additionally, the number of vehicles passing the road sections at the sampling locations was measured simultaneously on-site. The relationship between CO concentration and vehicle density was analyzed using simple linear regression statistics, processed with SPSS version 15

3. RESULTS AND DISCUSSIONS

During the study period, the average concentration of Carbon Monoxide (CO) in the morning at Urip Sumoharjo Street (A) was 470.467 µg/m³, with the highest concentration recorded at 671.30 µg/m³. The average CO concentrations for midday and afternoon air sampling were 478.15 µg/m³ and 618.61 µg/m³, respectively. Meanwhile, at the sampling location on Leimena Street (C), the average CO concentration in the morning was 355.45 µg/m³, with midday and afternoon averages of 421.07 µg/m³ and 610.97 µg/m³, respectively. The average CO concentrations during the sampling at three locations are presented in Table-1.

Table-1. Descriptive statistics of carbon monoxide concentration during sampling.

Monitoring Site	Sample taking time	Mean	Standard Deviation	Range
Sumoharjo Street (A)	Morning (µg/m³)	470.67	83.34	312.32-875.36
	Midday (µg/m³)	478.15	57.43	415.34-762.25
	Afternoon (µg/m³)	618.61	59.79	555.26-755.42
Leimena Street (B)	Morning (µg/m³)	471.30	68.80	335.26-847.14
	Midday (µg/m³)	389.21	64.12	324.34-757.13
	Afternoon (µg/m³)	642.40	48.18	537.18-743.27
Leimena Street (C)	Morning (µg/m³)	355.45	77.80	321.28-832.39
	Midday (µg/m³)	421.07	62.95	355.12-755.12
	Afternoon (µg/m³)	610.97	44.80	474.28-694.29

Based on the data in Table-1, the CO concentrations at all sampling locations remain within the safe limit of 30,000 µg/m³, as per the Air Quality Standard stipulated by the Government Regulation of the Republic of Indonesia No. 22 of 2021. From the study of carbon monoxide concentration measurements across various times and locations, as shown in the table, the highest average concentration across the three sampling points occurred in the morning, specifically at monitoring site (B) on Leimena Street, with an average concentration of 642.40 µg/m³. Meanwhile, the lowest average concentration was recorded in the morning at monitoring site (C) on Leimena Street, with an average concentration of 355.47 µg/m³.

3.1 The Relationship between CO Concentration and Vehicle Density

a) Urip Sumoharjo Street (Sampling Point A /West Side of PLTD)

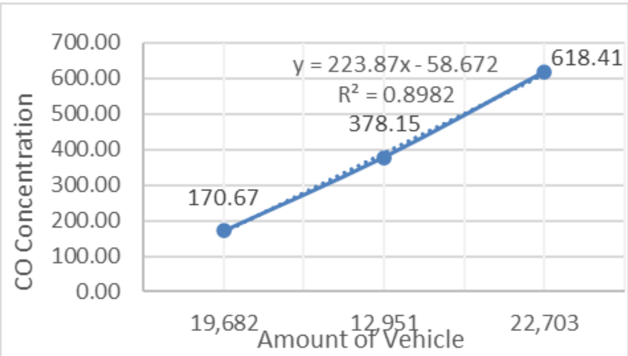

Figure-2. The relationship between vehicle count and co concentration on Urip Sumoharjo Street (A).

Based on the analysis results depicted in the graph for Urip Sumoharjo Street, the average vehicle count in the morning (07:30-08:30) was 19,682 units/day, with a CO concentration of 170.67 µg/m³. During the midday period (13:30–14:30), the vehicle count increased to 12,951 units/day, resulting in a CO concentration of 378.15 µg/m³. In the afternoon (17:30-18:30), the vehicle count decreased to 22,703 units/day, with a CO concentration of 618.41 µg/m³. The simple linear regression equation representing the relationship between the independent variable (X), which is the number of vehicles, and the dependent variable (Y), which is the CO concentration, is given by the equation Y = 223.87X - 58.672. The coefficient of determination (R^2) indicates that the number of vehicles significantly affects CO concentration, with an R^2 value of 0.8982. This demonstrates that the vehicle count explains 89.8% of the variance in CO concentration, while the remaining 10.2% is influenced by other variables not examined in the study, It has been reported in other studies that there is a relationship between vehicle density and pollution levels in Makassar [1], (16).

b) Doctor Leimena Street (Sampling Point B/North Side of the Tello Diesel Power Plant)

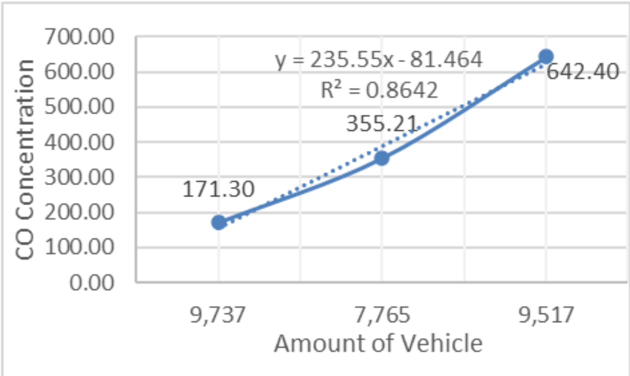

Figure-3. The relationship between vehicle count and co concentration on Doctor Leimena Street (B).

Based on the analysis results for Doctor Leimena Street (II), the average vehicle count in the morning (07:30-08:30) was 9,737 units/day, with a CO concentration of 171.30 µg/m³. At midday (13:30–14:30), the vehicle count increased to 7,765 units/day, with a CO concentration of 355.21 µg/m³. In the afternoon (17:30–18:30), the vehicle count decreased to 9,517 units/day, with a CO concentration of 642.40 µg/m³. The simple linear regression equation for the relationship between the independent variable (X), which is the number of vehicles, and the dependent variable (Y), which is the CO concentration, is Y = 235.55X - 81.464. The coefficient of determination (R^2) shows that vehicle count significantly influences CO concentration, with an R^2 value of 0.8642. This indicates that the vehicle count explains 86.4% of the variance in CO concentration, while the remaining 13.6% is influenced by other factors not examined in the study. This condition is almost the same as several research results conducted during the COVID-19 pandemic, which found that air quality was better than before the COVID-19 pandemic due to restrictions on human activities, including the use of transportation [3], [4], [5].

c. Dokter Leimena Street (Sampling Point C / East Side of the Tello Diesel Power Plant).

VOL. 20, NO. 1, JANUARY 2025 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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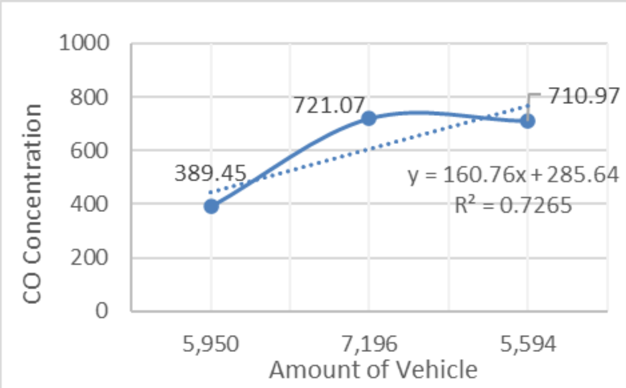

Figure-4. The relationship between vehicle count and co concentration on Doctor Leimena Street (C).

Based on the analysis results for Doctor Leimena Street (III), the average vehicle count in the morning (07:30–08:30) was 5,950 units/day, with a CO concentration of 389.45 µg/m³. At midday (13:30-14:30), the vehicle count increased to 7,196 units/day, with a CO concentration of 721.07 µg/m³. In the afternoon (17:30-18:30), the vehicle count decreased to 5,594 units/day, and the SO2 concentration was recorded at 710.97 µg/m³. The simple linear regression equation for the relationship between the independent variable (X), which is the number of vehicles, and the dependent variable (Y), which is the CO concentration, is $Y = 160.76X + 285.64$. The coefficient of determination (R^2) indicates that vehicle count influences CO concentration, with an R^2 value of 0.7265. This shows that 72.7% of the variation in CO concentration is explained by vehicle count, while the remaining 27.3% is influenced by other factors not examined in the study. The influence of vehicle density is very clear in several cities during the COVID-19 pandemic, where human activity during the pandemic is limited.[6], [7], [8], [9]

4. CONCLUSIONS

The vehicle count at the three sampling locations on roads surrounding the Tello Diesel Power Plant in Makassar varies by time of day. In the morning, the average vehicle density is approximately 11,789 units/day. During the midday, it averages around 9,304 units/day, while in the afternoon, it increases to about 12,604 units/day. The highest average vehicle density was observed on Urip Sumoharjo Street (A), and the lowest on Leimena Street (C), located east of the power plant. The carbon monoxide (CO) levels ranged from an average of 355.45 µg/Nm³ to 642.40 µg/Nm³. The highest average CO concentration was recorded on Leimena Street (B), and the lowest on Leimena Street (C). The study results indicate that all gas concentrations on roads surrounding the Tello Diesel Power Plant remain within the safe limits as per the National Ambient Air Quality Standards. Furthermore, the study shows a significant relationship between vehicle density and CO concentration. Across the three sampling locations, the average coefficient of determination (R^2) for CO was 90.3%, with the remaining 9.7% influenced by other variables not examined in the study.

ACKNOWLEDGMENTS

This research was conducted with the support of basic research grants from high education institutions from the Directorate of Research and Community Service (DRPM), Ministry of Education and Culture of the Republic of Indonesia through the Institute for Research and Resource Development (LP2S) of the Muslim University of Indonesia. Therefore, we take this opportunity to express our deepest appreciation and gratitude.

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