Asian Journal of Applied Research for Community Development and Empowerment. Vol 10 (2026), No.2

e-ISSN 2581-0405

Asian Journal of Applied Research for Community Development and Empowerment

Journal home page: http://ajarcde-safe-network.org ISSN 2581-0405

Analysis of Carbon Monoxide (CO) Dispersion Using AERMOD Modeling Along the Raya Tandes – Raya Manukan Kulon Corridor, Surabaya

Abrar Athaya Yuris Erbinavydho[1], *Okik Hendriyanto Cahyonugroho*[2*]

[1 123] *Environmental Engineering Department, Faculty of Engineering and Sains, UPN "Veteran" Jawa Timur, Surabaya.*

ARTICLE INFO

Article History
Received: 11 May 2026
Final Revision:17 June 2026
Accepted: 19 June 2026
Online Publication: 25 June 2026

KEYWORDS

AERMOD, Carbon Monoxide (CO), Air Dispersion, Air Quality, Traffic Emissions, RMSPE

CORRESPONDING AUTHOR

*E-mail: okikhc@upnjatim.ac.id

A B S T R A C T

The increase in motor vehicle activity along Tandes Street to Raya Manukan Kulon Street in Surabaya has the potential to degrade air quality due to carbon monoxide (CO) emissions. This study analysed the dispersion of CO using the AERMOD modelling system and direct field measurements at several observation points. The modeling results showed a maximum CO concentration of 14,972 µg/m³, while field measurements reached 16,749 µg/m³. Model validation using the Root Mean Square Percent Error (RMSPE) method produced a value of 19.23%, indicating that the AERMOD model has good accuracy in representing actual field conditions. The differences between simulation and observation results were influenced by meteorological conditions, traffic variations, and input data uncertainty. Overall, traffic activity significantly affects CO concentrations in the study area, although these concentrations remain within applicable air quality standards.

Contribution to Sustainable Development Goals (SDGs):
SDG 3: Good Health and Well Being
SDG 11: Sustainable Cities and Communities
SDG 13: Climate Action

1. INTRODUCTION

1.1. *Research Background*

The growing intensity of community activities has increased traffic volume on urban roads. The transportation sector significantly contributes to the deterioration of air quality in surrounding areas. In Surabaya, several roads frequently experience heavy traffic congestion, including Raya Tandes Street and Raya Manukan Kulon Street. These roads function as important urban access routes used by residents for their daily activities, resulting in high traffic density. In addition, the number of motor vehicles in Surabaya City continues to rise, further contributing to traffic congestion and air pollution problems.

The rising level of traffic congestion, especially on Raya Tandes street, is expected to increase the concentration of air pollutants in the surrounding area. Emissions produced by motor vehicles consist of various air contaminants, including nitrogen oxides (NOx), sulfur dioxide (SO_2), carbon dioxide (CO_2), hydrocarbons (HC), nitrogen oxides (NOx), carbon monoxide (CO) and lead (Pb) [1]. Among the various pollutants produced by motor vehicles, carbon monoxide (CO) has one of the highest emission concentrations, accounting for nearly 75% of the total pollutants released into the ambient atmosphere. The air quality in roadside environments is strongly affected by human activities and traffic emissions. Consequently, continuous monitoring of pollutant concentrations in the surrounding atmosphere is necessary to assess environmental air quality conditions. An alternative approach for evaluating air quality is the use of air dispersion modeling through the AERMOD View 8.9.0 software. One advantage of AERMOD View 8.9.0 is its capability to model pollutant dispersion from multiple emission source categories, including line, point, area source, and volume, in a single simulation process. [2]. In addition, AERMOD software is capable of estimating maximum pollutant concentrations for different averaging times, such as hourly, 3-hourly, 8-hourly, daily, monthly, and annual periods. To obtain reliable and accurate modeling results, the performance of the AERMOD model needs to be assessed through a validation process by comparing the predicted outputs with actual air quality measurement data collected in the field [3]. The model performance was assessed through a validation analysis using the root mean square percent error. Previous studies mainly focused on industrial emission sources, while studies have evaluated traffic related carbon monoxide (CO) dispersion using AERMOD in densely populated urban corridors in Surabaya.

1.2. Literature Review

1.2.1. Carbon Monoxide (CO)

Carbon monoxide (CO) is a gaseous pollutant that has no color, odor, or taste. At temperatures below −192°C, this gas can change into a liquid state. Most carbon monoxide (CO) emissions originate from the combustion of fossil fuels in the presence of air and are generally emitted into the atmosphere through vehicle exhaust and other emission sources [4]. The level of carbon monoxide (CO) concentration in the air is influenced by various factors, including emission intensity, pollutant dispersion, and the atmospheric removal process of carbon monoxide (CO). Pollutant dispersion is closely related to meteorological conditions, such as atmospheric stability, air turbulence, wind speed, and wind direction. In urban environments, air circulation tends to be restricted because of heavy traffic density and continuous vehicle movement. Consequently, these conditions can increase the likelihood of carbon monoxide accumulation in the atmosphere [5].

1.2.2. Emission Rate Carbon Monoxide (CO)

Carbon monoxide (CO) is a major air pollutant produced by the incomplete combustion of fuel from motor vehicles. The concentration of CO in roadside ambient air is highly dependent on the magnitude of vehicle emission rates along a particular roadway segment. Consequently, the estimation of emission rates is necessary to provide input data for atmospheric dispersion modeling using applications such as AERMOD View 8.9.0. In the transportation sector, pollutant emissions are generated by motor vehicles operating along roadway corridors and categoring as line emission sources in air dispersion modelling. Emission rate refers to the amount of pollutants released from an emission source into the atmosphere within a specific period of time. The magnitude of the emission rate is strongly influenced by traffic volume, vehicle type, and the emission factor associated with each vehicle category [6]. The calculation of emission rates along a roadway segment can be determined using the following equation:

$$E = \sum (Vi \ x \ EFi)$$

The formula used in the equation are defined as follows, E represents the emission rate (g/hour), Vi denotes the traffic volume of vehicle type (vehicles/hour), and Efi refers to the emission factor of vehicle type (g/km).

1.2.3. Software AERMOD 8.9.0

AERMOD is recognized as a Gaussian plume dispersion model developed by American Meteorological Society and Environmental Protection Agency Model developed under steady state atmospheric conditions, designed to simulate the transport of pollutant emissions through wind movement. Developed as an improvement over the ISCST3 model, AERMOD incorporates atmospheric boundary layer concepts to provide more accurate dispersion predictions. The model is applicable to both simple and complex terrains and can be used in either rural or urban areas [7]. Gaussian models are commonly applied in atmospheric dispersion studies, especially for regulatory compliance and air quality assessment purposes. These models use the Gaussian distribution to represent the dispersion of pollutant plumes in the vertical and lateral dimensions under stable atmospheric conditions. Generally, Gaussian dispersion models account for pollutant transport through advection and diffusion processes. Recent advancements in these models have further integrated physical processes, including pollutant deposition and rapid chemical transformations, to improve simulation accuracy [8]. The AERMOD modeling system is composed of three main components: the core dispersion model (AERMOD), the meteorological processor (AERMET), and the terrain processor (AERMAP). AERMET functions to process meteorological information, such as wind speed, wind direction, temperature, and cloud cover conditions. Furthermore, it also incorporates surface characteristic data, including albedo, Bowen ratio, and surface roughness. The collected data are then processed to calculate convective velocity scale, including friction velocity, temperature scale factors, Monin Obukhov length, surface heat flux, planetary boundary layer, and mixing height [9]. AERMAP functions as a terrain data processor that analyzes the relationship between topographical conditions, receptor locations, and emission source layouts. AERMAP is used to process terrain data related to receptor and emission source locations for input into the AERMOD model [10].

1.2.4. Root Mean Square Percent Error

The model validation process was performed by comparing carbon monoxide (CO) concentrations obtained from ambient air field observations with the predicted concentrations generated by the AERMOD simulation model. To assess the magnitude and characteristics of the model error, the validation analysis employed root mean square percent error [11]. RMSPE is a statistical for evaluating the mean percentage deviation between measured data and simulated results, which can be determined using the following equation :

$$RMSPE = \sqrt{\frac{1}{n}\left[\sum\nolimits_{n=1}^{n} (\frac{St - At}{At})^2\right] x \ 100}$$

The formula used in the equation are defined as follows, St represents the concentration value predicted by the simulation model at time (t), At denotes the observed or actual concentration value at time (t), n refers to the total number of observation or measurement points, where (t = 1, 2,..., n). The accuracy of a model is considered acceptable when the Root Mean Square Percent Error (RMSPE) value is below 25%. Furthermore, a model is considered to have good performance if its RMSPE is less than 10%.

1.3. Research Objective

This study aims to analyze the accuracy of the dispersion pattern of carbon monoxide (CO) pollutant emissions against actual monitoring by applying the root mean square percent error method.

2. MATERIALS AND METHODS

This research was carried out in March 2026 along the Raya Tandes–Raya Manukan Kulon street corridor in Surabaya City. The study location was selected due to the high level of traffic density on this urban roadway. The corridor is characterized by intense traffic activity dominated by both light-duty and heavy-duty vehicles and frequently experiences congestion, especially during peak traffic periods. The study applied a combination of direct field sampling and air dispersion modeling using the AERMOD model. Five sampling points were determined for data collection. Actual field measurements were conducted using an anemometer and an Aeroqual Series 500 device. Sampling was performed four times over a two-week period, specifically on Monday mornings and Saturday mornings each week. Each ambient air measurement was conducted for one hour. The AERMOD simulation utilized input data consisting of wind speed, wind direction, and vehicle emission estimates. To evaluate reliability of the modeling results, the predicted concentrations generated by AERMOD were compared with the actual field measurement data by applying the root mean square percent error method..

Fig. 1. Sampling Point

Fig. 2. Sampling Carbon Monoxide

3. RESULT AND DISCUSSION

3.1. Field Measurement of Carbon Monoxide (CO)

Carbon monoxide (CO) sampling was conducted in accordance with Government Regulation of the Republic of Indonesia no. 22 of 2021 concerning Environmental Protection and Management [12]. Measurements were performed over a one hour sampling period using the Aeroqual Series 500 instrument at several monitoring points along the Raya Tandes–Raya Manukan Kulon street corridor. The sampling was carried out under actual traffic conditions to illustrate the effect of traffic related emissions on air quality around roadside environments. Additionally, meteorological factors including wind characteristics were further monitored to assist in analyzing pollutant dispersion characteristics. The following section presents the results of carbon monoxide (CO) concentration measurements obtained during the study.

Table. 1. Concentration Carbon Monoxide Test Result

Date	Sampling Point	Carbon Monoxide Test Result ($\mu g/m^3$)	Goverment Regulation ($\mu g/m^3$)
Monday, 2 March 2026	1	7802	10000
	2	16794	10000
	3	5549	10000
	4	6587	10000
	5	6382	10000
Saturday, 7 March 2026	1	7081	10000
	2	7175	10000
	3	4982	10000
	4	7610	10000
	5	6993	10000
Monday, 9 March 2026	1	7524	10000
	2	14879	10000
	3	5025	10000
	4	6413	10000
	5	7856	10000
Saturday, 14 March 2026	1	4247	10000
	2	9128	10000
	3	4716	10000
	4	7544	10000
	5	6422	10000

In accordance with government regulation of the republic of Indonesia no. 22 of 2021 concerning environmental protection and management, the measurement was conducted over a one-hour duration with a permissible limit of 10,000 μg/m³. From the four sampling days carried out at five different locations, the measured carbon monoxide (CO) concentrations ranged from 4,247 μg/m³ to 16,794 μg/m³. Overall, the average concentration values still complied with the applicable air quality standards. However, several sampling points exceeded the allowable limit. On Monday, March 2 2026, at point 2 the measured carbon monoxide (CO) concentration reached 16,794 μg/m³. Similarly, on Monday, March 9 2026, at the same location, the CO concentration was recorded at 14,879 μg/m³. The higher concentration observed at point 2 was presumably associated with the high traffic intensity in the surrounding area, particularly because the sampling was performed during peak morning traffic periods. Furthermore, carbon monoxide (CO) level measured on Mondays were generally higher as a result of increased public activities, such as commuting to schools and workplaces, and other transportation that significantly increased vehicle density along the Raya Tandes-Raya Manukan Kulon street.

 https://doi.org/10.29165/ajarcde.v10i2.1036

3.2. AERMOD Modeling

The dispersion analysis of carbon monoxide (CO) emissions was performed using the AERMOD application with a 1 hour averaging period in accordance with the applicable regulatory standards. Several input parameters were utilized in the simulation, including vehicle emission data collected along the Raya Tandes–Raya Manukan Kulon street corridor, as well as meteorological factors including wind speed and direction.

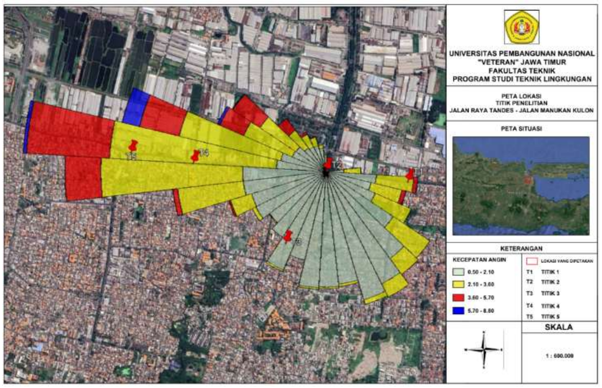

Fig. 3. Wind Dispersion

The wind dispersion map from January 2025 to December 2025 shows that pollutant dispersion was primarily influenced by wind direction and wind speed throughout the observation period. The dominant dispersion pattern moved toward the western and southwestern areas from the emission source along the Jalan Raya Tandes–Jalan Raya Manukan Kulon corridor, indicating that the prevailing wind generally flowed from east to west. The dispersion simulation was conducted within a study area of 2 × 1 km using the AERMOD modelling system. The resulting spatial distribution of carbon monoxide (CO) concentrations is presented in Figure 4.

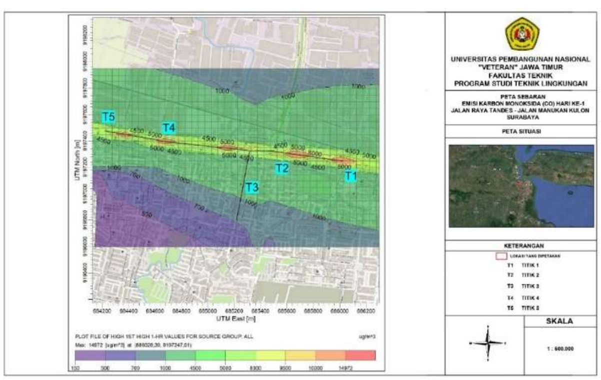

Fig. 4. First Simulation of Carbon Monoxide Dispersion

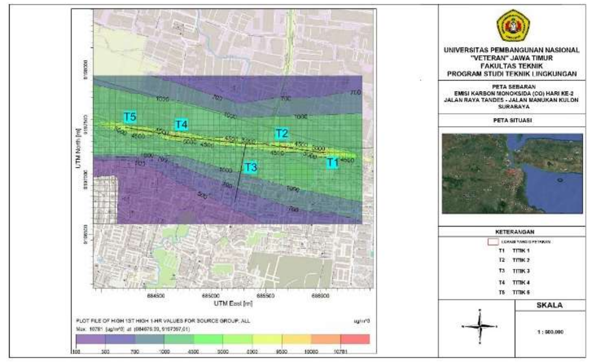

Fig. 5. Second Simulation of Carbon Monoxide Dispersion

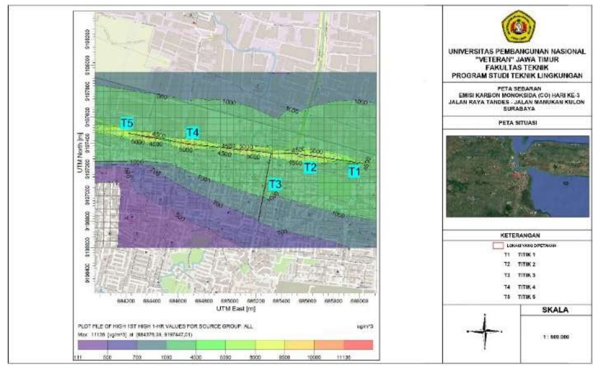

Fig. 6. Third Simulation of Carbon Monoxide Dispersion

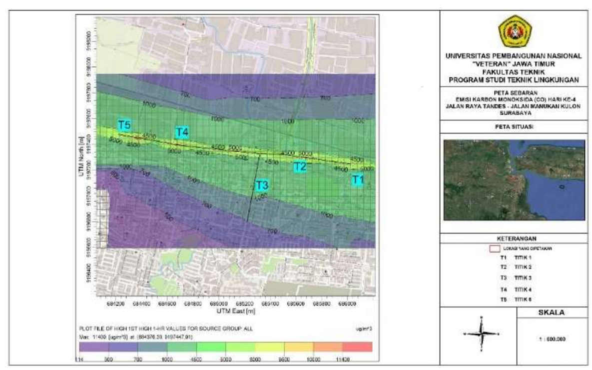

Fig. 7. Fourth Simulation of Carbon Monoxide Dispersion

According to the simulated carbon monoxide (CO) dispersion map analysis, pollutant concentrations were distributed in various directions across the study area. Higher concentrations were primarily concentrated along the roadway corridor, particularly in several road segments experiencing heavy traffic accumulation on Raya Tandes-Raya Manukan Kulon street. In contrast, the pollutant concentration gradually decreased as the distance from the highway emission sources increased. The simulation was conducted four times at five different sampling locations using a one-hour averaging period. The predicted CO concentrations ranged from 108 μg/m³ to 14,972 μg/m³. According to the government regulation of the republic of Indonesia no. 22 of 2021, the permissible limit for a one-hour exposure period is 10,000 μg/m³. Overall, the average concentration values remained within the allowable standard limits, although several locations showed relatively high concentration levels.

3.3. Root Mean Square Percent Error (RMSPE)

The validation of the modeling results was conducted by applying root mean square percent error (RMSPE) method to evaluate the accuracy and consistency between the carbon monoxide (CO) concentrations predicted by the AERMOD model and the actual concentrations obtained from direct field measurements. The RMSPE analysis was applied to assess the magnitude of error or deviation between the simulated values and the observed monitoring data. This validation procedure involved comparing the modeled CO concentration values with the corresponding actual measurement results collected at the same sampling points within the study area. The following table presents the results of root mean square validation analysis.

Table. 2. Root Mean Square Percent Error Validation

Date	**Carbon Monoxide Test Result** $(\mu g/m^3)$	**Carbon Monoxide Simulation** $(\mu g/m^3)$	**Validation RMSPE (%)**
Monday, 2 March 2026	7802	8000	19,23
	16794	14500	
	5549	4500	
	6587	8000	
	6382	8000	
Saturday, 7 March 2026	7081	7500	
	7175	8000	
	4982	4500	
	7610	7000	
	6993	5000	
Monday, 9 March 2026	7524	7000	
	14879	10500	
	5025	4500	
	6413	8500	
	7856	8500	
Saturday, 14 March 2026	4247	6000	
	9128	8000	
	4716	4500	
	7544	8000	
	6422	8000	

The results of the Root Mean Square Percent Error (RMSPE) validation analysis produced a value of 19.23%. This indicates that the discrepancy between the carbon monoxide (CO) concentrations predicted by the AERMOD simulation and the actual field measurement data is still within the acceptable range, since the RMSPE value is below 25%. Variations between the modeled and observed results were likely influenced by several dynamic factors, particularly traffic volume and meteorological factors including wind speed and direction.

4. CONCLUSION

The findings derived from the present study revealed that the concentrations of carbon monoxide along Raya Tandes–Raya Manukan Kulon street corridor varied across sampling locations and observation periods. The highest measured concentration was 16,794 $\mu g/m^3$, exceeding the applicable ambient air quality regulation of 10,000 $\mu g/m^3$ for a 1-hour measurement period, while the lowest was 4,247 $\mu g/m^3$. The AERMOD simulation demonstrated that CO pollutant dispersion spread in various directions, with higher concentrations concentrated near roadway segments experiencing heavy traffic density. Pollutant levels gradually decreased as the distance from the emission source increased. The highest simulated concentration reached 14,972 $\mu g/m^3$, whereas the lowest was approximately 4,500 $\mu g/m^3$. The RMSPE validation analysis produced a value of 19.23%, indicating that the difference between the modeled and observed data was still within the acceptable category (<25%). Therefore, the AERMOD model is considered reliable for representing CO dispersion patterns in the study area.

REFERENCE

[1] Jansen, F., Sengkey, S, l., & Wallah, S.E. (2011). Tingkat Pencemaran Udara CO Akibat Lalu Lintas Dengan Model Prediksi Polusi Udara Skala Mikro. *Jurnal Ilmiah Media Engineering. 1*(2).

[2] Demirarslan, K, O., Cetin, S., and Karademir, A. (2017), Evaluation Of Three Pollutant Dispersion Models For The Environmental Assessment Of A District In Kocaeli, Turkey, Global NEST Journal, 19.

[3] Rouhi, M., Moradi, H., and Ghorbani, M. (2013), Application of the AERMsOD Modelling System For Air Pollution Dispersion In The South Pars oilfield, Center for Natural Resources and Environment, Iran.

[4] Wardhana, W, A. (2004), Dampak Pencemaran Lingkungan, Penerbit Andi : Yogyakarta.

[5] Prabowo, K. & Muslim, B. (2018). Modul Penyehatan Udara. Bahan Ajar Kesehatan Lingkungan. Jakarta: Badan Pengembangan dan Pemberdayaan Sumber Daya Manusia Kesehatan (BPPSDM), Kementerian Kesehatan RI.

[6] Amsori, M. D, et al. (2024). Analysis Of Carbon Monoxide On Transportation Along The Eastern Crossroad Of Jambi. Presipitasi, 21(2), 527–542. https://doi.org/10.14710/presipitasi.v21i2.62183

[7] Ajayi, O. O., & Ngene, B. U. (2021). Plume Model : A Simple Approach to Air Quality Control. IOP Conference Series : Material Science and Engineering, 1036(1).

[8] Gurjar, B. R., Molina, L. T., & Ojha, C. S. (2010). Air Pollution: Health and Environment Impacts. Boca Raton, FL, CRC.

[9] Cimorelli, A. J., Perry, S. G., Venkatram, A., Weil, J. C., Paine, R. J., & Wilson, R. B. (2005). AERMOD : A Dispersion Model for Industrial Source Applications Part I : General Model Formulation and Boundary Layer Characterization. Journal of Applied Meteorology 44(5), 682 - 693.

[10] Seangkiatiyuth, K., Surapipith, V., & Tantrakarnapa, K. &. (2011). Application of the AERMOD Modeling System for Environmental Impact Assesment of NO2 Emissions from A Cement Complex. *Journal of Environmental Sciences 23(6)*, 931 - 940.

[11] Botcharev, A. (2018). Performance Metrics (error measures) in Machine Learning Regression, Forecasting and Prognostics: Property and Typology. airxiv preprint.

[12] Pemerintah Republik Indonesia, 2021. Peraturan Pemerintah Republik Indonesia Nomor 22 Tahun 2021 tentang Penyelenggaraan Perlindungan dan Pengelolaan Lingkungan Hidup. Jakarta: Pemerintah Republik Indonesia.

 https://doi.org/10.29165/ajarcde.v10i2.1036