

## Risk of Carbon Monoxide (CO) Exposure to Street Vendors in Bandar Lampung City

Azzahra Tazkia Cartama<sup>1</sup>, Prayudhy Yushananta<sup>2\*</sup>

<sup>1</sup> Environmental Sanitation Program, Department of Environmental Health, Politeknik Kesehatan Tanjung Karang, Lampung, Indonesia.

<sup>2</sup> Department of Environmental Health, Politeknik Kesehatan Tanjung Karang, Lampung, Indonesia.

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### ABSTRACT

High motor vehicle activity can be harmful to health. However, no research has specifically analyzed the risk of carbon monoxide (CO) exposure among street vendors in Bandar Lampung. The study aims to analyze the health risks associated with CO exposure among street vendors in Bandar Lampung City. The study used a case study design, employing an Environmental Health Risk Analysis (EHRA) approach, with 34 street vendors in Teuku Umar Street, Bandar Lampung City. The study was conducted from April to May 2025. Measurements of CO concentration and vehicle counts were conducted at three points using the Non-Dispersive Infrared (NDIR) method for 7 days, with 3 replications (morning, afternoon, and evening). So that 63 data points were obtained (N = 63). Exposure analysis was conducted on 34 traders purposively selected at each sample point. Furthermore, the data was analyzed to obtain a risk value (RQ). The study results found that the average CO concentration was  $6721 \mu\text{g}/\text{m}^3$  ( $1340 - 11112 \mu\text{g}/\text{m}^3$ ). The average number of vehicles was 2,814 units (93 - 6,324 units). Statistical analysis showed a very strong relationship between the number of vehicles and ambient CO levels ( $r = 0.807$ ;  $P = 0.001$ ). The risk analysis found that all respondents had RQ values  $> 1$ , indicating that CO exposure is associated with health risks. The study found that all respondents were at risk of health problems from CO exposure. In addition, it has been shown that ambient CO levels are closely correlated with the number of vehicles.

Tingginya aktivitas kendaraan bermotor dapat membahayakan kesehatan. Namun, hingga saat ini belum terdapat penelitian yang secara khusus menganalisis risiko paparan karbon monoksida (CO) terhadap pedagang kaki lima di Kota Bandar Lampung. Penelitian bertujuan menganalisis risiko kesehatan paparan CO terhadap pedagang kaki lima di Kota Bandar Lampung. Penelitian menggunakan rancangan studi kasus, dengan pendekatan Analisis Risiko Kesehatan Lingkungan (ARKL) terhadap 34 pedagang kaki lima di sepanjang Jalan Teuku Umar Kota Bandar Lampung. Penelitian dilaksanakan selama bulan April hingga Mei 2025. Pengukuran konsentrasi CO dan jumlah kendaraan dilakukan di tiga titik menggunakan metode *Non-Dispersive Infrared* (NDIR), selama tujuh hari, dengan tiga kali pengulangan (pagi, sore, dan malam). Sehingga diperoleh 63 data (N= 63). Analisis paparan dilakukan terhadap 34 pedagang yang dipilih secara purposive di setiap titik sampel. Selanjutnya data dianalisis untuk mendapatkan nilai risiko (RQ). Hasil penelitian menunjukkan bahwa rata-rata konsentrasi CO sebesar  $6721 \mu\text{g}/\text{m}^3$  ( $1.340 - 11.112 \mu\text{g}/\text{m}^3$ ). Sedangkan rata-rata jumlah kendaraan sebanyak 2.814 unit (93 – 6.324 unit). Uji statistik menunjukkan hubungan yang sangat kuat antara jumlah kendaraan dan kadar CO ambien ( $r = 0,807$ ;  $P = 0,001$ ). Hasil analisis risiko mendapatkan bahwa seluruh responden memiliki nilai RQ  $> 1$ , menunjukkan bahwa paparan CO berisiko terhadap gangguan kesehatan. Hasil penelitian ini mendapatkan bahwa seluruh responden berisiko mengalami gangguan kesehatan akibat paparan CO. Selain itu, telah dibuktikan bahwa kadar CO ambien berkaitan erat dengan jumlah kendaraan.

\* Corresponding author: Prayudhy Yushananta

Department of Environmental Health, Politeknik Kesehatan Tanjung Karang, Lampung, Indonesia

Email: [prayudhyushananta@gmail.com](mailto:prayudhyushananta@gmail.com)

## 1. Introduction

Indonesia is one of the countries with the highest levels of air pollution in the world, with approximately 60% to 70% of gas emissions coming from motor vehicles, the main contributor to air pollution. While industrial pollution only contributes around 10% to 15%. This is due to the large number of motorized vehicles in Indonesia, which has increased by more than 10% annually, making it a major factor in increasing air pollution. This situation is exacerbated by the fact that road development is increasing by only 2% per year, leading to declining air quality in many cities (Adillah, 2020).

Carbon monoxide (CO) is a dangerous gas produced by the incomplete combustion of fossil fuels and is colorless and odorless (Kumar et al., 2023; Majstorović et al., 2020; Pulster & Hillman, 2015; Yadava & Bhatt, 2021). Carbon monoxide produced by exhaust fumes is released into the air. When humans inhale it, this molecule travels through the respiratory system, then enters the lungs and binds to hemoglobin in the blood, forming carboxyhemoglobin (Kumar et al., 2023; Pulster & Hillman, 2015; Sihombing et al., 2022; Yadava & Bhatt, 2021). Exposure to CO in high concentrations and long duration has the potential to increase carboxyhemoglobin (COHb) levels in the circulatory system, especially for individuals who are frequently exposed to this gas without stopping (Kumar et al., 2023; Nuriyah et al., 2022; Pulster & Hillman, 2015; Rizaldi et al., 2021; Yadava & Bhatt, 2021).

Carbon monoxide has been shown to worsen ischemia, myocardial damage, especially in individuals with a history of coronary heart disease (Warburton et al., 2019). CO leaks can cause chronic poisoning, which is poisoning that occurs after repeated exposure to low to moderate concentrations of CO, such as headaches, nausea, shortness of breath, and anemia. The acute effects of sudden high exposure can be fatal (Anggelina et al., 2022; Pulster & Hillman, 2015; Yadava & Bhatt, 2021).

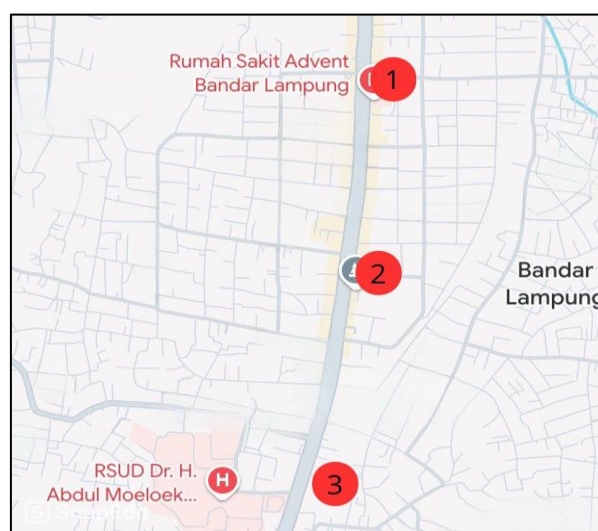
Teuku Umar Street in Bandar Lampung, located in front of Adventist Hospital, the Heroes' Cemetery, and the Abdul Moeloek Hospital intersection, is a high-traffic area because it serves as a main route for various community activities.

Based on initial observations, more than 1,000 vehicles were recorded passing through the location within 15 minutes. Furthermore, the majority of street vendors in this area spend approximately 8 hours a day on the roadside without wearing masks, indicating a high risk of carbon monoxide exposure.

One technique used to assess potential risks to human health is Environmental Health Risk Analysis (EHRA). Risk characteristics are the final result of the four EHRA stages, which include hazard identification, exposure analysis, and dose-response analysis (Directorate General of P2PL, 2012). The study aims to analyze the risk of carbon monoxide exposure to street vendors on Teuku Umar Street, Bandar Lampung City.

## 2. Methods

This study used a quantitative descriptive method with an Environmental Health Risk Analysis (EHRA) approach. The study location was on Jalan Teuku Umar, Bandar Lampung, with three measurement points (Figure 1): in front of Adventist Hospital (Point 1: 5°23'31.66498"S 105°15'44.07707"E), in front of the Heroes Cemetery (Point 2: 5.4294°S 105.2625°E), and at the intersection with Abdul Moeloek Hospital (Point 3: 5°24'11.1" S, 105°15'31.1" E).



**Figure 1.** Sample points

The population in this study was the ambient air and street vendors operating along Teuku Umar Street. A total of 34 vendors were selected as respondents through purposive sampling. The

selected respondents met the criteria of having been in business for at least one year.

Data collection was carried out by measuring ambient CO concentration using a CO Meter directly for one week, with measurements carried out every hour at three-time intervals:

1. Morning (06.00 AM– 1.59 PM)
2. Afternoon (2:00 PM – 09:59 PM)
3. Evening (10:00 PM – 5:59 AM)

The ambient air quality standard used was Government Regulation Number 22 of 2021 (Pemerintah RI, 2021). This risk analysis is carried out in 2 stages of calculation, namely Intake Calculation and Risk Calculation.

The intake value is calculated using the formula:

$$I = \frac{C \times R \times tE \times fE \times Dt}{Wb \times tavg} \dots\dots\dots(1)$$

Where, I= *intake* (mg/kg/day); C= CO concentration (mg/m<sup>3</sup>); R= inhalation rate (m<sup>3</sup>/h); tE= duration of exposure (hours/days); fE = frequency of exposure (days/year); Dt= exposure duration (Dt); Wb= body weight (kg); Tavg = daily average period (Dt x 365 days/year for non-carcinogenic substances).

The Risk Quotient value is calculated using the formula:

$$RQ = \frac{I}{RfC} \dots\dots\dots(2)$$

Where, RQ= *Risk Quotient*; I= *intake* (mg/kg/day); RfC = reference dose of CO (mg/kg/day). The risk level is unsafe if RQ > 1, while the risk level is safe if RQ ≤ 1.

### 3. Results

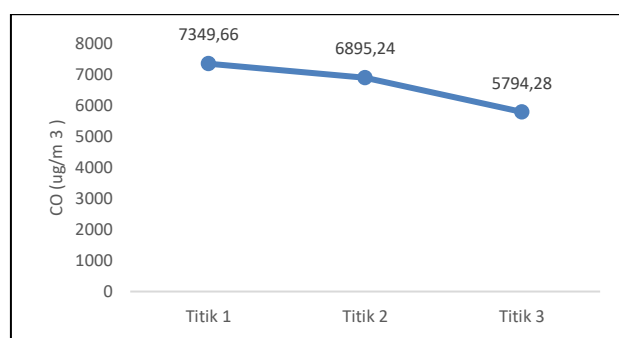
#### 3.1. Ambient CO concentration

Based on the measurement results (Table 1) for a week at three points (N= 63 data), it was found that the CO concentration ranged from 1340 µg/m<sup>3</sup> to 11112 µg/m<sup>3</sup>, with an average of 6721 µg/m<sup>3</sup>.

**Table 1.** CO and number of vehicles

Parameter	N	Mean	Min	Max
CO ( µg/m <sup>3</sup> )	63	6721	1340	11112
Number of vehicles (units)	63	2814	93	6324

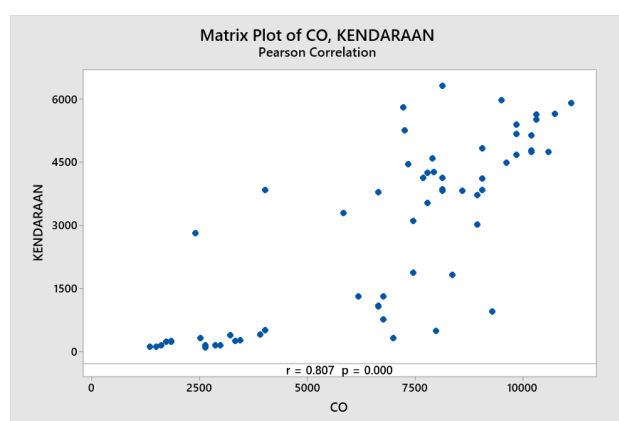
Based on the measurement location, the highest CO concentration was at point 1 (7349.66 µg/m<sup>3</sup>), followed by point 2 (6895.24 µg/m<sup>3</sup>), and the lowest at point 3 (5794.28 µg/m<sup>3</sup>).



**Figure 2.** CO (ambient) Concentration

#### 3.2. Number of Vehicles

Based on observations (Table 1) over a week at three locations, the number of vehicles were 2,814 (93 - 6,324). The relationship between vehicle numbers and CO levels showed a very strong correlation ( $r = 0.807$ ;  $P < 0.0001$ ). This indicates that increasing vehicle numbers will lead to increased CO levels measured in the air.



**Figure 3.** Relationship between Number of Vehicles and CO Concentration

#### 3.3. Respondent exposure

Table 2 shows that the average weight of respondents was 59.85 (40-76) kg. The average

exposure for respondents was 8.76 hours per day (4 - 14 hours per day). Meanwhile, the average annual exposure frequency was 344.76 days, indicating that most respondents were exposed

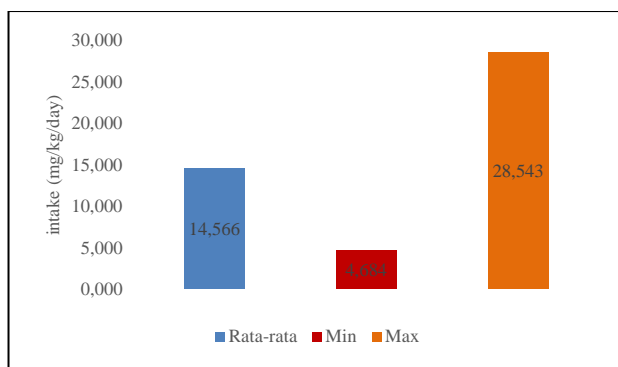
almost every day, with a minimum of 260 days and a maximum of 365 days. The average duration of exposure was 7.44 (1 – 30) years.

**Table 2.** Respondent exposure

No.	Variables	Mean	Min	Max
1.	Body Weight (kg)	59.85	40	76
2.	Exposure Time (hours/days)	8.76	4	14
3.	Exposure Frequency (days/year)	344.76	260	365
4.	Duration of Exposure (years)	7.44	1	30
5.	Inhalation Rate (m <sup>3</sup> /hour)	14.73	12.65	16.05

### 3.4. Respondents' CO Intake

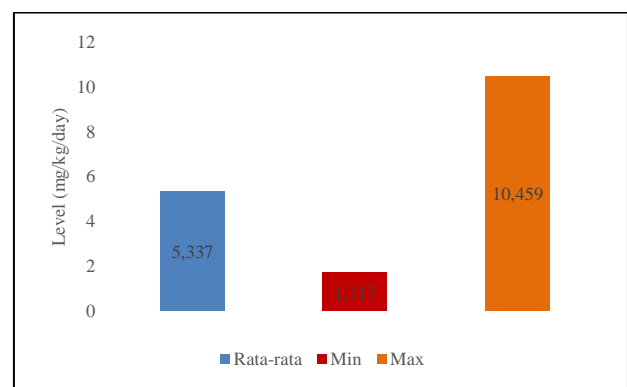
Figure 3 shows that the CO intake of street vendors on Teuku Umar Street in Bandar Lampung ranges from 4.684 to 28.543 mg/kg/day (mean= 14.566 mg/kg/day).



**Figure 4.** Respondents' CO Intake

### 3.5. Risk Level (RQ)

Figure 4 shows that the non-carcinogenic risk level of CO exposure among street vendors on Jalan Teuku Umar, Bandar Lampung, ranges from 1.717 mg/kg/day to 10.459 mg/kg/day, with an average value of 5.337 mg/kg/day. This indicates that all respondents were above the exposure threshold, indicating they were at risk to their health.



**Figure 5.** Respondents' Risk Level

## 4. Discussion

CO (ambient) concentrations in Teuku Umar Street, Bandar Lampung, exceeded air quality standards set by Government Regulation No. 22 of 2021 (Pemerintah RI, 2021). The highest point was found in front of Adventist Hospital (point-1), followed by the point in front of the Heroes Cemetery (point-2), and at the intersection of Abdul Moeloek Hospital (point-3). The main source of CO from motor vehicle emissions. Vehicles with incomplete combustion, such as gasoline-fueled vehicles, produce high levels of CO (Adillah, 2020; Rizaldi et al., 2021; Salma Laela & Ernyasih, 2025; Wahyuni et al., 2018). One environmental control strategy is to plant pollutant-absorbing trees, such as Yellow Tabebuaya (*Handroanthus chrysotrichus*). This type of tree not only has a root system that does not damage road structures, but it has also been shown to significantly absorb CO<sub>2</sub> (Fahira, 2021; Gustin & Sutrisno, 2024; Slot et al., 2021).

Analysis of the relationship between the number of vehicles and CO concentration shows a very strong positive correlation ( $r = 0.807$ ;  $P < 0.001$ ). This indicates that the more motorized

vehicles passing, the higher the CO concentration. This result in line with Adillah (2020) and Nurmaya et al., (2024), which found that motorized vehicles account for 60-70% of CO emissions in urban areas. The same results were also conveyed by Rizaldi et al., (2021); Salma Laela & Ernyasih, (2025); and Wahyuni et al., (2018). To reduce CO emissions from vehicles, efforts include implementing regular emission tests and calibrating vehicle combustion systems. According to Shehata et al., (2024), that routine emission checks can significantly reduce the contribution of vehicles to air pollution.

The high concentration of CO, influenced by the number of motorized vehicles, also affects the daily exposure levels received by street vendors at the study site. Respondents' exposure varied depending on body weight, daily work hours, and the duration and frequency of exposure. The average respondent's body weight was 59.85 kg, with exposure of 8.76 hours per day over 7.44 years. Most respondents were exposed almost daily, with an average frequency of 344.76 days per year. The combination of long work hours and the vendors' location on the main road resulted in a high daily accumulated dose. These factors are the main determinants of CO *intake*, which leads to high RQ values.

Based on the calculation results of CO intake among street vendors on Teuku Umar Street, Bandar Lampung, it ranges from 4,684 mg/kg/day to 28,543 mg/kg/day, with an average of 14,566 mg/kg/day. This value is obtained from a combination of daily exposure, inhalation rate, body weight, and work duration of each respondent. Respondents with daily work durations of more than 8 hours, relatively light body weight, and trading locations in areas with high CO exposure showed the highest intake values. This result is in line with Anggelina et al., (2022), which found that exposure duration and body weight are important factors in determining intake levels and health risks from CO exposure. This high intake value is an early indicator of the high risk of CO exposure to health.

All respondents in this study had an RQ value > 1, with the highest value reaching 10.459. This value indicates that the CO exposure dose exceeds the threshold, indicating a non-carcinogenic health risk. As a mitigation measure for vulnerable groups, such as street vendors, the use of personal

protective equipment, including masks, is still recommended. Although masks such as KN95 or carbon masks do not directly filter CO, they are useful for reducing exposure to other pollutants, such as fine particulates. According to Soeroso et al., (2020) and Rachmadinasya et al., (2023) shows that masks with high filtration remain effective at filtering particles and other irritant gases associated with motor vehicle emissions.

## 5. Conclusions

This study shows that CO concentrations on Teuku Umar Street in Bandar Lampung exceed ambient air quality standards, especially in areas with high motor vehicle. There is a strong relationship between the number of vehicles and CO concentrations. Exposure among street vendors resulted in high intake levels, with all respondents having RQ values > 1. This indicates that all respondents are at risk from CO exposure.

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