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Carbon Monoxide (CO) Exposure to Health Risks for Street Vendors in Trade Centers, Traditional Five Bridges

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ABSTRACT

Carbon monoxide (CO) exposure from motor vehicle emissions is a major environmental health concern for street vendors with prolonged outdoor activities. This study aimed to assess the health risks of CO exposure among street vendors in the Jembatan Lima Market, West Jakarta. A descriptive cross-sectional study was conducted using the Environmental Health Risk Analysis (ARKL) approach. CO concentrations were measured over three days using an Indoor Air Quality Monitor. The results showed CO concentrations ranging from 3.43 to 21.98 mg/m³, with an average of 12.91 mg/m³. Risk characterization indicated that real-time exposure was within safe limits (RQ ≤ 1). However, lifetime risk analysis demonstrated potential non-carcinogenic health risks, with Risk Quotient (RQ ≥ 1) occurring from the 10th year at maximum concentrations and from the 15th year at average concentrations. These findings indicate that long-term CO exposure may pose significant health risks to street vendors.

Keywords : Carbon monoxide (CO); ARKL; Non-carcinogenic risk; Street vendors; Ambient air quality

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INTRODUCTION

Air pollution remains a major global environmental health problem, with approximately 99% of the world's population exposed to air quality levels exceeding the World Health Organization (WHO) guidelines [1]. In Indonesia's urban areas, motor vehicle emissions are the primary source of air pollution, particularly in densely populated cities such as DKI Jakarta. The transportation sector contributes 12–98% of total air pollutant emissions, supported by a rapid increase in motor vehicle ownership from 21.0 million units in 2021 to 22.9 million units in 2023[2]. Carbon monoxide (CO) is a major pollutant produced by the incomplete combustion of fuel in motor vehicles and poses significant health risks due to its ability to reduce oxygen delivery in the body[3]. Long-term exposure to CO has been associated with cardiovascular, neurological, and respiratory disorders. Street vendors are a vulnerable occupational group because they spend prolonged working hours near traffic emission sources and often lack adequate protective measures. Continuous exposure to CO in roadside trading areas may therefore increase long-term health risks, underscoring the importance of environmental health risk analysis to assess exposure levels and support preventive interventions [4].

Motorized vehicles emit various pollutants that are harmful to the environment and human health, including lead (Pb), nitrogen oxides (NOx), hydrocarbons (HC), suspended particulate matter (SPM), carbon monoxide (CO), and photochemical oxidants (Ox)[5]. Carbon monoxide (CO) is one of the primary pollutants generated from incomplete fuel combustion in motor vehicles. Air quality monitoring conducted at five stations in DKI Jakarta in 2024 reported CO concentrations ranging from 900.0 to 1750.0 $\mu g/m^3$, with the highest levels recorded at Bundaran HI and Lubang Buaya[6]. Carbon monoxide exposure poses significant health risks due to its high affinity for hemoglobin, forming carboxyhemoglobin (COHb) and reducing oxygen transport in the blood [7].Prolonged exposure to CO has been associated with neurological, cardiovascular, and respiratory health effects, including cognitive impairment, behavioral changes, chronic respiratory diseases such as asthma and chronic obstructive pulmonary disease (COPD), decreased lung function, and persistent shortness of breath [8].

Environmental Health Risk Analysis (ARKL) is widely used to estimate potential health risks resulting from exposure to environmental pollutants, including carbon monoxide (CO)[9]. Previous ARKL studies conducted in traditional market settings have consistently reported elevated CO concentrations and significant health risks among street vendors[10]. CO concentrations exceeding 21,000 $\mu g/m^3$ in Jambi City markets, with a substantial proportion of vendors classified as at risk ($RQ \geq 1$). Similarly, extremely high CO levels were reported along Jalan Kedondong, Kendari City, where most vendors experienced unacceptable risk levels. In addition to exposure assessment[11], documented various health complaints among roadside vendors, suggesting potential impacts of prolonged exposure[12].

Despite these findings, existing studies have primarily focused on single-time measurements or specific locations, with limited attention to long-term risk projection and exposure variability across different time periods. Moreover, evidence on lifetime risk characterization in highly congested urban markets, such as those in West Jakarta, remains limited. Therefore, this study addresses this gap by conducting a comprehensive ARKL of CO exposure among street vendors in Jembatan Lima Market, incorporating multi-time measurements and lifetime risk estimation [13]. Previous studies have shown that street vendors are particularly vulnerable to carbon monoxide (CO) exposure due to their close proximity to traffic emission sources. Based on this condition, the present study was conducted in the Jembatan Lima Market area, West Jakarta, a location characterized by high traffic density and intensive street vending activities. Jembatan Lima Market is located on Jalan KH. Moh. Mansyur, Tambora District, West Jakarta, and is dominated by street vendors who occupy pedestrian pathways and roadside drainage areas. This spatial arrangement causes road narrowing and contributes to severe traffic congestion [14].

Street vendors in this area typically begin preparing their stalls in the afternoon and actively sell from 15:00 to 23:00 WIB, resulting in daily working durations of up to eight hours. Most vendors work on a daily basis, have been operating at the site for more than one year, and demonstrate low use of personal protective equipment, such as masks. Preliminary CO measurements conducted on May 29, 2025, recorded concentrations of 36,943 $\mu g/m^3$, exceeding the ambient air quality standard of 10,000 $\mu g/m^3$ stipulated in Government Regulation No. 22 of 2021. Therefore, an Environmental Health Risk Analysis (ARKL) approach was applied to evaluate the potential health risks associated with CO exposure in this setting.

METHOD

This study employed a descriptive, cross-sectional design. The variables assessed included ambient carbon monoxide (CO) concentration, dose–response (RfC), carbon monoxide intake (Ink), and risk level (Risk Quotient/RQ). The study was conducted from April to July 2025 in the Jembatan Lima Market area, West Jakarta. The study population consisted of 55 street vendors, and a total sampling was applied. Carbon monoxide concentrations were measured using an Indoor Air Quality Monitor. Additional data on activity patterns and body weight were collected through structured questionnaires. Data analysis was performed using univariate analysis. Ethical considerations were addressed in this study. Ethical approval was obtained from the Research Ethics Committee of Universitas Esa Unggul (Ethical Clearance No. 0925-07.038/DKPE-KEP/FINAL-EA/UEU/VII/2025). All participants were informed about the study objectives and procedures, participation was voluntary, and data confidentiality was ensured. The study involved non-invasive environmental measurements and did not include biological sample collection.

RESULTS

Carbon Monoxide (CO) Concentration 3 Points

Carbon monoxide (CO) concentrations were measured at three time periods—15:00–16:00, 18:00–19:00, and 21:00–22:00—with five-minute intervals over one hour at each sampling point. The detailed measurement results are presented in Table 1.

Table 1. Results of Carbon Monoxide (CO) Measurements at 3 Points

Point	Measurement Time	Min (mg/m3)	Max (mg/m3)	Average (mg/m3)
1	15.00-16.00	18.44	21.54	19.96
	18.00-19.00	11.57	13.29	12.56
	21.00-22.00	8.59	9.84	9.12
2	15.00-16.00	17.42	20.16	18.48
	18.00-19.00	16.84	18.56	17.65
	21.00-22.00	8.01	8.94	8.84
3	15.00-16.00	19.24	21.98	20.94
	18.00-19.00	12.25	17.99	12.94
	21.00-22.00	3.43	6.07	4.68
Minimum				3.43
Maximum				21.98
Average				13.91

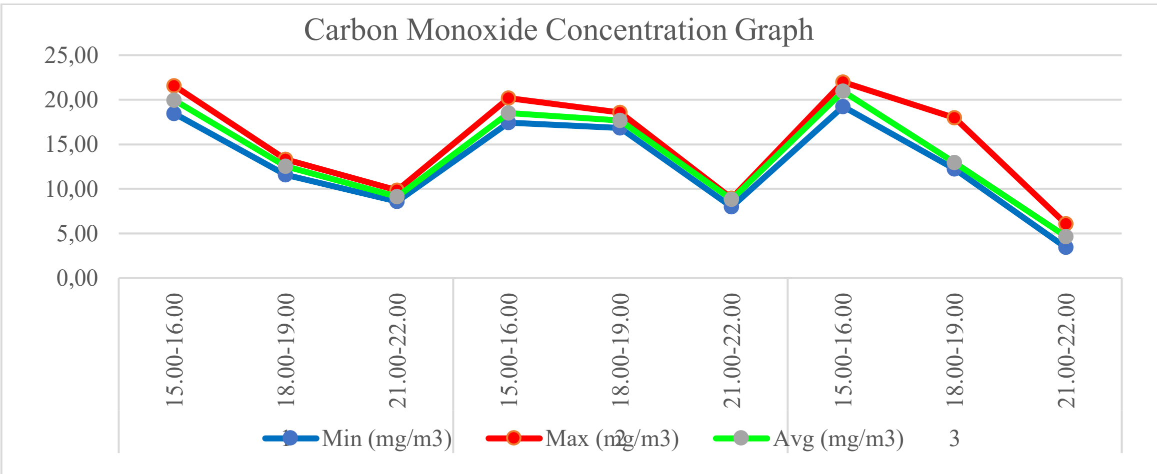

Figure 1. Carbon Monoxide Concentration Graph

As shown in Table 1, CO concentrations varied by both location and time of measurement. The highest concentrations were consistently observed during the 15:00–16:00 period at all three points, with the maximum value reaching 21.98 mg/m³ at Point 3. In contrast, the lowest concentration (3.43 mg/m³) was recorded during the 21:00–22:00 period at the same point. This temporal pattern is further illustrated in Figure 1, which shows a consistent decline in CO concentrations from afternoon to night across all measurement points. The average CO concentration from all measurements was 13.91 mg/m³, exceeding the ambient air quality standard for 1-hour exposure (10 mg/m³). These findings indicate that street vendors are exposed to higher CO levels during peak traffic hours, particularly in the afternoon, when vehicular activity is most intense.

Dose Response (*RfC*) Carbon Monoxide (CO)

The parameters used in the risk calculation were based on the ambient air quality standard for carbon monoxide (CO) stipulated in Government Regulation No. 22 of 2021, which sets a 1-hour CO concentration limit of 10,000 µg/m³, equivalent to 10 mg/m³. Standard default exposure parameters from the Environmental Health Risk Analysis (ARKL) guidelines were applied, including an adult inhalation rate (R) of 0.83 m³/hour, exposure duration (tE) of 8 hours/day, exposure frequency (fE) of 250 days/year, exposure duration (Dt) of 30 years, average adult body weight (Wb) of 55 kg, and an averaging time (tavg) of 10,950 days (30 years × 365 days). Based on these parameters, the calculated reference concentration (RfC) for carbon monoxide was 0.83 mg/kg/day. This RfC represents the maximum acceptable daily intake of CO for non-carcinogenic effects and is considered a safe exposure limit for long-term inhalation under the specified conditions.

Carbon Monoxide (CO) Intake (*Ink)*

Carbon monoxide (CO) intake (Ink) in this study was calculated for two exposure scenarios, namely real-time and lifetime exposure. The intake calculation was based on respondent characteristics, including exposure duration (tE), exposure frequency (fE), duration of exposure (Dt), and body weight (Wb). The characteristics of the respondents used in the intake calculation are presented in **Table 2**.

Table 2. Respondent Characteristics

Characteristics	Average
Duration of exposure (hours/days) (t_E)	8
Frequency exposure (days/years) (fE)	365
Duration exposure (D_t)	4
Body weight (kg) (W_b)	61.76

As shown in Table 2, street vendors had an average exposure duration of 8 hours per day, with an exposure frequency of 365 days per year and an average exposure duration of 4 years. The mean body weight of respondents was 61.76 kg. A standard adult inhalation rate (R) of 0.83 m³/hour was applied in accordance with the Environmental Health Risk Analysis (ARKL) guidelines. For lifetime exposure assessment, the averaging time (tavg) was calculated as 10,950 days, based on an assumed exposure duration of 30 years (30 years × 365 days).

***Real Time* Carbon Monoxide (CO) Intake (*Ink*)**

Calculation results for daily intake (*Ink*), carbon monoxide (CO), based on minimum, maximum, and average concentrations of measurement, *real-time* in three points, are presented in the table following:

Table 3. Real Time Carbon Monoxide (CO) Intake Values (Ink)

Minimum (mg/kg/day)	Maximum (mg/kg/day)	Average (mg/kg/day)
0.0491	0.3150	0.1846

Calculation results mark *real-time* (*Ink*) intake carbon monoxide (CO) in street vendors show a minimum value of 0.0491 mg/kg/day, a maximum value of 0.3150 mg/kg/ day, and an average value of 0.1846 mg/kg/day. Street vendors with a body weight of 61.76 kg are safe working in the environment for 8 hours/day with frequency 365 days/year in a term of 4 years, if the concentration of daily carbon monoxide (CO) does not exceed 10 mg/m^3.

Lifetime Carbon Monoxide (CO) Intake (*Ink*)

Calculation of carbon intake (*Ink*) long-term carbon monoxide (CO) long done to describe potential exposure to street vendors in period 30 years to front. Calculation results mark *lifetime* intake (*Ink*) based on Minimum, maximum, and average concentrations are in the table following:

Table 4. Lifetime Intake (Ink) of Carbon Monoxide (CO)

Exposure Time	5 Year	10 Year	15 Year	20 Year	25 Year	30 Year
Minimum (mg/kg/day)	0.0614	0.1264	0.1843	0.2458	0.3073	0.3687
Maximum (mg/kg/day)	0.3938	0.7877	1,1815	1,5754	1.9692	2,3631
Average (mg/kg/day)	0.2492	0.4985	0.7477	0.9970	1.2462	1.4955

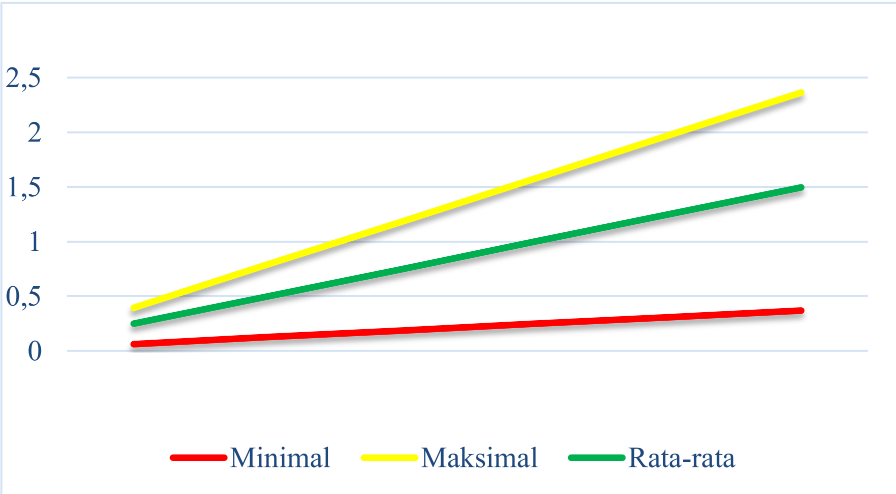

Figure 2. Lifetime Carbon Monoxide (CO) Intake Graph

Lifetime carbon monoxide *(CO)* intake (*Ink*) shows that the maximum value begins to increase from the 15th year of 1.1815 mg/kg/day, the 20th year of 1.5754 mg/kg/day, the 25th year of 1.9692 mg/kg/day, then in the 30th year it reaches 2.3631 mg/kg/day. Meanwhile, the average intake (*Ink*) increases from the 25th year of 1.2462 mg/kg/day in the 30th year to 1.4955 mg/kg/day. Street vendors weighing 61.76 kg are categorized as unsafe to work in the environment for 8 hours/day with an exposure frequency of 365 days per year over 30 years, if the highest carbon monoxide (CO) concentration exceeds 10 mg/m^3.

Risk Level (*RQ*)

Characterization is carried out to determine the level of risk or whether a risk agent at a specific concentration analyzed in the ARKL can cause health problems in the community. Risk. This is done by comparing or sharing the mark Intake (*Ink*) with the dose response (*RfC*).

***Real Time* Risk Level (*RQ*)**

Evaluation level *real-time* risk (*RQ*) aims to identify the impact of non-carcinogenic health effects that result from carbon monoxide (CO) exposure based on the current concentration in the environment, among street vendors. Level of value risk (*RQ*) obtained from the distribution of *real-time* (*Ink*) intake with a mark dose response (*RfC*) of 0.83 mg/kg/ day. The calculation results *RQ* based on minimum, maximum, and average concentrations are presented in the table following:

Table 5. Real Time Risk Level (RQ)

Minimum	Maximum	Average
0.0591	0.3795	0.2224

Calculation results mark *Risk Quotient* (*RQ*) in *real time* show that street vendors with a body weight of 61.76 kg, exposure time of 8 hours/ day, frequency 365 days/year, as well as duration of 4 years of exposure categorized as No risky ($RQ \leq 1$), with minimum value 0.0591, value maximum 0.3795, and average value 0.2224.

***Lifetime* Risk Level (*RQ*)**

Evaluation level risk term long done with share mark *lifetime* carbon intake (*Ink*) monoxide (CO) with mark dose response (*RfC*) of 0.83 mg/kg/ day. The calculation results are served in the table following:

Table 6. Lifetime Risk Level (*RQ*)

Exposure Time	5 Year	10 Year	15 Year	20 Year	25 Year	30 Year
Minimum	0.0739	0.1522	0.2220	0.2961	0.3702	0.4442
Maximum	0.4744	0.9490	1.4234	1,8980	2.3725	2,8471
Average	0.3002	0.6006	0.9008	1,2012	1,5014	1,8018

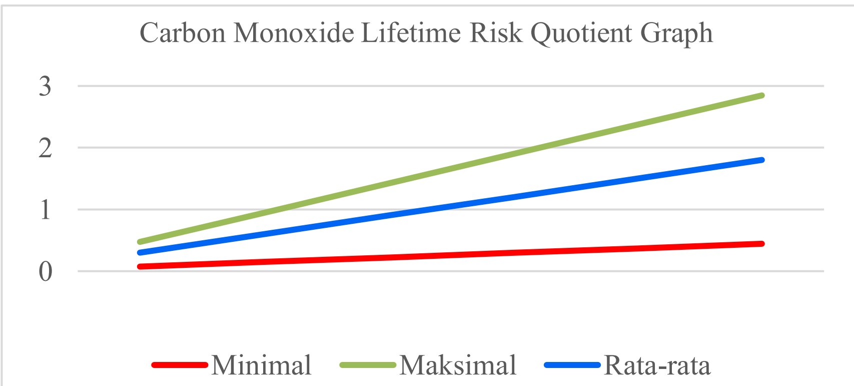

Figure 3. Carbon Monoxide Lifetime Risk Quotient Graph

The Risk Quotient (*RQ*) value for *a lifetime* show that street vendors with a body weight of 61.76, exposure time of 8 hours/day, exposure frequency of 365 days/year and exposure duration ranging from 5 to 30 years are categorized as at risk ($RQ \geq 1$) at a maximum value of 1.4234 in the 15th year, 1.8980 in the 20th year, 2.3725 in the 25th year, and 2.8471 in the 30th year. The average *Risk Quotient* (*RQ) value is categorized as at risk (* $RQ \geq 1$) starting from the 20th year at 1.2012, the 25th year at 1.5014, and in the 30th year at 1.8018.

DISCUSSION

Carbon Monoxide (CO) Concentration

Within the Environmental Health Risk Analysis (ARKL) framework, hazard identification aims to assess whether an environmental agent poses a potential health risk based on its concentration and exposure context, rather than merely restating measurement results. In this study, carbon monoxide (CO) was identified as the primary risk agent due to repeated exceedances of ambient air quality standards during peak activity periods in the Jembatan Lima Market area[15]. The elevated CO concentrations observed in this study reflect specific local environmental conditions, including high traffic density, limited road width, and intensive street vending activities that restrict air circulation [16]. Similar findings have been reported in studies conducted in congested market environments, such as those which documented substantially higher CO concentrations under conditions of heavy traffic exposure[17]. In contrast, reported considerably lower CO levels in Bandar Market, Padang City, where traffic volume, spatial layout, and ventilation conditions were more favorable. These comparisons indicate that differences in CO concentrations across studies are primarily driven by local environmental and infrastructural characteristics rather than methodological variations [18].

Meteorological factors may further influence CO accumulation in roadside environments. Elevated temperatures, high humidity, and low wind speeds can reduce pollutant dispersion and promote the accumulation of CO near emission sources[19]. Consequently, the exceedance of air quality standards observed in this study should be interpreted as the combined effect of emission intensity and unfavorable dispersion conditions, rather than as an isolated or anomalous measurement. Although elevated CO concentrations indicate potential exposure hazards, it is essential to distinguish between environmental risk estimation and observed health outcomes. The ARKL approach provides a theoretical framework for estimating health risk based on exposure and toxicity parameters but does not directly assess clinical conditions or disease occurrence[20]. Epidemiological evidence has shown that long-term CO exposure is associated with neurological and cardiovascular impairments however, these outcomes represent documented effects in exposed populations and were not directly observed in the present study[21]. From a public health perspective, these findings emphasize the importance of preventive interventions rather than suggesting the presence of existing disease among street vendors. Regulatory measures, such as vehicle emission testing mandated under Governor Regulation No. 66 of 2020, are essential for reducing ambient CO concentrations and mitigating long-term exposure risks in high-density urban environments, particularly traditional market areas.

Dose Response (*RfC*) for Carbon Monoxide

Within the Environmental Health Risk Analysis (ARKL) framework, dose–response assessment, expressed as the Reference Concentration (RfC), is a conceptual tool used to estimate the level of exposure that is unlikely to cause non-carcinogenic health effects over a lifetime [22]. The RfC does not represent observed health outcomes but serves as a theoretical benchmark for comparing estimated intake and characterizing potential risk. Therefore, this stage is applied only to risk agents with established toxicological reference values [23]. In this study, the RfC for carbon monoxide (CO) was derived using the 1-hour ambient air quality standard stipulated in Government Regulation No. 22 of 2021 (10 mg/m^3), combined with standard exposure assumptions recommended in the ARKL guidelines. Based on these regulatory and exposure parameters, an RfC value of 0.83 mg/kg/day was obtained. This value represents a reference threshold for long-term non-carcinogenic exposure and has been widely applied in previous ARKL studies, including that of, enabling comparability across studies using similar regulatory frameworks[24]. Variations in RfC values reported in other studies should be interpreted within the context of differing regulatory standards and exposure durations. For example, reported a lower RfC value (0.463 mg/kg/day) by applying a 24-hour CO standard (4 mg/m^3), which reflects a more conservative exposure scenario. These differences do not indicate inconsistency in toxicological risk but rather demonstrate that RfC values are dependent on the selected standard and exposure assumptions. Consequently, RfC values should be understood as context-specific reference points for risk estimation, rather than as direct indicators of clinical health effects[25].

Carbon Monoxide (CO) Intake (*Ink)*

Within the Environmental Health Risk Analysis (ARKL) framework, exposure analysis is used to estimate the magnitude of human exposure to environmental agents based on intensity, frequency, and duration, rather than to directly assess health effects. Intake (Ink) represents a calculated estimate of the amount of carbon monoxide (CO) entering the body through inhalation and serves as an intermediate parameter for subsequent risk characterization. In this study, real-time intake values remained relatively low, indicating that short-term exposure under current conditions is unlikely to result in immediate non-carcinogenic health effects [26]. Similar intake levels were reported by, whose study was conducted in an environment with moderate traffic density. In contrast, substantially higher intake values reported by were associated with roadside trading areas characterized by heavier traffic flow and higher ambient CO concentrations. These comparisons suggest that variations in intake across studies are primarily influenced by differences in local emission intensity and environmental conditions rather than by methodological discrepancies [27].

Lifetime intake projections demonstrated a progressive increase in cumulative CO intake with longer exposure duration[28]. This pattern is consistent with the findings of, who reported markedly higher lifetime intake values among traders with prolonged exposure histories. Conversely, lower lifetime intake values observed by reflect differences in exposure duration and ambient concentration levels. These findings underscore that lifetime intake estimates should be interpreted as indicators of cumulative exposure potential rather than as evidence of existing health impairment. Differences in intake magnitude are influenced by multiple factors, including ambient CO concentration, inhalation rate, daily exposure duration, exposure frequency, and total exposure duration[29]. As exposure duration increases, cumulative intake also rises, increasing the potential for adverse health effects over time. However, intake values alone do not confirm the occurrence of health outcomes and must be interpreted within the broader risk characterization framework.

Risk Level (*RQ*) of Carbon Monoxide (CO)

Risk characterization is the final stage of the Environmental Health Risk Analysis (ARKL) and aims to estimate potential health risks by comparing the calculated intake (Ink) with the reference concentration (RfC). This stage integrates exposure parameters such as body weight, inhalation rate, exposure duration, and frequency to provide a theoretical estimate of non-carcinogenic risk, rather than to diagnose actual health effects. In this study, real-time RQ values remained below the acceptable threshold ($RQ \leq 1$), indicating that short-term exposure to carbon monoxide (CO) among street vendors in the Jembatan Lima Market is unlikely to pose immediate non-carcinogenic health risks[30]. Similar findings have been reported by, whose study was conducted in an environment with relatively low ambient CO concentrations. In contrast, higher real-time RQ values reported were associated with substantially elevated CO concentrations in highly congested roadside settings, highlighting the influence of local emission intensity and exposure conditions on risk magnitude[31].

Lifetime risk assessment revealed a different pattern, with RQ values exceeding the safe threshold after prolonged exposure durations. This increase reflects the cumulative nature of exposure over time rather than an abrupt change in environmental conditions[32]. Comparable trends have been documented in studies conducted in locations with sustained high exposure levels, where long-term accumulation resulted in elevated RQ values. Conversely, lower lifetime RQ values reported by can be attributed to lower ambient concentrations and shorter effective exposure durations. It is important to emphasize that RQ values represent theoretical estimates of potential risk rather than evidence of existing health effects. An $RQ \geq 1$ indicates an increased probability of adverse health outcomes if exposure continues over time, not the presence of disease at the time of measurement. Long-term exposure to carbon monoxide has been associated in epidemiological studies with respiratory and cardiovascular impairments due to chronic hypoxia. However, such outcomes were not directly assessed in this study. Therefore, the elevated lifetime RQ values observed should be interpreted as an early warning signal, underscoring the need for preventive interventions to reduce exposure and mitigate future health risks among street vendors[33].

CONCLUSIONS AND RECOMMENDATIONS

This study indicates that carbon monoxide (CO) concentrations in the Jembatan Lima Market exceeded the ambient air quality standard during peak traffic hours. Although real-time exposure among street vendors remained within acceptable non-carcinogenic risk limits (RQ ≤ 1), lifetime risk assessment revealed potential health risks, with Risk Quotient (RQ ≥ 1) occurring after prolonged exposure, particularly at maximum and average concentration scenarios. These findings suggest that continuous long-term exposure to CO may pose significant health risks for street vendors. Preventive measures are needed to reduce long-term CO exposure among street vendors, including improving traffic management around market areas, enforcing regular vehicle emission testing, and promoting the use of personal protective equipment. Local authorities should also consider spatial reorganization of vending areas to improve air circulation. Future studies are recommended to incorporate health outcome assessments and longer monitoring periods to strengthen the evaluation of chronic exposure effects.

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