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Environmental Health Risk Analysis of Exposure Carbon Monoxide (CO) on Traders in Manado City Self-Service Jumbo Area

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Abstract. *Background: Motor vehicle activity in shopping mall areas is a primary source of carbon monoxide (CO) emissions, posing a potential long-term health risk for workers with sustained exposure. This study aimed to conduct an environmental health risk assessment of CO exposure for traders operating in the Jumbo Supermarket Area of Manado City. Methods: An observational study with a quantitative approach was conducted in July-August 2025. Ambient air CO concentration was measured in real-time using a CO meter at three location points, with purposive sampling of 30 traders. Respondent characteristics, including exposure parameters, were collected via questionnaire. Health risk analysis was performed by calculating the Average Daily Dose (ADD) and Risk Quotient (RQ), following the US EPA (2022) guidelines, where an RQ > 1 indicates an unacceptable non-carcinogenic risk. Results: The mean ambient CO concentration was 1,591.89 $\mu g/m^3$, which is significantly below the national air quality standard (10,000 $\mu g/m^3$) set by Indonesian Minister of Health Regulation No. 02 of 2023. The risk assessment yielded average RQ values of 8.38 x 10^{-5} for real-time exposure and 1.23 x 10^{-5} for lifetime exposure. All calculated RQ values were substantially below the safety threshold of 1. Conclusion: Current CO concentrations in the study area do not exceed regulatory standards and do not pose an unacceptable non-carcinogenic health risk to traders. However, implementing periodic air quality monitoring is recommended to ensure the continued protection of worker health in this environment.*

Keywords: *Environmental Health Risk Analysis; Carbon Monoxide; Traders; Jumbo Self-Serving; Non-Carcinogenic Risks*

1. Introduction

Air pollution has emerged as a major global public health threat. The World Health Organization (WHO) reported that approximately 99% of the global population is exposed to air pollutant concentrations exceeding recommended safety limits, thereby significantly increasing the risk of cardiovascular and respiratory diseases. Specifically, air pollution exposure elevates the risk of heart disease by 25%, stroke by 24%, chronic obstructive pulmonary disease (COPD) by 43%, and lung cancer by 29% (1). Major air pollutants originating from motor vehicle emissions include carbon monoxide (CO), nitrogen oxides (NOx), sulfur oxides (SOx), and lead (Pb), all of which contribute substantially to adverse health outcomes.

This global condition is highly relevant to Indonesia. Data from the Central Statistics Agency (BPS) indicate that Indonesia is among the countries with the highest growth in motor vehicle ownership worldwide, increasing from 126,508,776 units in 2019 to 136,137,451 units in 2020 (2). This rapid increase in vehicle numbers has been directly associated with declining

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air quality, with DKI Jakarta consistently recorded as the region with the highest air pollution index nationally (3). In line with this national trend, Manado City has also experienced a marked rise in motor vehicle numbers, reaching 429,267 units in 2023 (4).

Areas characterized by intense human activity and dense traffic flow—such as traditional markets and shopping centers—are recognized as air pollution hotspots. These environments have a high potential for elevated concentrations of sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and carbon monoxide (CO) (1). Chronic exposure to these pollutants, particularly CO, is associated with adverse effects on the respiratory, cardiovascular, and nervous systems. One prominent example in Manado City is Jumbo Self-Service (Jumbo Swalayan), a major commercial center strategically located near the city core and the Port of Manado. High vehicle density, combined with limited parking capacity and frequent traffic congestion during peak hours, exacerbates pollutant accumulation in this area.

To evaluate the public health impact of pollutant exposure, the Environmental Health Risk Assessment (EHRA/ARKL) approach is widely applied. According to the United States Environmental Protection Agency (US EPA), EHRA estimates health risks by integrating exposure concentration, intake parameters, reference doses, and population characteristics (5). Previous studies conducted in Jakarta and Surabaya demonstrated that CO concentrations in market environments may exceed safety thresholds, yielding Hazard Quotient (HQ) values greater than one, which indicates unacceptable non-carcinogenic health risks (6,7).

The novelty of the present study lies in the integration of direct ambient air quality measurements at local economic activity centers, such as Jumbo Supermarket, with EHRA analysis specifically targeting vulnerable populations, namely traders. Unlike previous studies that primarily focused on industrial or residential settings, this study evaluates CO exposure in dense urban microenvironments while accounting for actual exposure duration and traders' time–activity patterns (6,7). This approach provides empirical evidence to support evidence-based policymaking in environmental health protection.

Preliminary observations and interviews revealed that many traders in the Jumbo Self-Service area have been actively working for 10–30 years without adequate personal protective measures. Commonly reported health complaints included cough, headache, and dizziness. These findings are consistent with health center records indicating hypertension as the most prevalent disease, followed by acute respiratory infections (ARI), during the 2022–2024 period—conditions known to be associated with air pollution exposure.

Based on this context, the present study aims to analyze environmental health risks associated with carbon monoxide (CO) exposure among traders in the Jumbo Supermarket area of Manado City. Specifically, the study seeks to measure ambient CO concentrations and to quantify non-carcinogenic health risks faced by the trader population.

2. Methods

This study uses an observational analytical research type with a quantitative approach. The main approach applied is the Environmental Health Risk Assessment (EHRA) which refers to the US EPA (2022) guidelines. The study was designed to measure actual exposure and quantify the level of non-carcinogenic health risks faced by the study population.

The research location was purposively chosen in the Jumbo Swalayan Area, Jalan Suprapto, Pinaesaan Village, Wenang District, Manado City. The selection of this location was based on the consideration that the area is a *hotspot* for human activity and vehicular traffic, which has the potential to lead to the accumulation of CO pollutants.

The population in this study is all street vendors who are active around the Manado Swalayan Jumbo area. A sample was taken as many as 30 respondents who were selected using the purposive sampling technique. Sampling was performed at three different sampling points within the area, which were chosen to represent variations in exposure intensity, such as near major highways and parking areas. The inclusion criteria applied include: traders who are willing to become respondents through *informed consent*, have a minimum working period of 1 year, and are active at the location on a regular basis for at least 8 hours per day.

The variables studied in this study can be grouped as follows:

1. Exposure Variables: Ambient air CO concentrations measured directly on site.
2. Response Variable: Risk Quotient (RQ) or *Hazard Quotient* (HQ) value as an indicator of non-carcinogenic health risk.
3. Variables Characteristics of the Subject: Inhalation *rate*, frequency of exposure (day/year), duration of exposure (hours/day), and body weight. These variables are used to calculate *the Average Daily Dose* (ADD) of CO exposure.

Data collection is carried out through two main methods. First, the measurement of ambient air CO concentration was carried out in *real-time* using *a CO meter* with *a data logger* placed at three sampling points during a time period representing the operating hours of the area. Second, data on the characteristics of the subjects (duration of exposure, frequency of exposure, weight, and medical history) were collected through structured interviews using questionnaires that have been tested for validity and reliability.

Data analysis was carried out by following the ARKL standard procedure which includes four stages:

1. Hazard Identification: Establishes CO as a hazardous chemical with non-carcinogenic effects.
2. Dose-Response Assessment: Using *Reference Concentration* (RfC) values for CO from the U.S. EPA or WHO as a comparison.
3. Exposure Assessment: Calculates *the Average Daily Dose* (ADD) of inhaled CO exposure with the formula: ADD = (C x IR x ET x EF x ED) / (BW x AT), where C = CO concentration, IR=*inhalation rate*, ET=exposure time, EF=exposure frequency, ED=exposure duration, BW=body weight, and AT=averaging time.
4. Risk Characterization: Calculate Risk Quotient (RQ) with the formula RQ = ADD/RfC. If RQ ≤ 1, the risk is declared *acceptable*; if RQ is > 1, the risk is declared *unacceptable* and a recommendation for mitigation measures is required.

With this method, the research is expected to provide a comprehensive and quantitative picture of the magnitude of health risks due to CO exposure, so that the results can be a scientific basis for the formulation of targeted environmental health policies.

3. Results and Discussion

3.1 Results

In this section, the distribution of respondent characteristics, CO concentration, frequency of exposure, duration of exposure, CO intake value, and health risk value (RQ) are explained. This can be seen in Table 1-9.

Table 1. Descriptive Characteristics of Respondents

	N	Range	Min	Max	Mean
Age (years)	30	49	19	68	41,17
Body Weight (kg)	30	37	42	79	60,77
Length of Work (hours per day)	30	10	5	15	10,17
Length of Work (Days per Year)	30	183	182	365	350,5
Tenure (years)	30	29	1	30	9,47
Valid N (listwise)	30				

Table 1 shows that the age of the respondents ranged from 19-68 years with an average of 41.17 years. The weight ranges from 42-79 kg with an average weight of 60.77 kg. The length of work ranges from 5-15 hours/day and 182-365 days/year and the working period is 1-30 years.

Table 2. Characteristics of Traders by Gender

Gender	N	(%)
Man	12	40,0
Woman	18	60,0
Total	**30**	**100,0**

From table 2, it can be seen that male traders amounted to 12 respondents with a percentage of 40.0%, less than female traders who amounted to 18 people or 60.0% of the total respondents.

Table 3. Characteristics of Respondents by Age Group

Age (years)	N	(%)
17-25	6	20,0
26-35	6	20,0
36-45	3	10,0
46-55	10	33,3
56-65	4	13,3
>66	1	3,3
Total	**30**	**100,0**

Based on Table 3, it is known that traders aged 46-55 years are 10 respondents (33.3%) more compared to the age group > 66 years old which is only 1 respondent or (3.3%) of the total respondents.

Table 4. Characteristics of Traders Based on Weight

Weight	N	(%)
< 55kg	8	26,7
≥ 55kg	22	73,3
Total	**30**	**100,0**

Based on Table 4, it is known that traders with a Weight of > 55 kg amounted to 22 respondents (73.3%), more than < Weight of 55 kg which was only 8 respondents (26.7%) of the total respondents.

Table 5. CO Concentration in Ambient Air

Location	Measurement Time	Quality Standards	Result	Method/Tool
Point 1	Morning 09:30-10:30	10,000 (1 Hour)	1420	SNI 7119.10:2011
N: 1o29'33.0"	Noon 12:40-13:40	10,000 (1 Hour)	1512	SNI 7119.10:2011
E: 124o50'22.3"	Afternoon 15:35-16:35	10,000 (1 Hour)	2016	SNI 7119.10:2011
Point 2	Morning 08:25-09:25	10,000 (1 Hour)	1008	SNI 7119.10:2011
N: 1o29'32.6"	Noon 11:35-12:35	10,000 (1 Hour)	962	SNI 7119.10:2011
E: 124o50'22.1"	Afternoon 15:00-16:00	10,000 (1 Hour)	1477	SNI 7119.10:2011
Point 3	Morning 10:40-11:40	10,000 (1 Hour)	1431	SNI 7119.10:2011
N: 1o29'33.4"	Noon 13:45-14:45	10,000 (1 Hour)	2497	SNI 7119.10:2011
E: 124o50'22.5"	Afternoon 16:45-17:45	10,000 (1 Hour)	2004	SNI 7119.10:2011

Based on table 5 above, the CO concentration ranges from 962 – 2497 µg/m3 with an average value of CO concentration of 1591.89 µg/m3. This value is still at the quality standard of 10,000 µg/m3.

Table 6. Frequency of CO Exposure in Traders

Value size	CO exposure frequency (Hr/th)
Average	350,5
Median	365
Interval	183
Minimum	182
Maximum	365

The data in table 6 shows that the frequency of CO exposure ranges from 182-365 hr/year with an average of 350.5 hr/year.

Table 7. Duration of Exposure (Years)

Value size	CO Exposure Duration (years)
Average	9,56
Median	4,5
Interval	29
Minimum	1
Maximum	30

The data in table 7 shows that the duration of CO exposure ranges from 1-30 years with an average of 9.56 years.

Table 8. Value of CO Intake in Traders

Value size	CO Intake *Real Time*	CO Intake *Life Time*
Average	0,0126	0,0018
Median	0,0141	0,0011
Interval	0,0105	0,0072
Minimum	0,0066	0,00009
Maximum	0,0171	0,0073

The data in table 8 shows that the value of CO intake for *real time* ranges from 0.0066 – 0.0171 with an average of 0.0126. Furthermore, the value of CO intake for *life time* ranged from 9E-05 – 0.0073 with an average of 0.0018.

Table 9. Health Risk Assessment

Value size	RQ CO *Real Time*	RQ CO *Life Time*
Average	8.38 x10-5	1.23 x10-5
Median	9.40 x10-5	7.31 x10-5
Interval	7.01 x10-5	4.81 x10-5
Minimum	4.37 x10-5	6.25 x10-5
Maximum	11.4 x10-5	4.88 x10-5

Table 6 shows that:

1. Real Time Risk Analysis

This risk describes potential health impacts based on short-term exposure or in periods of active work.

- **Average RQ Value**: 8.38 x 10^{-5} (or 0.0000838)
- **Maximum RQ Value**: 11.4 x 10^{-5} (or 0.000114)

Interpretation:

All RQ values, including mean and maximum values, are well below 1. Even the maximum value of exposure measured in the field is only about 0.011% of the set threshold. This shows that during the working period, acute exposure to CO in the region does not bring a significant negative impact on the health of traders.

2. Lifetime Risk Analysis

This risk takes into account the accumulation of long-term exposure (assumed over 70 years) and is more relevant to looking at potential chronic impacts.

1. **Average RQ Value**: 1.23×10^{-5} (or 0.0000123)
2. **Maximum RQ Value**: 4.88×10^{-5} (or 0.0000488)

Interpretation: Just like real time risk, all RQ values for lifetime exposure are also well below 1. The average value is even lower than the real-time calculation. This indicates that even if a trader worked at the site for decades, his or her accumulated CO exposure did not reach levels considered dangerous to cause chronic health effects.

3.2 Discussion

Ambient Air Carbon Monoxide Concentration

The results demonstrated that ambient CO concentrations ranged from 962 to 2,497 µg/m³, with an average concentration of 1,591.89 µg/m³. These values remain below the national ambient air quality threshold of 10,000 µg/m³ (8,9). These findings are consistent with a study by Jusuf et al., which reported elevated PM_{10} concentrations exceeding regulatory limits, while CO concentrations remained within permissible levels (10). Similarly, Mentari et al. reported CO concentrations below the established threshold in market environments (11).

Observational analysis indicated that CO concentration levels were strongly associated with traffic density, particularly in areas experiencing congestion and prolonged vehicle idling. Meteorological factors also played a role in pollutant dispersion. Consistent with findings from Anggelina et al., higher temperatures, lower humidity, and higher wind speeds—especially with dominant northern wind directions—were shown to influence ambient CO levels (12).

Frequency and Duration of Exposure

The frequency of CO exposure among traders ranged from 5 to 15 working hours per day. This exceeds the standard working duration of 8 hours per day or 40 hours per week as stipulated by the Indonesian Ministry of Manpower. Several studies reported exposure frequencies of approximately 359–363 days per year, with daily working durations ranging from 6 to 12 hours and cumulative working periods extending up to 30–35 years (11–14). Such prolonged exposure significantly contributes to increased non-carcinogenic health risks.

In the present study, the duration of CO exposure ranged from 1 to 30 years, with an average exposure duration of 9.56 years. This is consistent with previous studies in Indonesia reporting exposure durations of 7–32 years, with average values of 13–15 years (15).

Health Risk Assessment (RQ)

The calculated real-time Risk Quotient (RQ) values ranged from 4.37×10^{-5} to 1.14×10^{-4} (mean: 8.38×10^{-5}), while lifetime RQ values ranged from 6.25×10^{-7} to 4.88×10^{-5} (mean: 1.23×10^{-5}). These values are comparable with previous findings indicating that the majority of respondents had RQ ≤ 1, suggesting acceptable risk levels, although a subset of traders exhibited RQ > 1, indicating potential health risks (12,16).

CO concentration was directly proportional to intake values, whereby higher concentrations resulted in greater intake and increased risk. Lifetime projections over a 30-year exposure horizon were conducted to estimate long-term health risks, in accordance with

EHRA methodology (5,17). Although current CO concentrations were below regulatory thresholds, cumulative exposure over prolonged periods remains a concern.

Health Impacts of Carbon Monoxide Exposure

Carbon monoxide is a colorless, odorless, and tasteless toxic gas produced by incomplete combustion of carbon-based fuels. Despite ambient concentrations remaining below regulatory limits, cumulative exposure can adversely affect health. Previous studies demonstrated increased carboxyhemoglobin (COHb) levels among exposed individuals, accompanied by symptoms such as dizziness and fatigue (18).

Low-level acute and chronic CO exposure has been associated with headaches, nausea, fatigue, palpitations, visual disturbances, muscle weakness, and increased cardiovascular risk, including hypertension (19–21). Elevated reticulocyte counts observed in exposed individuals suggest increased blood viscosity, which may contribute to hypertension development (15).

Prevention and Control Measures

Preventive strategies to reduce ambient CO concentrations include routine vehicle maintenance, periodic emission testing, and traffic management to reduce congestion. The use of personal protective equipment, such as masks, is recommended to minimize individual exposure. Within the EHRA framework, risk mitigation can be achieved by reducing pollutant concentrations or limiting exposure duration. Given that CO levels in this study were below regulatory limits, concentration modification is not prioritized; however, reducing exposure duration remains challenging, as trading activities are essential for livelihood (22,23,24,25).

Conclusions

Based on the results of the Environmental Health Risk Analysis of carbon monoxide (CO) exposure to traders in the Manado City Jumbo Self-Service Area, it can be concluded that the ambient CO concentration at the location is still within the safe limit set by regulations. The average CO concentration value from measurements at three points during the morning, afternoon, and evening periods was 1,591.89 µg/m^3, which is significantly lower than the ambient air quality standard according to the Regulation of the Minister of Health of the Republic of Indonesia Number 02 of 2023, which is 10,000 µg/m^3. The implications of these findings are confirmed through the characterization of health risks, where the average Risk Quotient (RQ) value for real time exposure is 8.38×10^{-5} and for lifetime exposure is 1.23×10^{-5}. Since all RQ values obtained from the 30 trader respondents are far below threshold one (RQ ≤ 1), it can be stated that CO exposure in the region has not posed an unacceptable health risk to the population studied. Thus, ambient air quality specific to CO pollutants in the Jumbo Supermarket area is declared good and does not have the potential to cause adverse health impacts based on the measured parameters.

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Conflicts of Interest

The authors declare no conflict of interest

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