International Journal of Natural and Health Sciences (IJNHS)
Vol.3, No.4, 2025: 263-274

Mapping of Environmental Health Risks Due to Carbon Monoxide (CO) Exposure Among Traders at Bersehati Market in Manado City

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A R T I C L E I N F O

Keywords: Carbon Monoxide, Environmental Health Risk Assessment (EHRA), Risk Quotient (RQ), Traditional Market, Air Pollution

Received : 5 August
Revised : 23 September
Accepted : 23 October

A B S T R A C T

Air pollution, particularly from carbon monoxide (CO) in vehicle emissions, poses a health threat to chronically exposed populations, including traders in traditional markets. Bersehati Market in Manado is a shopping center with high vehicle activity, potentially leading to increased ambient CO concentrations. This study aimed to analyze the non-carcinogenic environmental health risks due to CO gas exposure among traders at Bersehati Market. This observational study with an Environmental Health Risk Assessment (EHRA) approach was conducted from March to July 2025. Ambient air samples were measured at three different points and times (morning, afternoon, evening) using a Carbon Monoxide Meter, and exposure characteristics (duration, frequency, length) and anthropometric data were collected from 30 purposively selected trader respondents. Risk analysis was performed by calculating the intake and Risk Quotient (RQ) for both real-time and lifetime (70 years) exposure. The measurement results showed an average CO concentration of 348.67 µg/m³, with the highest concentration of 973 µg/m³ at a morning measurement point. However, all concentrations remained below the threshold set by Indonesian Government Regulation No. 41 of 1999 (30,000 µg/m³). The average real-time intake was 0.018 mg/kg/day, while the lifetime intake was 0.009 mg/kg/day. The highest real-time RQ value was 0.02788 and the highest lifetime RQ was 0.03584. Since all RQ values were < 1, this study concludes that, statistically, CO exposure to traders at Bersehati Market does not yet indicate a significant non-carcinogenic health risk, either under current conditions or in long-term projections. Nonetheless, the long daily exposure duration and fluctuating CO concentrations necessitate ongoing vigilance and monitoring

INTRODUCTION

Air pollution has become a problem for almost every country in the world. In 2019, air pollution was a major factor in premature deaths, causing around 6.6 million deaths worldwide. In 2021, 8.1 million deaths were caused by air pollution, with 58% of those deaths caused by PM2.5 air pollution (WHO, 2024). In 2024, Indonesia ranked 15th among countries with the highest cases of air pollution, with the city of South Tangerang having the highest pollution level with an air quality index (AQI) of 155 (IQAir, 2024).

North Sulawesi, particularly in Manado, according to available data, has air quality that is generally in the moderate category. This means that air quality is still within acceptable limits, but serious attention is needed to prevent it from worsening. In 2024, air quality in Manado, based on the ISPU, is in the moderate category, with an air quality index between 51-100. The main causes of air pollution in Manado are the increase in the number of motor vehicles and traffic congestion, as well as the operation of old vehicles that produce emissions. (IQAir, 2024)

Markets and shopping centers are locations with high human activity and heavy vehicle traffic, making them highly susceptible to air pollution, especially from pollutants such as carbon monoxide (CO). Chronic exposure to these pollutants can have adverse effects on health, particularly on the respiratory, cardiovascular, and nervous systems. (WHO, 2024)

Measuring CO levels is important to determine the level of air pollution in these locations and as a basis for making health and environmental policy decisions. The Environmental Health Risk Assessment (EHRA) method is used to assess the magnitude of public health risks due to pollutant exposure, based on intake parameters, reference doses, and the characteristics of the exposed population. (US EPA, 2022). The results of this risk analysis enable the determination of risk levels (acceptable or unacceptable risk) so that mitigation measures can be designed effectively.

Research by Hidayatulloh et al. (2024) on the analysis of environmental health risks of carbon monoxide (CO) exposure among traders at Cikutra Market in Bandung City in 2024 showed that the RQ value was >1 at eight sampling points, so it can be concluded that all traders at Cikutra Market are at risk or unsafe from exposure to CO pollutants in the air, which can cause health problems. Research conducted by Juhanda et al. (2024) also showed similar results, where in their research, an RQ value >1 was considered unsafe, therefore requiring control through risk management. The longer the duration of exposure, the greater the intake received by respondents. As a result, the greater the health risk due to CO gas exposure received by respondents. (Juhanda et al., 2024)

LITERATURE RIVIEW

According to data from the Wenang Community Health Center, from 2020 to 2024, respiratory tract infections (RTIs) were among the 10 most common diseases, ranking first in 2020-2021 as the most prevalent disease and second in 2022-2024. Other commonly encountered diseases include HPT, diabetes mellitus, osteoarthritis, gastritis, myalgia, eye refraction, dyspepsia, heart disease, and oral cavity diseases.

Pasar Bersehati Manado is one of the shopping centers in Manado City, located in Calaca Village, Wenang District, Manado City. Every day, the area is crowded with all types of vehicles, where exhaust fumes from motor vehicles can reduce air quality and cause carbon monoxide (CO) pollution. CO gas that is inhaled enters the lungs and enters the bloodstream, preventing oxygen from entering the body. This affects the health of traders.

The high volume of motor vehicle activity around Bersehati Market in Manado contributes to high levels of carbon monoxide (CO) pollution in the air. This certainly has a significant impact on the health of traders around the Bersehati market, who are most often exposed to air pollution from motor vehicle activity. This is what motivated researchers to study "Analysis of Environmental Health Risks of Carbon Monoxide (CO) Exposure in Traders at the Bersehati Market in Manado City."

METHODOLOGY

This type of research is observational, using an environmental health risk analysis approach to assess and predict the effects of future exposure to hazardous substances (Aminah, 2019). In conducting the research, the researchers referred to the ARKL calculation procedure following the draft model harmonized by the IPCS 2004, with the following formal steps: hazard identification, hazard characterization, exposure analysis, and risk characterization. The research was conducted in the Bersehati Market area of Manado, located at Jl. Nusantara No. 17, Calaca Village, Wenang District, Manado City. Three ambient air CO quality samples were taken, considering the locations with the highest number of traders and vehicles as representative of the entire Bersehati Market area. The research was conducted from March to July 2025. Samples in this study were taken purposively by determining the number of ambient air sampling points and the number of vendor respondents who were the subjects of the study. The total population of vendors was unknown, so the researchers took 10 vendors at each point to be the subjects of the study. The criteria for being a subject of the study were those who had been active as vendors for at least 1 year at the study location. So, in total, there were 30 vendors who were the subjects of the study.

RESULT

This section describes the distribution of respondent characteristics, CO concentration, smoking rate, body weight and duration of exposure, frequency of exposure, intake, and RQ value. This is shown in the following table.

Table 1. Distribution of Gender of Traders

Gender	**n**	**%**
Male	14	46,7
Female	16	53,3
Total	**30**	**100**

Table 1 shows that there were 14 male traders, representing 46.7% of the total respondents, which is less than the 16 female traders, representing 53.3% of the total respondents.

Table 2. Characteristics of Traders Based on Age

Age (Years)	**n**	%
18-27	10	33,3
28-37	4	13,3
38-47	6	20,0
48-57	7	23,3
58-67	1	3,3
68-77	2	6,7
Total	**30**	**100**

Table 2 shows that traders aged 18-27 years numbered 10 respondents (33.3%), which was more than the 58-67 age group, which had only 1 respondent or (3.3%) of the total respondents.

Table 3. Characteristics of Traders Based on Body Weight

Body Weight	**n**	%
<55 Kg	7	23,3
>55 Kg	23	76,7
Total	**30**	**100**

Table 3 shows that most respondents weighed > 55 kg (76.7%). Next, the results of measurements of air temperature, air humidity, wind speed, and ambient CO are described. This can be seen in Table 4.

Table 4. Results of Measurements of Air Temperature, Air Humidity, Wind Speed and Ambient CO

Sampling Point	**Measurement Time**	**Air Temperature (°C)**	**Humidity (%)**	**Wind Speed (m/s)**	**CO (µg/m³)**
1	Pagi (09:00-10:00)	35.0	46.8	0.9	**504**
	Siang (11:05-12:05)	35.5	47.2	0.7	**355**
	Sore (15:30-16:30)	32.2	58.7	0,3	**481**
2	Pagi (08.15-09.15)	31.0	54.1	0.4	**973**
	Siang (11.45-12.45)	33.6	51.8	1.6	**115**
	Sore (15:05-16:05)	34.7	54.6	0,6	**240**
3	Pagi (08.40-09.40)	37.4	43,0	1.2	**332**
	Siang (11.30-12.30)	34.6	49.5	2.9	**23**
	Sore (15:00-16:00)	33.0	54.3	3.0	**115**

The measurement of CO gas concentration at point 1 was the highest concentration, with an average measurement result of 446.67 µg/m3. During the morning measurement, the highest concentration was obtained, which was 504 µg/m3. The highest CO concentration at point 2 was in the morning with a

concentration of 973 µg/m3, and the lowest was during the afternoon measurement at 115 µg/m3, with an average measurement result of 442.667 µg/m3. The average CO concentration at point 3 was 156.667 µg/m3, with the highest concentration in the morning at 332 µg/m3, when the temperature was 35.7 °C and the wind speed was 1.2 m/s.

Table 5. Distribution of Exposure Duration for Vendors

Variabel	N	Mean	Median	SD	Min	Max
Number of Hours in a Day (Hours)	30	11,40	12,00	3,549	6	18

Table 5 shows that out of a total of 30 respondents, the average exposure time was 11.40 hours, with the shortest exposure time being 6 hours and the longest being 18 hours. The exposure time results were found to be non-normally distributed, so when the exposure time values were entered into the intake formula, the median value of 12 hours was used.

Table 6. Frequency Distribution of Merchant Exposure

Variabel	N	Mean	Median	SD	Min	Max
Number of Days in a Year (Days)	30	354,93	365,00	21,014	309	365

Table 6 shows that the average exposure frequency for traders is 354.93 days per year, with the lowest frequency being 309 days and the highest being 365 days per year. The results of exposure frequency were also found to be non-normally distributed, so when the exposure frequency value is entered into the intake formula, the value used is the median value of 365 days.

Table 7. Distribution of Trader Exposure Duration

Variabel	N	Mean	Median	SD	Min	Max
Length of stay (Years)	30	13,90	10,00	12,030	1	33

Table 7 shows that the average length of stay for traders at Bersehati Market is 10 years, with the longest stay being 33 years and the shortest being 1 year. Similar to the length of exposure and frequency of exposure, the value that will be used later in the formula is the median value of 10 years because the values are not normally distributed.

Table 8. Real-Time Intake and Lifetime Intake

Value Size	**CO Intake *Real Time***	**CO Intake *Life Time***
Minimum	0,008093	0,000347
Maximum	0,023136	0,029747
Average	0,018053	0,009556
Interval	0,015044	0,0294
Median	0,022929	0,007283

Table 8 shows that the real-time intake value has an average value of 0.018 mg/kg/day, while the average lifetime intake value is 0.009 mg/kg/day. The real-time CO intake value ranges from 0.008 to 0.23 mg/kg/day, while the lifetime value ranges from 0.003 to 0.029 mg/kg/day. The inhalation rate in this study uses a default value of 0.83 m^3.

Table 9. Distribution of Real-Time and Lifetime RQ Values

Value size	**RQ *Real Time***	**RQ *Life Time***
Minimum	0,00975	0,000418
Maximum	0,027875	0,035839
Average	0,02175	0,011513
Interval	0,018125	0,035421
Median	0,027625	0,008775

Table 9 shows that the average real-time RQ value is 0.021 mg/kg/day, while the average lifetime RQ value is 0.011 mg/kg/day. The table also shows that all values indicate an RQ < 1, which means there is no risk.

DISCUSSION

Hazard Identification

The first step in ARKL is hazard identification, which is the process of recognizing various potential threats that can impact individuals or communities in the surrounding environment. These threats can be factors that cause environmental damage, injury, or health problems. One example of a hazard that can affect health is air pollution. Air pollution has various negative effects on health. People who are vulnerable and sensitive to pollution are those who are exposed to air pollution every day, even at low levels. Several studies have shown that fine particles can cause more serious diseases when they enter the body, because these particles are able to penetrate the respiratory tract to the inner parts and easily enter the bloodstream.

According to the WHO, there are six main types of air pollutants, namely particulate matter, ozone, carbon monoxide, sulfur oxides, nitrogen oxides, and lead. Air pollution can damage the environment, such as groundwater, soil, and air, and pose a serious threat to living things. This study focuses on carbon monoxide (CO) because the research location is in a densely populated city

center. The large number of vehicles causes the concentration of CO in the air to be quite high, especially because vehicle exhaust gases accumulate at one point, namely the major intersection where the research was conducted.

In this study, carbon monoxide (CO) concentrations were measured for one hour at three points at three different times of the day, namely morning, afternoon, and evening. Measurements were taken at the edge of the highway using a carbon monoxide meter mounted on a 1.5-meter-high support 2 meters from the road. This method follows the guidelines of Minister of Environment Regulation No. 12 of 2010 concerning Air Pollution Control in the region and SNI 19-7119.9-2005 concerning the determination of sampling locations for air quality monitoring on the side of the road.

From the results of research conducted at three points at three times (morning, afternoon, evening) for 1 hour at Bersehati Market in Manado, it was found that the average concentration of carbon monoxide (CO) was 348.667 µg/m³, with the highest concentration of 973 µg/m³ occurring at point 2 during the morning measurement. Meanwhile, the lowest concentration was found at point 3 during the afternoon measurement, with a CO concentration of 23 µg/m³. When compared to the carbon monoxide (CO) threshold value according to Government Regulation (PP) No. 41 of 1999, the average carbon monoxide (CO) measurement at Bersehati Market in Manado did not exceed the specified threshold of 30,000 µg/m³ for 1-hour measurements. Carbon monoxide (CO) concentrations affect the exposure values or risks obtained by shoe sole workers at the research location.

Dose-Response Analysis

Dose-response analysis is a method used to determine the threshold of a substance in causing toxic effects. This process aims to assess the extent to which a substance has the potential to cause negative impacts on human health, especially for individuals exposed to it in the environment. For non-carcinogenic effects through inhalation or the respiratory system, this dose-response value is expressed in the form of a Reference Concentration (RfC).

In this study, the dose-response value (RfC) used is 0.83 mg/kg/day. The RfC value is not specifically determined, which means that the default value provided can be used. Similar to this study, there is a study by Dofendra (2023) that uses an RfC value of 0.826899 mg/kg/day, where the threshold value for carbon monoxide (CO) concentration refers to Government Regulation No. 22 of 2021 concerning the implementation of environmental protection and management, which is 10,000 µg/m³.

Exposure Analysis

Exposure analysis was conducted based on carbon monoxide (CO) concentration data, activity patterns, and anthropometric characteristics of respondents, such as body weight (Wb), daily exposure time (tE), exposure frequency (fE), and exposure duration (Dt). The results of this analysis are referred to as Intake, which serves to determine the level of risk in the risk characterization stage.

a. Exposure time
   Traders at Bersehati Market in Manado are exposed to 12 hours of sunlight per day. Based on interviews, on average, traders start work at 6:00 a.m. WITA and finish at 5:00 p.m. WITA. The study also found that the average working hours for traders is 11.40 hours/day, which exceeds the US-EPA standard for ideal working hours of 8 hours/day.
b. Exposure Frequency
   In Table 15, we can see that the exposure frequency in this study is 365 days, with workers spending an average of 354.93 days per year at work. This study is similar to the study conducted by Pamungkas Rionaldo et al. (2017), in which the frequency of exposure for workers was 365 days with the lowest frequency of exposure being 156.43 days.
c. Duration of Exposure
   The length of employment was calculated from the first year of employment until the time of the study. Based on Table 16, this study had an exposure duration of 10 years with an average exposure duration of 13.90 years. Each study had a different exposure duration, as was the case in the study conducted by Chairunissa (2022), where the exposure duration of workers only reached 5 years.
d. Intake
   Personal exposure concentration (intake) of CO is the amount of CO concentration received and entering the human body with an average sample per body weight (kg) per day. In calculating this intake, three calculations will be distinguished according to the measurement point of CO air concentration at Bersehati Market in Manado. In this study, non-carcinogenic intake was calculated based on the length of time traders remained at the location or sold at Bersehati Market in Manado until this study was conducted and projected intake for the next 70 years (lifespan).

In this study, the highest average real-time intake value was 0.023 mg/kg/day, while the lowest real-time intake value was at point three with a value of 0.008 mg/kg/day. Meanwhile, the highest lifetime intake value for the 70-year projection was 0.029 mg/kg/day. All real-time and lifetime intake values obtained were still below the RfC value (0.83). The real-time intake value in this study was still lower than that in the study conducted by Chairunnisa (2022), where the real-time intake was 0.5145 mg/kg/day and the lifetime intake was 1.9119 mg/kg/day.

Risk Characteristics

Risk characteristics were assessed to determine the extent of risk to respondents from exposure to carbon monoxide (CO). This was done using the Risk Quotient (RQ) formula, which compares the intake or exposure value of respondents with the response dose (RfC) value. The risk values calculated are for real-time exposure risk and lifetime risk (30 years).

The risk category can be determined from the Risk Quotient (RQ) value. If RQ < 1, the respondent is considered not at risk and does not need to be controlled, but all conditions must be maintained so that the RQ value does not

exceed 1. If the RQ value is ≥ 1, the respondent is at risk or at higher risk and needs to be controlled so that the value does not exceed the threshold.

The results of calculations conducted on traders at Bersehati Market in Manado show that the highest risk characteristic has a value of 0.02788. However, this value is still below the standard RQ value, which means that of the 30 respondents, none are at risk. Similarly, the lifetime RQ value up to a projection of 70 years in the future does not pose a risk because the RQ value is still below 1.

This study is in line with research conducted by Wahyuni et al. (2018), in which the average risk characterization (RQ) value was 0.037 (real-time) and 0.104 (lifetime), indicating that the risk characterization (RQ) value of 46 street vendor respondents on Setiabudi Street, both real-time and lifetime, was RQ ≤ 1, meaning it was still in the non-carcinogenic health risk category.

In contrast to this study is the research by Anggelina et al. (2022), where the RQ calculation results for all respondents showed that 116 respondents (80%) had an RQ ≤ 1, meaning that CO concentrations were less risky to the health of respondents, and 29 respondents (20%) had an RQ > 1, meaning that CO concentrations were risky to the health of respondents/street vendors.

The magnitude of risk is influenced by many factors, including carbon monoxide (CO) concentration, body weight, daily exposure duration, exposure frequency, and exposure duration. The RQ value is influenced by the intake of each respondent based on exposure pattern data and respondent anthropometry. Differences in exposure patterns in terms of concentration and duration affect the intake received by respondents. Based on the RQ calculation results, the longer the exposure duration of the respondents, the greater the intake of those respondents. As a result, the greater the health risk due to the CO gas exposure received by the respondents.

CONCLUSION AND RECOMMENDATION

The conclusion of this study is that the average CO concentration is 348.67 µg/m³ and the highest risk characterization (RQ) value is 0.2788 (real-time) and 0.1151 (lifetime), indicating that the risk characterization (RQ) values of the 30 merchant respondents at Pasar Bersehati Manado, both in real-time and lifetime, are RQ ≤ 1, meaning they are still in the non-carcinogenic health risk category.

ACKNOWLEDGMENTS

The author would like to thank Pasar Bersehati Kota Manado for granting permission to conduct this research, as well as the respondents who voluntarily participated in this study. The author would also like to thank the Faculty of Public Health, Sam Ratulangi University, Manado, for their support in conducting this research.

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