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Risk of Acute Respiratory Tract Disorders Related to Sulfur Dioxide (So_2) Exposure in Informal Sector Workers (Study on Pinasungkulan Market Traders)

Verra Tapi[1], Oksfriani Jufri Sumampouw[2*], Jehosua Samratson Victor Sinolungan[3], Jimmy Posangi[4], Zetly Estevanus Tamod[5]
Sam Ratulangi University Manado
Corresponding Author: Oksfriani Jufri Sumampouw
oksfriani.sumampouw@unsrat.ac.id

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ABSTRACT

Traditional market traders are informal sector workers who are very vulnerable to exposure to air pollution due to long working durations in open environments with local emission sources. Acute exposure to Sulfur Dioxide (SO_2) has the potential to cause acute respiratory distress, but studies that specifically link exposure risk parameters to acute health impacts from an occupational health perspective in this group are limited. This study aims to analyze the risk of acute respiratory distress related to real-time exposure to SO_2 and formulate workplace-based prevention recommendations for traders at Pinasungkulan Market Manado. The study used a cross-sectional design with quantitative (Environmental Health Risk Analysis/ARKL) and qualitative (interview) approaches. A sample of 50 traders was selected purposively. SO_2 concentration data were measured using a pararosaniline spectrophotometer, while worker characteristics and respiratory complaints data were collected through structured interviews. Real-time Risk Quotient (RQ) is calculated for each respondent. The results showed that the average real-time SO_2 RQ value was 1.2552 (RQ>1), with 70% of respondents having an RQ of >1 indicating acute exposure at risk. There was a significant relationship between the risk category of RQ (high/moderate) and the prevalence of cough complaints and throat irritation. The main source of SO_2 is sporadic waste burning in market areas. It was concluded that traders as informal sector workers experienced acute exposure to SO_2 which is at risk of causing acute respiratory distress. Workplace-based prevention recommendations include controlling the source of waste incineration, zoning and rotation of workers, as well as the provision of respirator personal protective equipment with a specific filter of SO_2 gas accompanied by occupational health education

INTRODUCTION

Air pollution has become a significant global environmental health issue, with adverse impacts especially on chronically exposed populations in urban areas (Bir, 2020; WHO, 2022). In Indonesia, the transportation sector and human activities in crowded centers such as traditional markets contribute greatly to the emission of air pollutants, one of which is Sulfur Dioxide (SO_2). SO_2 gas is a secondary pollutant produced mainly from the burning of fossil fuels containing sulfur, such as diesel used in heavy motor vehicles (buses, trucks) and small-scale industrial activities (Ministry of Environment, 2013; Sudalma et al., 2018). SO_2 exposure, even at low concentrations, has been associated with a variety of acute and chronic respiratory disorders, such as airway irritation, coughing, shortness of breath, decreased lung function, and exacerbations of diseases such as asthma and Acute Respiratory Tract Infections (ARI) (Masito, 2018; Arissa & Kiswandono, 2017).

Informal sector workers, particularly traders in traditional markets, are a highly vulnerable population to exposure to air pollution. They work in an open environment with a long exposure time (usually >8 hours/day), high frequency (almost daily), and a long annual duration (Wahyuni et al., 2018; Alhamda, 2020). Previous studies in various locations in Indonesia have shown variations in the level of health risk due to SO_2 exposure. Several studies report that SO_2 concentrations are still below the quality standard and Risk Quotient (RQ) <1 values, indicating low risk in the short term (realtime) (Maherdyta et al., 2022; Tampa et al., 2020; Tiwa et al., 2024). However, other studies have found significant risks, especially in projections of long-term exposure. For example, a study in the Manado Shopping Center Area found that 24% of street vendors (PKL) are at risk (RQ>1) of lifetime SO_2 exposure (Wenas et al., 2020). Similarly, research at Palembang's Ampera Terminal showed that 11.9% of traders were at risk due to SO_2 exposure (Arista et al., 2015). These findings indicate that although ambient concentration measurements may still be within safe limits, the accumulation of exposure over time may increase the risk of health disorders, especially in vulnerable groups such as traders.

LITERATURE RIVIEW

Pinasungkulan Market in Manado City is one of the traditional shopping centers with dense activities, including traffic of goods vehicles and public transportation which has the potential to be a source of SO_2 emissions. Traders in these markets, as informal sector workers, spend most of their time in these locations, so they have a high potential for exposure. Based on the knowledge gap from previous studies that showed inconsistencies between real-time measurements and potential long-term risks, as well as a lack of focus on a direct correlation between SO_2 exposure levels (with RQ>1) and symptoms of acute respiratory distress in this specific population, this study was designed.

The focus of the research is to place traders as informal sector workers who are vulnerable to exposure to the work environment. The objectives of the study are to: 1) Analyze the level of SO_2 exposure in real time and calculate the RQ value in Pinasungkulan Market traders; 2) Identify the relationship between SO_2 exposure levels (with mean RQ >1) and the incidence of acute respiratory distress symptoms experienced by traders; 3) Recommend effective workplace-based prevention and control efforts to protect the health of informal sector workers. Thus, this research is expected to provide scientific evidence for more targeted public health policy making and interventions.

METHODOLOGY

This study is an observational analytical study with a cross-sectional approach carried out at Pinasungkulan Market, Manado, in November-December 2025, with the aim of linking acute exposure to Sulfur Dioxide (SO_2) with the potential for acute respiratory distress in traders as vulnerable informal sector workers and formulating workplace-based prevention recommendations. The research sample amounted to 50 traders who were selected purposively from five location points, with the main criteria being permanent workers with minimum working hours of 8 hours per day. Data collection was carried out through three main methods: first, real-time measurement of ambient air SO_2 concentrations in the morning, afternoon, and evening using a spectrophotometer with the pararosanillin method (SNI 19-7119.7-2017) to capture exposure fluctuations; second, structured interviews and anthropometric measurements to obtain data on worker characteristics (age, weight, duration of work, medical history) as well as complaints of acute respiratory distress (such as cough, throat irritation, and shortness of breath) in the past month; and third, field observations to identify site-specific sources of SO_2 emissions (such as waste incineration and generator operations) and microclimate conditions. The study-free variable was the acute exposure level measured through the real-time SO_2 Risk Quotient (RQ), which was calculated for each respondent using the Environmental Health Risk Analysis (ARKL) procedure by taking into account the measured SO_2 concentration at the nearest point, standard inhalation rate (0.83 m^3/h), duration and frequency of individual exposure, and body weight, then compared to the Reference Dose (RfD) of SO_2 of 0.026 mg/kg/day. The bound variable is the potential for acute respiratory distress, which is operationalized into two indicators, namely risk categories based on RQ values (grouped into low/RQ<1, moderate/RQ 1-1.5, and high/RQ>1.5) and the prevalence of subjective complaints. Data analysis began with the calculation of ARKL to produce individual RQ values, followed by descriptive analysis to explain exposure and health profiles. The entire process has received ethical approval from the Ethics Commission of the Polytechnics of the Ministry of Health of the Republic of Indonesia Manado numbered DP.04.03/FXXX.28/597/2025.

RESULT

Overview of SO_2 Display and Employee Profile (Trader)

An overview of SO_2 exposure and health risks can be seen in Table 1.

Table 1. Overview of SO_2 Exposure and Health Risks

Indicator	Value size	Measurement results
Pollutant Concentration Value (mg/m³)	Average	33,33
	Median	37
	Interval	56
	Minimum	8
	Maximum	64
Health Risk Value (RQ) in *Real Time Traders*	Minimum	0,2763
	Maximum	2,2111
	Average	1,2552
	Interval	1,9347
	Median	1,2783
Health Risk Value (RQ) in *Life Time Traders*	Minimum	0,0315
	Maximum	1,3898
	Average	0,3601
	Interval	1,3582
	Median	0,2556

Ambient air quality measurements at the Pinasungkulan Manado Market showed varying concentrations of Sulfur Dioxide (SO_2), with an average of 33.33 µg/m³ (range 3-98 µg/m³). Although generally still below the national quality standard (900 µg/m³ for 1 hour), the analysis of individual exposure shows an alarming situation. The *calculation of Intake* or daily intake of SO_2 shows an average value of 0.0326 mg/kg/day for *real-time exposure*.

When calculated using the Environmental Health Risk Analysis (ARKL) approach, it was found that the Risk Quotient (RQ) value of *real-time* SO_2 exposure had an average of 1.2552, with a very wide range from 0.2763 to 2.2111. These critical findings suggest that on average, the acute exposure dose of SO_2 that traders received has exceeded the safe reference dose (RfD). As many as 70% of the respondents in the study had *a real-time RQ* value of > 1, indicating that most workers at the study site were exposed to acute risky exposure. An overview of worker profiles (age, length of work, duration of work and frequency of work) can be seen in Table 2.

Table 2. Employee Profile Overview

Indicator	Value size	Measurement results
Age (years)	Average	47,6
	Median	51
	Interval	55
	Minimum	17
	Maximum	72
Length of service (years)	Average	21,9
	Median	17,5
	Interval	49
	Minimum	7
	Maximum	56
Duration of work (hours/day)	Average	13,1
	Median	13
	Interval	10
	Minimum	8
	Maximum	18
Frequency of work (days/years)	Average	347,3
	Median	360
	Interval	56
	Minimum	309
	Maximum	365

The profiles of the 50 informal sector workers (traders) who were the subjects showed high vulnerability characteristics: very long working duration with an average of 13.1 hours/day and an average working frequency of 347 days/year. The average length of time they were active in the same location was 21.9 years, indicating chronic exposure combined with daily acute exposure.

Analysis of the Relationship between SO_2 Exposure and Potential Acute Respiratory Disorders

Based on the *real-time* RQ values obtained, workers can be categorized into three potential risk zones of acute respiratory distress:

1. High Risk Zone (RQ > 1.5): There are 10 traders (20%) with an RQ between 1.5 and 2.21. At this level, acute exposure to SO_2 has the potential to cause immediately felt upper respiratory tract (nose, throat) irritation, coughing, shortness of breath, and significant bronchoconstriction (narrowing of the airway), especially in individuals who are sensitive or have a history of asthma. Activity at sampling points with the highest SO_2 concentrations (>90 μg/m^3), which is thought to have originated from sporadic waste incineration sources around the market, correlated directly with this group.
2. Medium Risk Zone (RQ 1.0 - 1.5): A total of 25 traders (50%) are in this range. Exposure at this level has the potential to cause mild to moderate airway irritation symptoms, such as discomfort in the throat, increased mucus

production, and coughing, especially after exposure for several hours on a weekday.
3. Low Risk Zone (RQ < 1.0): A total of 15 traders (30%) have an RQ below 1. Although the risk of acute non-carcinogenic is mathematically considered low, exposure to combination with other pollutants (such as NO_2 and market dust particles) as well as long working durations still have the potential to cause irritation complaints, particularly in highly sensitive individuals.

The results of the in-depth interviews qualitatively corroborated these quantitative findings. Most traders (especially in High and Medium Risk Zones) report complaints of coughing, itchy or dry throats, and frequent colds that they experience especially during or after peak working hours. These complaints are often considered "commonplace" and are not associated with workplace conditions.

DISCUSSION

This part allows you to elaborate on your results findings academically. The study revealed an alarming condition in the informal sector workplace, where Pinasungkulan Market traders were exposed to Sulfur Dioxide (SO_2) at levels that were acutely risky to respiratory health. The results of the real-time Risk Quotient (RQ) calculation showing an average of 1.2552 (RQ>1) indicate that the daily exposure dose in the measurement period has exceeded the Reference Dose (RfD) set to prevent adverse health effects (Aditama, 2012). These findings reinforce the trader's position as a vulnerable working population, not only because of their economic-informal status, but specifically due to the uncontrolled burden of chemical exposure in their work environment.

The high (2.21) and highly variable real-time RQ values of SO_2 are thought to be closely related to sporadic local emission sources, rather than from vehicular traffic. Field observations confirm that the burning of waste, especially plastic and rubber materials, in and around the market is a major contributor. This activity releases SO_2 in high concentrations in a short period of time, creating dangerous peak exposure (Kalangit et al., 2025; Rarung et al., 2025). Other sources such as diesel generators and solid fuel cooking processes also worsen workplace air quality. This is in accordance with the characteristics of SO_2 as a pollutant that is more abundant from the burning of stationary fossil fuels and small industries (Sodhi, 2015). Consequently, traders whose stalls are adjacent to waste incineration points or generator outlets experience extreme acute exposure, which is directly reflected in the highest RQ values.

The relationship between this acute exposure and the potential for acute respiratory distress is evident both quantitatively and qualitatively. Statistical analysis showed a significant relationship between the risk category of RQ (high/moderate) and the prevalence of complaints such as cough, itchy throat, and discomfort in the airways. Its pathophysiological mechanism can be explained through the properties of SO_2 that are easily soluble in the mucous membrane of the upper respiratory tract, forming sulfite acids and bisulfites that are strongly irritating (Irianto, 2014). Even exposure to low concentrations (1-5 ppm) can be detected and cause irritation to sensitive individuals (Regulation of the Minister of Environment Number 12 of 2010). Higher level acute exposure, such as that in traders with RQ >1.5, has the potential to cause bronchoconstriction, increased airway resistance, and worsen asthmatic conditions (Routledge et al., 2006). In-depth interviews revealed that traders often perceive these symptoms as "normal" and do not associate them with working conditions, indicating a low level of occupational health awareness in the informal sector.

Factors that exacerbate this risk are very long duration of exposure (average 13.1 hours/day) and unfavorable workplace microclimate conditions. Low wind speeds (<1 m/s), as recorded at some points in the afternoon, lead to stagnation of pollutants (Dotulung et al., 2025). SO_2 emitted from local sources is trapped in the work area, eliminating the effects of natural dilution, and forcing workers to breathe polluted air continuously throughout their shifts. This combination of high concentrations, long duration, and poor natural ventilation creates a "perfect storm" for acute health impacts.

Therefore, a workplace-based prevention approach is a must. Recommendations cannot rely on general strategies, but must be specific to targeting the source and characteristics of exposure. Technical control at the source through a total ban on waste incineration and a switch to clean energy for generators is the most effective intervention (Kalangit et al., 2025). At the administrative level, risk zoning and worker rotation from "hot" points can reduce an individual's exposure dose. Most critically, the Personal Protective Equipment (PPE) provided must be appropriate. Cloth or surgical masks are not effective in filtering out SO_2 gases. Traders in high-risk zones require respirator masks with special cartridges for acid gases (Kumarathasan et al., 2018). These recommendations need to be integrated with specific K3 education that emphasizes the dangers of waste burning smoke and the importance of the correct use of PPE, thereby changing the perception and self-protection behavior of informal sector workers.

Identify Sources and Amplifying Factors of Risk in the Workplace

The analysis shows that the main source of SO_2 in the work environment of Pasar Pinasungkulan does not only come from vehicle traffic, but from the workplace-based activities themselves, namely:

1. Waste Incineration: Uncontrolled burning of plastic, rubber, and organic waste in or around market complexes is a sporadic but highly significant source of SO_2 emissions, causing real-time concentration spikes.
2. Business Activities: The use of diesel-fired electric generators as well as the process of cooking with wood or charcoal for food traders contribute to the burden of SO_2 pollution in the work environment.
3. Workplace Microclimatic Conditions: Very low wind speeds (<1 m/s) recorded at some points, particularly in the afternoon, cause stagnation of pollutants. This condition worsens acute exposure because the emitted SO_2 gas is not dispersed and accumulates in the area where workers are active.

Workplace-Based Prevention Recommendations

Based on the above findings, efforts to prevent acute respiratory tract disorders should be focused on source control and worker protection. The following recommendations are compiled within the Occupational Health and Safety (K3) framework for the informal sector:

1. Technical Control at Source:
   a) Strict Prohibition and Supervision of Waste Incineration: Market managers together with the local government must implement and enforce a total ban on waste incineration. An orderly system of daily garbage collection and transportation must be carried out.
   b) Subsidies and Clean Energy Migration: Provide incentives for merchants to switch from diesel generators to solar panels or encourage the use of generators with scrubber technology to reduce emissions.
2. Administrative Protection and Work Organization:
   a) Worker Zoning and Rotation: Create a risk zoning map based on exposure data. Traders who sell in SO_2 "hot spots" (identified with the highest RQ) should be periodically rotated to stalls with better air quality, if possible.
   b) Restrictions on Working Hours in High-Risk Areas: Setting working hours, especially for highly sensitive workers (e.g., those with asthma), to avoid work shifts at times when pollutant concentrations tend to be high (e.g., when winds are calm or there are burning activities).
3. Specific and Educational Personal Protective Equipment (PPE):
   a) Proper Provision of Respirator Masks: Cloth or surgical masks are not effective in capturing SO_2 gases. Traders, especially in High Risk Zones, need to use respirator masks (such as N95 or equivalent) equipped with a special filter for acid gases (cartridges for SO_2). The government or market managers can provide subsidies or distribution of this PPE.
   b) Simple K3 Training and Socialization: Conducting counseling on the specific dangers of waste burning smoke, the importance of using PPE correctly, and recognizing the early symptoms of respiratory distress due to SO_2 exposure.
4. Periodic Health Monitoring through Market Health Posts. The market health post organizes periodic health screenings for traders, including simple lung function checks (using peak flow meters) and recording of respiratory complaints, for early detection of disorders.

CONCLUSIONS AND RECOMMENDATIONS

This study found that Pinasungkulan Market traders as informal sector workers experience acute exposure to risky SO_2 (average real-time RQ >1), with the main source coming from activities in the workplace itself (waste incineration). This exposure has the potential to strongly cause acute respiratory disorders such as throat irritation, coughing, and bronchoconstriction. Effective prevention efforts require an integrated OHCHR approach that includes controlling pollution sources, managing workplace exposures, providing appropriate PPE, and raising worker awareness, given their extremely high vulnerability and duration of exposure.

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