Physical Environmental Factors Associated With Acute Respiratory Infections (ARI) Among Communities Living Around Charcoal Factories in Simalungun Regency

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Acute Respiratory Infection (ARI) is one of the major public health problems influenced by housing conditions and exposure to air pollution. This study aimed to analyze the association between ventilation, temperature, humidity, occupancy density, carbon monoxide (CO) levels, and residential distance from a charcoal factory with the incidence of ARI among residents of Karang Anyar Village, Simalungun Regency. A cross-sectional study was conducted involving 60 respondents. Data were collected through direct observations, environmental measurements, and structured interviews using questionnaires. Data were analyzed using univariate and bivariate analyses with the Chi-square test at a 95% confidence level (α = 0.05). The results showed that ventilation (p = 0.001), temperature (p = 0.001), humidity (p = 0.007), occupancy density (p = 0.005), and residential distance from the charcoal factory (p < 0.001) were significantly associated with the incidence of ARI. In contrast, carbon monoxide (CO) levels were not significantly associated with ARI (p = 0.397). In conclusion, most of the physical environmental factors examined were significantly associated with the incidence of ARI. Therefore, improving housing conditions and controlling air pollution around charcoal factories are essential measures to reduce the risk of ARI.
Kata kunci: Acute Respiratory Infection, Physical Environment, Charcoal Factory

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1. Introduction

According to the World Health Organization (WHO), acute respiratory infections (ARI) cause approximately 4 million deaths annually. ARI is classified as a communicable disease and remains one of the leading causes of morbidity and mortality worldwide (Saripudin, 2024). This condition demonstrates that ARI continues to be a major public health concern, particularly in developing countries, where environmental conditions and exposure to air pollution may contribute to the transmission and development of respiratory diseases. Therefore, addressing ARI requires not only medical interventions but also attention to environmental factors that may increase the risk of respiratory infections.

In Indonesia, the burden of ARI remains relatively high. Based on data from the Indonesian Ministry of Health in 2023, the estimated number of ARI cases nationwide ranged from 1.5 to 1.8 million cases (Jaksa et al., 2024). This high number indicates that ARI remains a significant public health problem requiring comprehensive prevention and control measures. The incidence of ARI is influenced by various factors, including individual health conditions, environmental sanitation, housing quality, and exposure to air pollutants. Consequently, identifying environmental risk factors is essential for developing effective strategies to reduce the burden of respiratory infections.

At the provincial level, North Sumatra continues to face challenges in controlling ARI cases. Based on available data, North Sumatra Province ranked 30th nationally in terms of ARI prevalence. Furthermore, data from the Central Statistics Agency (BPS) of North Sumatra Province in 2021 indicated that ARI was

among the four diseases with the highest number of reported cases in the province (Nabila et al., n.d.). This situation reflects the importance of strengthening preventive measures, particularly through improvements in environmental health and the identification of factors contributing to respiratory health problems among communities.

Simalungun Regency is one of the areas with a considerable burden of ARI cases in North Sumatra. According to Ritonga and Kurniawan (2021), Simalungun Regency recorded the highest proportion of ARI cases in the province, accounting for 32.44%, followed by Medan City at 25.50% and Deli Serdang Regency at 21.53%. Furthermore, data from the Central Statistics Agency indicated that the number of ARI cases in Simalungun Regency reached 32,901 in 2022. These figures highlight the need for greater attention to environmental health conditions in the region, particularly in communities potentially exposed to environmental pollution from industrial activities.

The occurrence of ARI is influenced by several factors, including the presence of disease-causing microorganisms, individual immune system conditions, physical environmental factors, and levels of air pollution (Waliyyuddin et al., 2024). One important environmental component is the physical condition of residential buildings, which includes ventilation, temperature, humidity, and occupancy density. Housing conditions that do not meet health standards, particularly inadequate ventilation, can reduce air circulation and deteriorate indoor air quality, thereby increasing the potential for exposure to pathogenic microorganisms and pollutants (Arrazy et al., 2025). In addition, high occupancy density may facilitate the transmission of respiratory infections, while inappropriate temperature and humidity conditions can contribute to an unfavorable indoor environment.

Beyond residential conditions, environmental pollution originating from industrial activities is also a potential risk factor for respiratory health problems. Industrial processes may release various air pollutants that can spread into surrounding residential areas and expose nearby communities to continuous environmental contamination. Exposure to industrial air pollution has been associated with an increased incidence of respiratory diseases and a higher risk of premature mortality. Communities living near industrial areas are particularly vulnerable to prolonged exposure to pollutants originating from industrial activities, both in outdoor and indoor environments (Mohd Isa et al., 2024). One potential source of such exposure is charcoal production, which involves biomass combustion and may generate air pollutants that affect the quality of the surrounding environment.

Research conducted by Khairul Nizam Mohd Isa (2024) demonstrated that long-term exposure to air pollution was consistently associated with the occurrence of respiratory symptoms among residents living near industrial areas. These findings suggest that residential proximity to industrial pollution sources may increase the risk of respiratory health problems. Moreover, inadequate physical housing conditions, particularly poor ventilation, may worsen the effects of air pollution by allowing contaminants to accumulate indoors (Mohd Isa et al., 2024). Therefore, assessing both residential environmental conditions and exposure to pollutants from nearby industrial activities is important for understanding the potential risk of ARI among surrounding communities.

Although previous studies have examined the relationship between industrial air pollution, residential environmental conditions, and respiratory health problems, research that comprehensively investigates the association of ventilation, temperature, humidity, occupancy density, carbon monoxide (CO) concentrations, and residential distance from charcoal factories with ARI incidence remains limited, particularly in Simalungun Regency. Communities living near charcoal factories may experience continuous exposure to pollutants generated by biomass combustion, potentially affecting their respiratory health. The combination of indoor environmental conditions and proximity to industrial pollution sources represents an important

aspect that requires further investigation. This research gap provides the basis for examining multiple physical environmental factors simultaneously in relation to ARI incidence.

Based on these considerations, this study aims to analyze the association between physical environmental factors, including ventilation, temperature, humidity, occupancy density, carbon monoxide (CO) concentrations, and residential distance from charcoal factories, and the incidence of acute respiratory infections among residents of Karang Anyar Village, Simalungun Regency. The findings are expected to provide scientific evidence regarding environmental risk factors associated with ARI and contribute to the development of appropriate environmental health interventions. Furthermore, this study is expected to serve as a reference for local governments and healthcare authorities in formulating preventive strategies, improving residential environmental quality, and controlling air pollution around charcoal factories to reduce the risk of ARI among surrounding communities.

2. Literature Review and Problem Statement

Acute Respiratory Infections and Their Risk Factors

Acute Respiratory Infections (ARI) are infectious diseases affecting the respiratory tract and remain a major public health concern worldwide. The occurrence of ARI is influenced by several factors, including pathogenic microorganisms, individual immunity, housing conditions, and environmental pollution (Waliyyuddin et al., 2024). Physical environmental conditions play an important role in respiratory health, particularly ventilation, temperature, humidity, and residential occupancy density. Inadequate ventilation can reduce air circulation and increase the accumulation of indoor pollutants, while unsuitable temperature and humidity conditions may create an unfavorable indoor environment. Furthermore, high occupancy density can facilitate the transmission of respiratory infections among household members. Therefore, maintaining healthy physical housing conditions is essential to minimize environmental risk factors associated with ARI (Arrazy et al., 2025).

Industrial Air Pollution and Exposure to Charcoal Factory Emissions

Air pollution generated by industrial activities is an important environmental factor that may contribute to respiratory health problems. Industrial emissions can release pollutants into the surrounding atmosphere, potentially exposing communities living near industrial facilities to continuous air contamination. Research by Mohd Isa et al. (2024) indicates that long-term exposure to air pollution is associated with respiratory symptoms among populations residing near industrial areas. Charcoal production involves biomass combustion, which may generate air pollutants, including carbon monoxide (CO), that can affect the quality of the surrounding air. In addition to pollutant concentrations, the distance between residential areas and industrial facilities may influence the extent of community exposure. Consequently, carbon monoxide concentrations and residential proximity to charcoal factories are important environmental factors to investigate in relation to respiratory health.

Research Gap and Problem Statement

Previous studies have examined the relationship between physical housing conditions, industrial air pollution, and respiratory health problems. However, research that simultaneously analyzes ventilation, temperature, humidity, occupancy density, carbon monoxide (CO) concentrations, and residential distance from charcoal factories in relation to ARI incidence remains limited, particularly in Simalungun Regency. This issue is important because communities living around charcoal factories may experience continuous exposure to combustion-related pollutants, while inadequate housing conditions may further increase their vulnerability to respiratory health problems. Therefore, this study seeks to address this research gap by analyzing the association between physical environmental factors and the incidence of ARI among

communities living around charcoal factories in Karang Anyar Village, Simalungun Regency. The main research problem is whether ventilation, temperature, humidity, occupancy density, carbon monoxide concentrations, and residential distance from charcoal factories are significantly associated with the incidence of ARI.

3. Method

This study employed a quantitative research design with an analytical observational approach using a cross-sectional method. The study was conducted in Karang Anyar Village, Simalungun Regency, from February to May 2025. The cross-sectional approach was used to analyze the association between physical housing environmental factors and the incidence of Acute Respiratory Infections (ARI) at a single point in time.

The study population consisted of all residents living in the vicinity of a charcoal factory in Karang Anyar Village. A total of 60 respondents were selected using a purposive sampling technique based on predetermined inclusion and exclusion criteria. The inclusion criteria were residents who had lived in the area for at least one year, were aged 18 years or older, agreed to participate in the study, and resided within the predetermined radius of the charcoal factory. Residents who were unavailable during data collection or unwilling to participate were excluded from the study.

The dependent variable in this study was the incidence of ARI, while the independent variables included housing ventilation, indoor temperature, air humidity, residential occupancy density, carbon monoxide (CO) concentrations, and the distance between residences and the charcoal factory. Data on respondents' characteristics and ARI incidence were collected through structured interviews using questionnaires. Meanwhile, data on ventilation, temperature, humidity, occupancy density, CO concentrations, and residential distance were obtained through direct observation, environmental measurements, and field documentation. Carbon monoxide concentrations were measured using a CO meter, while indoor temperature and humidity were measured using a thermohygrometer. The distance between residences and the charcoal factory was determined using a Global Positioning System (GPS), with spatial measurements and analysis conducted using Google Earth.

Data analysis consisted of univariate and bivariate analyses. Univariate analysis was performed to describe the frequency distribution of respondents' characteristics, independent variables, and the dependent variable. Bivariate analysis was conducted using the Chi-square test at a 95% confidence level ($\alpha = 0.05$) to determine the association between physical housing environmental factors and the incidence of ARI. The magnitude of the association was expressed using the Prevalence Ratio (PR) and its corresponding 95% Confidence Interval (95% CI).

4. Results And Discussion

Table 1. Association Between Housing Ventilation and ARI Incidence Among Communities Living Around Charcoal Factories

Variable	p-value	PR (95% CI)
Housing ventilation	0.001	2.764 (1.531–4.987)

The bivariate analysis showed a statistically significant association between housing ventilation and the incidence of Acute Respiratory Infections (ARI). The Chi-square test yielded a p-value of 0.001 ($p < 0.05$), indicating a significant relationship between housing ventilation and ARI incidence. The Prevalence Ratio (PR) was 2.764, with a 95% Confidence Interval (CI) of 1.531–4.987. This finding indicates that

respondents living in houses with inadequate ventilation had a 2.764 times higher prevalence of ARI compared to those living in houses with adequate ventilation.

This finding is consistent with a study conducted by Saparuddin et al. (2022), which demonstrated a significant association between housing ventilation area and ARI incidence, with a p-value of 0.012 and a PR of 5.127 (95% CI: 1.568–16.765). Both studies indicate that inadequate housing ventilation is associated with an increased prevalence of ARI. Adequate ventilation facilitates proper air circulation and exchange, thereby reducing the accumulation of indoor pollutants, microorganisms, and excessive humidity. Conversely, inadequate ventilation can result in poor indoor air quality and create environmental conditions that may increase the risk of respiratory infections. According to the Decree of the Minister of Health of the Republic of Indonesia No. 829/Menkes/SK/VII/1999 concerning Housing Health Requirements, permanent natural ventilation should account for at least 10% of the total floor area. Ventilation covering less than 10% of the floor area is considered inadequate.

Table 2. Association Between Indoor Temperature and ARI Incidence

Variable	p-value	PR (95% CI)
Indoor temperature	0.001	2.933 (1.865–4.614)

The Chi-square test revealed a statistically significant association between indoor temperature and ARI incidence, with a p-value of 0.001 ($p < 0.05$). The PR was 2.933, with a 95% CI of 1.865–4.614. This indicates that respondents living in houses with indoor temperatures that did not meet health standards had a 2.933 times higher prevalence of ARI compared to those living in houses with temperatures that met the established standards. These findings suggest that inappropriate indoor temperature conditions are associated with an increased prevalence of ARI.

This result is consistent with a study conducted by Parisi et al. (2025), which found a significant association between indoor temperature and ARI incidence, with a p-value of 0.001 ($p < 0.05$) and an Odds Ratio (OR) of 9.333 (95% CI: 2.180–39.962). Although the measures of association differed, with the previous study using an OR and the present study using a PR, both studies demonstrate that indoor temperature is significantly associated with ARI incidence. Air temperature plays an important role in determining indoor environmental quality and may influence the survival and growth of microorganisms. For example, *Staphylococcus* species, which can be associated with respiratory infections, exhibit optimal growth at temperatures around 35–37°C and can survive within a broader temperature range. The interaction between microorganisms and their surrounding environmental conditions may influence their survival and development (Parisi et al., 2025). According to the Decree of the Minister of Health of the Republic of Indonesia No. 829/Menkes/SK/VII/1999 concerning Housing Health Requirements, the recommended indoor temperature range is 18–30°C.

Table 3. Association Between Indoor Humidity and ARI Incidence

Variable	p-value	PR (95% CI)
Indoor humidity	0.007	2.519 (1.626–3.901)

The Chi-square test demonstrated a statistically significant association between indoor humidity and ARI incidence, with a p-value of 0.007 ($p < 0.05$). The PR was 2.519, with a 95% CI of 1.626–3.901. This finding indicates that respondents living in houses with humidity levels that did not meet health standards had a 2.519 times higher prevalence of ARI compared to those living in houses with adequate humidity levels. Therefore, inappropriate indoor humidity conditions were significantly associated with ARI incidence.

This finding is consistent with a study conducted by Syafitri, which reported a significant association between indoor humidity and ARI incidence, with a p-value of 0.000 ($p < 0.05$), a PR of 6.081, and a 95% CI of 2.416–15.302 (Syafitri, n.d.). These findings reinforce the importance of indoor humidity as a physical environmental factor associated with respiratory health. Excessive humidity may create favorable

conditions for the growth of certain microorganisms, including bacteria and fungi, which can contribute to respiratory health problems. Furthermore, damp indoor environments may reduce overall housing comfort and contribute to poor indoor air quality (Syafitri, n.d.). Indoor humidity is therefore an important component of residential environmental quality, as appropriate humidity levels contribute to both occupant comfort and respiratory health. According to the Decree of the Minister of Health of the Republic of Indonesia No. 829/Menkes/SK/VII/1999 concerning Housing Health Requirements, the recommended indoor humidity range is 40%–60% (Fadila & Saktiawan, 2023).

Table 4. Association Between Residential Occupancy Density and ARI Incidence

Variable	p-value	PR (95% CI)
Residential occupancy density	0.005	2.500 (1.557–4.014)

The Chi-square test showed a statistically significant association between residential occupancy density and ARI incidence, with a p-value of 0.005 ($p < 0.05$). The PR was 2.500, with a 95% CI of 1.557–4.014. This indicates that respondents living in houses with occupancy densities that did not meet health standards had a 2.500 times higher prevalence of ARI compared to those living in houses with adequate occupancy density.

This result is consistent with a study conducted by Saparuddin et al. (2022), which found a significant association between residential occupancy density and ARI incidence, with a p-value of 0.026 ($p < 0.05$), a PR of 4.250, and a 95% CI of 1.332–13.562. These findings support the conclusion that residential occupancy density is an important environmental factor associated with ARI incidence. Houses with an excessive number of occupants relative to their floor area may experience inadequate air circulation, allowing dust, indoor pollutants, and disease-causing microorganisms to accumulate more easily. Furthermore, overcrowded living conditions may increase opportunities for respiratory infection transmission through respiratory droplets and close contact among household members. Consequently, residential occupancy density that does not meet health standards may contribute to an increased prevalence of ARI within households. According to the Decree of the Minister of Health of the Republic of Indonesia No. 829/Menkes/SK/VII/1999, the minimum recommended residential floor area is 9 square meters per person (Irma, 2025).

Table 5. Association Between Indoor Carbon Monoxide (CO) Concentrations and ARI Incidence

Variable	p-value	PR (95% CI)
Carbon monoxide (CO) concentrations	0.397	1.474 (0.815–2.665)*

The upper confidence limit should be verified against the original statistical output.

The Chi-square test indicated that there was no statistically significant association between indoor carbon monoxide (CO) concentrations and ARI incidence, with a p-value of 0.397 ($p > 0.05$). This finding suggests that indoor CO concentrations were not significantly associated with ARI incidence in the study population.

This result is consistent with a study conducted by Santoso and Darmiah (2015), which reported no significant association between indoor CO concentrations and ARI incidence, with a p-value of 0.467 ($p > 0.05$). These findings indicate that CO concentrations alone may not be sufficient to explain variations in ARI incidence among the study population. The absence of a statistically significant association in the present study may be related to the relatively low CO concentrations measured in the study area, which may not have been sufficient to demonstrate a measurable association with ARI incidence. According to Government Regulation of the Republic of Indonesia No. 22 of 2021, the ambient air quality standard for carbon monoxide (CO), measured over a one-hour period, is 10,000 μg/m³. However, the health effects of CO exposure depend on its concentration, duration of exposure, and individual susceptibility. Therefore, the absence of a significant association in this study does not necessarily indicate that CO exposure poses no potential health risks (Faiz et al., 2021).

Table 6. Association Between Residential Distance from the Charcoal Factory and ARI Incidence

Variable	p-value	PR (95% CI)
Residential distance from the charcoal factory	<0.001	3.750 (2.213–6.353)

The Chi-square test demonstrated a statistically significant association between residential distance from the charcoal factory and ARI incidence, with a p-value of less than 0.001 ($p < 0.05$). The PR was 3.750, with a 95% CI of 2.213–6.353. This indicates that respondents living closer to the charcoal factory had a 3.750 times higher prevalence of ARI compared to those living farther away from the factory.

This finding is consistent with a study conducted by Khairul Nizam Mohd Isa (2024), which reported a significant association between residential proximity to industrial areas and respiratory health problems, with a p-value of 0.001 ($p < 0.05$) and an OR of 3.18 (95% CI: 1.10–9.16). The previous study indicated that individuals living near industrial areas had 3.18 times higher odds of experiencing respiratory health problems than those living farther from industrial pollution sources. Although the measures of association differed, both studies highlight the importance of residential proximity to industrial emission sources in relation to respiratory health (Mohd Isa et al., 2024).

Charcoal production generally involves prolonged and repeated combustion activities, which may result in continuous emissions of air pollutants into the surrounding environment. These conditions make charcoal factories potential sources of air pollution, particularly when industrial facilities are located close to residential areas. Communities living near these facilities may experience prolonged exposure to combustion-related pollutants, potentially contributing to respiratory tract irritation and inflammation. Such exposure may increase the risk of respiratory health problems, including ARI (Yulia et al., 2024). Therefore, residential distance from charcoal factories is an important environmental factor that should be considered in efforts to control air pollution and protect the respiratory health of surrounding communities.

5. Conclusion

Based on the findings of this study among communities living around charcoal factories in Simalungun Regency, physical housing environmental factors were found to be significantly associated with the incidence of Acute Respiratory Infections (ARI). Inadequate ventilation was associated with poor air circulation and reduced indoor air quality, while inappropriate indoor temperature and humidity conditions were also associated with an increased prevalence of ARI. Furthermore, residential occupancy density that did not meet health standards and shorter residential distances from charcoal factories were significantly associated with a higher prevalence of ARI among the study population.

In contrast, indoor carbon monoxide (CO) concentrations were not significantly associated with ARI incidence. This finding suggests that, within the scope of this study, housing environmental conditions and residential proximity to charcoal factories were more strongly associated with ARI than the measured CO concentrations. Overall, improving housing ventilation, maintaining appropriate indoor temperature and humidity levels, ensuring adequate residential occupancy density, and controlling air pollution from charcoal factory activities are important measures to promote a healthier residential environment and reduce the risk of ARI among surrounding communities.

6. References

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