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Air Quality, Physical Housing Conditions, and Pulmonary Tuberculosis Risk in the Working Area of Tamalate Community Health Center, Makassar City

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Abstract

Background: Pulmonary tuberculosis (TB) remains a major public health problem in Indonesia. Environmental factors, including indoor air quality and physical housing conditions, may contribute to the transmission of TB in residential settings.

Objective: This study aimed to analyze the risk factors of air quality and physical housing conditions associated with the incidence of pulmonary tuberculosis in the working area of the Tamalate Community Health Center, Makassar City.

Methods: An observational analytic study with a case-control design was conducted from October 2024 to April 2025. The study involved 72 households, consisting of 36 pulmonary TB cases and 36 controls selected through simple random sampling. The variables examined were airborne bacterial counts, temperature, humidity, lighting, residential density, and ventilation. Data were collected through direct measurements and observations using environmental health instruments and analyzed using multiple logistic regression.

Results: The study found that lighting (OR=5.091; 95% CI=1.487–17.534) and residential density (OR=4.086; 95% CI=1.518–11.000) were significant risk factors for pulmonary tuberculosis. Meanwhile, airborne bacterial counts, temperature, humidity, and ventilation were not significantly associated with pulmonary TB incidence.

Conclusion: Inadequate lighting and overcrowded housing increase the risk of pulmonary tuberculosis. Improving housing conditions should be prioritized as part of environmental health-based tuberculosis prevention and control strategies.

Keywords: Pulmonary Tuberculosis, Air Quality, Housing Conditions, Residential Density, Environmental Health.

Introduction

Tuberculosis (TB) is a major infectious disease caused by Mycobacterium tuberculosis and transmitted through airborne droplets.[1] Globally, TB caused an estimated 10.6 million cases and 1.3 million deaths in 2022. Indonesia remains one of the highest-burden countries, contributing around 10% of global cases, with TB incidence increasing from 354 per 100,000 population in 2021 to 385 per 100,000 in 2022, and 821,200 new cases reported in 2023.

The burden of TB remains high in Makassar City, with cases increasing from 3,260 in 2020 to 6,677 in 2023. The Tamalate Community Health Center reported 183 pulmonary TB cases in 2024, indicating that TB continues to be a major health concern influenced by both biological and environmental factors, particularly housing quality and indoor air conditions.[2] The home environment plays a key role in TB transmission because people spend much of their time indoors. Poor housing conditions, such as inadequate ventilation, insufficient lighting, overcrowding, high humidity, and unsuitable temperatures, may increase the risk of Mycobacterium tuberculosis transmission.[3,4]

Indoor air quality is an important determinant of respiratory health and can be assessed through indicators such as airborne bacterial counts, temperature, humidity, and ventilation adequacy.[5] Poor indoor environmental conditions, including elevated airborne bacterial counts, inadequate lighting, and overcrowded housing, have been associated with an increased risk of pulmonary TB transmission.[6] A study reported that airborne bacterial counts were significantly associated with pulmonary TB incidence, while inadequate lighting and overcrowded housing have also been recognized as key factors contributing to TB transmission.[7]

Although numerous studies have examined individual housing factors associated with TB, limited research has comprehensively evaluated both indoor air quality indicators and physical housing conditions within the same analytical framework. Furthermore, evidence regarding the role of airborne bacterial counts as an environmental risk factor for TB remains limited, particularly in urban settings with high population density.[8] Therefore, a comprehensive assessment of indoor air quality and housing conditions is needed to better understand their contribution to TB occurrence. This study aimed to examine the relationship between indoor air quality, housing conditions, and pulmonary tuberculosis incidence in the working area of the Tamalate Community Health Center, Makassar City, to support environmental health interventions and TB prevention efforts.

Methods

This analytical observational study employed a case-control design to assess the association between indoor air quality, housing conditions, and pulmonary tuberculosis (TB) incidence. The study was conducted in the working area of Tamalate Community Health Center, Makassar City, Indonesia. The preparatory phase, including proposal development and data collection planning, was carried out from October to December 2024, while field data collection was conducted from March to April 2025.

The study population consisted of all registered pulmonary TB patients in the working area of Tamalate Community Health Center from January to November 2024, totaling 183 individuals. The study subjects were divided into two groups: a case group comprising individuals

diagnosed with pulmonary TB and a control group consisting of individuals without pulmonary TB residing in the same area.

The minimum sample size was calculated using the Lemeshow formula for unmatched case-control studies based on an Odds Ratio (OR) obtained from a previous study investigating housing lighting conditions and pulmonary TB. Using an OR of 3.889, a control exposure proportion (P2) of 0.38, a 95% confidence level, and 80% statistical power, the minimum sample size required was 36 subjects per group. Therefore, a total of 72 households were included in the study, consisting of 36 case households and 36 control households, with a case-to-control ratio of 1:1.

Samples were selected using simple random sampling, ensuring that each eligible individual had an equal probability of being selected. Inclusion criteria for the case group were individuals diagnosed with pulmonary TB and residing permanently in the study area, whereas controls were individuals without a history of pulmonary TB who lived in the same community.

The dependent variable was pulmonary TB incidence, while the independent variables included airborne bacterial count, indoor temperature, relative humidity, lighting intensity, occupancy density, and ventilation area. Primary data were collected through direct household observations, environmental measurements, and interviews using structured questionnaires. Secondary data were obtained from the South Sulawesi Provincial Health Office, Makassar City Health Office, and Tamalate Community Health Center records.

Environmental measurements were conducted using standardized instruments. Indoor temperature was measured using a thermometer, humidity using a hygrometer, and lighting intensity using a lux meter. Occupancy density and ventilation adequacy were assessed through direct observation and household measurements using standardized observation sheets. Airborne bacterial counts were determined using the settle plate method. Petri dishes containing nutrient agar were exposed at ear-height level inside the house for five minutes, incubated at 35–37°C for 24 hours, and the resulting colonies were counted using a colony counter. Results were expressed as colony-forming units and categorized according to applicable environmental health standards.

Data analysis was performed using IBM SPSS Statistics software. Univariate analysis was conducted to describe the distribution of each variable. Bivariate associations between independent variables and pulmonary TB incidence were assessed using logistic regression analysis. Variables with a p-value < 0.25 in the bivariate analysis were included in the multivariable logistic regression model using a stepwise selection procedure. Statistical significance was established at $p < 0.05$, and adjusted odds ratios (AORs) with 95% confidence intervals (95% CIs) were calculated to identify significant risk factors for pulmonary TB.

Ethical approval for this study was obtained from the Health Research Ethics Committee of Poltekkes Kemenkes Makassar with Ethical Exemption Certificate No. 0240/M.KEPK-PTKMS/II/2025. The ethical clearance was valid from February 26, 2025, to February 26, 2026. All participants provided informed consent before data collection, and confidentiality of participant information was strictly maintained throughout the study.

Results

A total of 72 respondents participated in this case-control study, consisting of 36 pulmonary tuberculosis (TB) cases and 36 controls without pulmonary TB. Overall, respondents were predominantly aged 26–35 years, male, and had completed senior high school education. The distribution of cases and controls was equal (1:1), as determined by the study design.

Table 1. Characteristics of Respondents in the Working Area of Tamalate Community Health Center, Makassar City

Characteristics	Category	Frequency (n)	Percentage (%)
Age (years)	15–25	12	16.7
	26–35	17	23.6
	36–45	11	15.3
	46–55	14	19.4
	56–65	10	13.9
	66–75	8	11.1
Gender	Male	39	54.2
	Female	33	45.8
Educational Level	No Schooling	0	0.0
	Elementary School	2	2.8
	Junior High School	14	19.4
	Senior High School	50	69.4
	College/University	6	8.3
Occupation	Civil Servant	1	1.4
	Private Employee	4	5.6
	Self-Employed	14	19.4
	Farmer	0	0.0
	Farm Laborer	0	0.0
	Casual Laborer	8	11.1
	Student	7	9.7
	Unemployed	8	11.1
	Others	30	41.7
Study Group	Pulmonary TB cases	36	50.0
	Controls (without pulmonary TB)	36	50.0

Table 1 shows the characteristics of 72 respondents, comprising 36 pulmonary tuberculosis cases and 36 controls. The majority were aged 26–35 years (23.6%) and male (54.2%). Most respondents had completed senior high school education (69.4%), while the largest occupational category was other occupations (41.7%), followed by self-employed workers (19.4%). The equal distribution of cases and controls (50.0% each) reflects the 1:1 ratio applied in the case-control study design.

Table 1 shows the characteristics of 72 respondents, consisting of 36 pulmonary tuberculosis cases and 36 controls without pulmonary TB. The majority of respondents were aged 26–35 years (23.6%) and were male (54.2%). Most respondents had completed senior high school education (69.4%), while the largest occupational category was other occupations (41.7%), followed by self-employed workers (19.4%). The equal distribution of pulmonary TB cases and controls (50.0% each) reflects the 1:1 ratio applied in the case-control study design.

Table 2. Bivariate Analysis of Air Quality and Physical Housing Conditions Associated with Pulmonary Tuberculosis Incidence in the Working Area of Tamalate Community Health Center, Makassar City

Variables	Category	Pulmonary TB n (%)	Non-Pulmonary TB n (%)	Total n (%)	p-value	OR (95% CI)
Airborne Bacterial Count	Not Eligible	0 (0.0)	0 (0.0)	0 (0.0)	NA	NA
	Eligible	36 (100.0)	36 (100.0)	72 (100.0)		
Temperature	Not Eligible	0 (0.0)	0 (0.0)	0 (0.0)	NA	NA
	Eligible	36 (100.0)	36 (100.0)	72 (100.0)		
Humidity	Not Eligible	3 (8.3)	5 (13.9)	8 (11.1)		0.564
	Eligible	33 (91.7)	31 (86.1)	64 (88.9)	0.458	(0.124–2.559)
Lighting	Not Eligible	14 (38.9)	4 (11.1)	18 (25.0)		5.091
	Eligible	22 (61.1)	32 (88.9)	54 (75.0)	0.010*	(1.487–17.534)
Residential Density	Not Eligible	26 (72.2)	14 (38.9)	40 (55.6)		4.086
	Eligible	10 (27.8)	22 (61.1)	32 (44.4)	0.005*	(1.518–11.000)
Ventilation	Not Eligible	33 (91.7)	31 (86.1)	64 (88.9)		1.774
	Eligible	3 (8.3)	5 (13.9)	8 (11.1)	0.458	(0.391–8.055)

** Statistically significant at p<0.05.*

NA: Not applicable / cannot be analyzed because all respondents were classified in the "Eligible" category, resulting in no exposure variation and preventing the calculation of odds ratios and p-values.

Table 2 shows that lighting and residential density were the only environmental factors significantly associated with pulmonary tuberculosis in the working area of Tamalate Community Health Center, Makassar City. Respondents living in houses with inadequate lighting had 5.091 times higher odds of pulmonary tuberculosis compared with those living in houses with adequate lighting (OR = 5.091; 95% CI: 1.487–17.534; p = 0.010), while respondents living in overcrowded houses had 4.086 times higher odds of pulmonary tuberculosis compared with those living in houses with eligible residential density (OR = 4.086; 95% CI: 1.518–11.000; p = 0.005). In contrast, humidity and ventilation were not significantly associated with pulmonary tuberculosis (p > 0.05). For airborne bacterial count and temperature, all respondents were classified in the eligible category, resulting in no exposure variation between pulmonary TB cases and controls; therefore, odds ratios and p-values could not be calculated, and the association of these variables with pulmonary tuberculosis could not be evaluated in this study. Overall, these findings suggest that inadequate lighting and overcrowded housing were the environmental conditions most strongly associated with pulmonary tuberculosis among the variables examined.

Discussion

Airborne bacterial count is widely recognized as an important indicator of indoor air quality because it reflects the concentration of microorganisms suspended in the air. In this study, all respondents' houses had airborne bacterial counts below the maximum permissible limit of 700 CFU/m³ established by the Indonesian Ministry of Health Regulation No. 2 of 2023[9]. Measurements were conducted in living rooms using the settle plate method with nutrient agar exposed at three sampling points for five minutes. Airborne bacterial count was not identified as a risk factor for pulmonary tuberculosis; however, this finding should be interpreted cautiously.[10] The main analytical limitation was the absence of exposure variation across the study groups, as

both case and control households were uniformly classified as meeting the regulatory standard. With little or no contrast in airborne bacterial count between groups, the study had limited ability to detect a statistical association with pulmonary tuberculosis.[11] Although environmental factors such as cleanliness, lighting, ventilation, and humidity can influence airborne microbial concentrations, the present data do not allow the conclusion that good household environmental conditions or clean and healthy living behaviors were responsible for the low bacterial counts.[12] The low bacterial counts observed in this study may indicate the implementation of clean and healthy living behaviors, such as regular house cleaning, maintaining good air circulation, opening windows routinely, and preventing excessive indoor dampness. Therefore, the findings indicate that airborne bacterial counts were consistently within the acceptable range in this study population, rather than demonstrating a protective effect against pulmonary tuberculosis.

Temperature was also not significantly associated with pulmonary tuberculosis incidence. The findings are consistent with previous studies that reported no significant relationship between indoor temperature and pulmonary tuberculosis occurrence.[13,14] Temperature is an important microclimate parameter that influences human thermal comfort and is affected by solar radiation, humidity, wind movement, and building characteristics.[15] Although temperature is often considered a determinant of indoor environmental quality, all respondents in this study lived in houses with temperatures that met environmental health standards. The lack of association may be attributed to relatively homogeneous temperature conditions among the respondents. Moreover, urban housing characteristics, including the use of heat-absorbing building materials, limited green open spaces, and dense residential settlements, may contribute to elevated indoor temperatures across households, resulting in limited variation between case and control groups.[16] Therefore, temperature alone may not be sufficient to influence pulmonary tuberculosis transmission in the study area.

Humidity was not significantly associated with pulmonary tuberculosis incidence, as indicated by an OR of 0.564 (95% CI: 0.124–2.559), suggesting that humidity was not a risk factor for pulmonary tuberculosis in this study. These findings are in agreement with those reported by Derny et al., (2023), who also found no significant relationship between humidity and pulmonary tuberculosis. These findings are consistent with previous studies that also found no significant relationship between humidity and pulmonary tuberculosis.[17] Humidity represents the amount of water vapor present in the air and is influenced by temperature and geographical conditions.[18] Although high humidity is known to promote the survival and growth of microorganisms, including pathogenic bacteria, most respondents' houses in this study had humidity levels within the recommended range. This condition may be related to the use of building materials such as ceramic flooring and concrete walls, which have low water absorption capacity and therefore reduce moisture accumulation indoors. In addition, many houses were equipped with adequate roofing systems and moisture-resistant construction materials that helped maintain stable indoor humidity. According to the Indonesian Ministry of Health Regulation No. 2 of 2023, indoor humidity should be maintained between 40% and 60%, while adequate ventilation and regular window opening help control humidity and support respiratory health.

In contrast, lighting emerged as one of the most important environmental determinants of pulmonary tuberculosis in this study. The results showed that respondents living in houses with inadequate lighting had a 5.091-fold higher risk of developing pulmonary tuberculosis compared with those living in adequately lit houses (OR = 5.091; 95% CI: 1.487–17.534). This finding is consistent with previous studies reporting significant associations between inadequate lighting and pulmonary tuberculosis incidence.[17,19] Adequate natural lighting is an important component of a healthy home, as it helps prevent dark and damp conditions that favor microbial survival.

Sunlight also contains ultraviolet (UV) radiation with bactericidal properties that can reduce the survival of airborne pathogens, including Mycobacterium tuberculosis.[20] Exposure to natural sunlight can therefore contribute to reducing microbial contamination within the household environment. These findings suggest that improving natural lighting through larger windows, regular opening of curtains, and maximizing sunlight penetration may represent practical interventions for reducing pulmonary tuberculosis transmission in residential settings.

Residential density was another significant risk factor identified in this study. Respondents living in overcrowded houses were approximately four times more likely to develop pulmonary tuberculosis compared with those living in houses that met the recommended occupancy standards (OR = 4.086; 95% CI: 1.518–11.000). This finding supports previous studies demonstrating that overcrowding is a major determinant of pulmonary tuberculosis transmission [17]. Tuberculosis is transmitted through airborne droplet nuclei released when infected individuals cough, sneeze, speak, or breathe. In overcrowded households, prolonged and close contact among family members substantially increases the probability of inhaling infectious particles.[21] In addition, overcrowding contributes to deteriorating indoor environmental quality through increased humidity, elevated carbon dioxide concentrations, and the accumulation of airborne contaminants. Field observations revealed that several respondents lived in houses where multiple family members shared the same bedroom, thereby increasing the duration and intensity of exposure to potentially infectious individuals. These findings reinforce the importance of housing conditions as a key environmental determinant of tuberculosis transmission and highlight the need for housing improvement programs in densely populated urban communities.

Ventilation, although theoretically important for preventing airborne disease transmission, was not significantly associated with pulmonary tuberculosis incidence in this study (OR = 1.774; 95% CI: 0.391–8.055). Similar findings have been reported in previous studies, suggesting that ventilation alone may not adequately explain the dynamics of tuberculosis transmission.[22] Nevertheless, field observations showed that many respondents' houses had ventilation areas below the minimum standard of 10% of floor area as stipulated in the Indonesian Ministry of Health Regulation No. 2 of 2023. Several houses also had fixed windows that could not be opened, limiting natural air exchange. Despite these conditions, residents commonly opened doors and windows during daytime hours, which may have compensated for inadequate structural ventilation and improved indoor airflow. Adequate ventilation remains an essential component of healthy housing because it facilitates air exchange, reduces pollutant accumulation, and helps maintain optimal temperature and humidity levels.[23] Therefore, although ventilation was not statistically significant in this study, improving ventilation remains important because it supports air exchange, reduces pollutant accumulation, and helps maintain appropriate indoor temperature and humidity.

Overall, the findings suggest that housing environmental conditions contribute to pulmonary tuberculosis transmission. Inadequate lighting and overcrowded housing were identified as the main risk factors. Therefore, improving housing quality, enhancing natural lighting, reducing overcrowding, and promoting healthy living behaviors are important strategies for supporting tuberculosis prevention and control in urban communities.

Conclusion

This study found that inadequate lighting and overcrowded housing were associated with pulmonary tuberculosis in the working area of Tamalate Community Health Center, Makassar City. In contrast, airborne bacterial count, temperature, humidity, and ventilation were not significantly associated with pulmonary TB in this study population. However, these non-significant findings should be interpreted cautiously because the study had limited exposure

variation, particularly for airborne bacterial count, and environmental measurements were performed at a single point in time. Despite these limitations, the results suggest that improving access to adequate natural lighting and reducing residential overcrowding may support tuberculosis prevention efforts in urban communities. The findings also highlight the importance of promoting healthy housing conditions and community awareness as part of integrated TB control strategies. Further studies with larger sample sizes, repeated environmental measurements, and adjustment for additional behavioral and socioeconomic factors are recommended to better clarify the role of indoor environmental conditions in pulmonary tuberculosis transmission.

Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication of this study.

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