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Email : editorijhess@gmail.com

Analysis Of Residential Environmental Health Factors And The Incidence Of Tuberculosis: A Cross-Sectional Study

Eka Joni Yansyah[1)], Fera Novitry[2)]
[1,2)] Program Studi S1 Kesehatan Masyarakat, Sekolah Tinggi Ilmu Kesehatan Al-Ma'arif Baturaja

*Coresponding Author
Email: joniyansyah.eka@gmail.com

Abstract

Pulmonary tuberculosis remains a major public health problem, particularly in areas where residential environmental conditions do not meet healthy housing standards. Poor ventilation, inadequate natural lighting, unsuitable humidity, overcrowding, and inappropriate room temperature may increase the risk of domestic tuberculosis transmission. This study aimed to analyze the relationship between residential environmental health factors and the incidence of pulmonary tuberculosis in Batu Belang Jaya Village, the working area of Muaradua Public Health Center, South Ogan Komering Ulu Regency. This study used an analytical quantitative design with a cross-sectional approach. The study population consisted of 1,002 heads of households, and 286 respondents were selected using simple random sampling. Data were collected through interviews, observation, and direct measurement of residential environmental conditions. House ventilation was measured using a measuring tape, natural lighting was measured using a digital lux meter, and air humidity and room temperature were measured using a digital thermo-hygrometer. Data were analyzed using the Chi-square test with a significance level of 0.05. The results showed that 84 respondents (29.4%) were identified as pulmonary tuberculosis cases. The Chi-square test showed significant relationships between pulmonary tuberculosis incidence and house ventilation (p = 0.015), natural lighting (p = 0.038), air humidity (p = 0.014), occupancy density (p = 0.012), and room temperature (p = 0.046). Residential environmental health factors were significantly associated with pulmonary tuberculosis incidence. Environmental surveillance and healthy housing interventions should be strengthened to reduce household transmission risk.

Keywords: ***Air Humidity; Natural Lighting; Occupancy Density; Pulmonary Tuberculosis; Residential Environment; Room Temperature; Ventilation***

INTRODUCTION

Pulmonary tuberculosis remains a major global public health problem because this disease contributes substantially to morbidity and mortality across populations (World Health Organization, 2025). The World Health Organization reported that tuberculosis continues to be one of the leading causes of death from infectious diseases worldwide (World Health Organization, 2025). Indonesia carries a high tuberculosis burden because the country is among the largest contributors to global tuberculosis cases (Kementerian Kesehatan Republik Indonesia, 2025). This situation requires strengthened tuberculosis control through case detection, treatment adherence, transmission prevention, and improvement of environmental risk factors at the community level (World Health Organization, 2025; Kementerian Kesehatan Republik Indonesia, 2025).

The tuberculosis burden at the regional level also shows an increasing pattern that requires serious attention from public health programs (Dinas Kesehatan Provinsi Sumatera Selatan, 2026). The South Sumatra Provincial Health Office reported an increase in tuberculosis case findings from year to year in South Sumatra Province (Dinas Kesehatan Provinsi Sumatera Selatan, 2026). South Ogan Komering Ulu Regency also showed an increasing trend in tuberculosis cases based on district-level contact investigation and tuberculosis surveillance reports (Dinas Kesehatan Kabupaten Ogan Komering Ulu Selatan, 2025). This local increase indicates the need to identify modifiable risk factors, particularly residential environmental health factors that are directly related to the living space of patients and their families (Prasetyo et al., 2023; Meliyanti, 2026).

Pulmonary tuberculosis transmission occurs through droplet nuclei containing *Mycobacterium tuberculosis* that can remain suspended in the air under certain environmental conditions (World Health Organization, 2022). Poor physical housing conditions can prolong the retention of infectious

aerosols indoors and increase exposure among other household members (Meliyanti, 2026; Prasetyo et al., 2023). Poor air quality and environmental exposure have also been associated with increased pulmonary tuberculosis risk in environmental epidemiology studies (Dimala & Kadia, 2022; Zhu et al., 2022). These findings confirm that tuberculosis control should not only focus on clinical treatment but also address residential environmental quality as a key space for domestic transmission (Anwar et al., 2023; Kurniawan et al., 2023).

Several components of the physical housing environment play an important role in determining the risk of pulmonary tuberculosis transmission in domestic spaces (Prasetyo et al., 2023; Meliyanti, 2026). Inadequate house ventilation can reduce air exchange and increase the accumulation of infectious droplets indoors (Hidayat & Lestari, 2024; Kurniawan et al., 2023). Poor natural lighting can reduce sunlight penetration into the house and maintain indoor conditions that support the survival of tuberculosis bacteria (Ramadhan & Wijaya, 2024; Saputra & Wijaya, 2024). Air humidity, room temperature, and occupancy density can create an indoor microclimate that increases tuberculosis transmission risk through close contact among household members (Dewi & Subagyo, 2025; Ramli & Utami, 2024; Wulandari & Santoso, 2024).

Previous studies have described the relationship between physical housing conditions and pulmonary tuberculosis incidence in several regions of Indonesia (Meliyanti, 2026; Ida Royani et al., 2025). Other studies have also shown that occupancy density, ventilation quality, humidity, and physical housing characteristics contribute to secondary tuberculosis transmission at the household level (Anwar et al., 2023; Kurniawan et al., 2023). However, several previous studies have focused more on behavioral factors, treatment adherence, knowledge, or clinical factors among tuberculosis patients (Heryanto, 2026; Nurhayati & Febrianti, 2024; Ardika Pratiwi et al., 2025). This gap highlights the need for a local study that specifically analyzes the relationship between residential environmental health factors and pulmonary tuberculosis incidence in an area with an increasing case trend (Dinas Kesehatan Kabupaten Ogan Komering Ulu Selatan, 2025; Meliyanti, 2026).

Batu Belang Jaya Village is a relevant setting for this study because it is located in a district that continues to face an increasing burden of pulmonary tuberculosis (Dinas Kesehatan Kabupaten Ogan Komering Ulu Selatan, 2025). Direct measurement of household environmental factors can provide more applicable evidence for environmental surveillance and healthy housing interventions at the primary health care level (Annisa, 2026; Kementerian Kesehatan Republik Indonesia, 2025). The analysis of house ventilation, natural lighting, air humidity, occupancy density, and room temperature can help health workers determine environmental-based priorities for tuberculosis transmission prevention (Prasetyo et al., 2023; Meliyanti, 2026). Therefore, this study aimed to analyze the relationship between residential environmental health factors and pulmonary tuberculosis incidence in Batu Belang Jaya Village, the working area of Muaradua Public Health Center, South Ogan Komering Ulu Regency.

RESEARCH METHODS

This study used an analytical quantitative design with a cross-sectional approach. This design was selected because the independent and dependent variables were measured at the same time. The independent variables in this study were house ventilation, natural lighting, air humidity, occupancy density, and room temperature. The dependent variable was the incidence of pulmonary tuberculosis. The cross-sectional approach was considered appropriate because this study aimed to describe the relationship between residential environmental health conditions and pulmonary tuberculosis incidence during one period of observation.

This study was conducted in Batu Belang Jaya Village, Muaradua District, South Ogan Komering Ulu Regency, which is included in the working area of Muaradua Public Health Center. This location was selected because the area had epidemiological relevance to the increasing trend of pulmonary tuberculosis cases in South Ogan Komering Ulu Regency. The unit of analysis in this study

was the household. The respondents were heads of households or adult family members who met the study criteria. Data collection was conducted through home visits to assess the physical condition of the residential environment directly.

The population in this study consisted of all heads of households officially residing in Batu Belang Jaya Village, Muaradua District, South Ogan Komering Ulu Regency. The total population was 1,002 heads of households. The sample size was calculated using the Slovin formula with a 5% margin of error. The calculation produced a minimum sample size of 285.87 respondents. This number was rounded up to 286 respondents to ensure that the sample was representative of the study population.

The sampling technique used in this study was probability sampling with a simple random sampling method. This technique was used to provide each head of household in the population with an equal opportunity to be selected as a respondent. The researcher first obtained the list of heads of households residing in Batu Belang Jaya Village. This list was then used as the sampling frame. A total of 286 respondents were randomly selected using a digital randomizer application and were then visited at their homes according to the selected names.

The inclusion criteria were heads of households, spouses of heads of households, or independent adult family members who were officially recorded as residents of Batu Belang Jaya Village. Respondents were required to have lived continuously in the same house for at least one year. This criterion was applied to ensure that respondents had experienced sufficient exposure to the physical housing environment. Respondents also had to be conscious, cooperative, able to communicate well, and willing to participate in the study. Respondent willingness was confirmed through the signing of an informed consent form after the study explanation was provided.

The exclusion criteria included households whose houses were undergoing total renovation at the time of data collection. Houses that had been newly built within the last three months were also excluded because their physical conditions did not represent stable environmental exposure. Respondents were excluded when their houses were empty or locked after two repeated home visits by the researcher. Respondents who withdrew or refused to continue the data collection process were also excluded from the final analysis.

Data were collected through brief interviews, direct observation of physical housing conditions, and direct measurement of residential environmental components. The researcher used an observation sheet to record household environmental characteristics and pulmonary tuberculosis status. House ventilation was measured using a measuring tape by comparing the ventilation area with the floor area. Natural lighting was measured using a digital lux meter to obtain indoor light intensity. Room temperature and air humidity were measured using a digital thermo-hygrometer to obtain objective indoor microclimate data.

Occupancy density was assessed by comparing the floor area or bedroom area with the number of household occupants. House ventilation was categorized as meeting the requirement when the permanent ventilation area was at least 10% of the floor area. Natural lighting was categorized as meeting the requirement when indoor light intensity reached at least 60 lux without glare. Air humidity was categorized as meeting the requirement when it was within the range of 40% to 70%. Room temperature was categorized as meeting the requirement when it was within the range of 18°C to 30°C. Occupancy density was categorized as meeting the requirement when the available space reached at least 8 m^2 per person.

Pulmonary tuberculosis incidence was categorized into pulmonary tuberculosis cases and non-pulmonary tuberculosis cases. The tuberculosis status was determined based on pulmonary tuberculosis case data available in the working area of Muaradua Public Health Center and was confirmed during field data collection. Respondents recorded as active pulmonary tuberculosis patients were categorized as the pulmonary tuberculosis group. Respondents who were not recorded and did not have active pulmonary tuberculosis status were categorized as the non-pulmonary

tuberculosis group. This classification was used to compare the distribution of housing environmental conditions between households with and without pulmonary tuberculosis cases.

The researcher maintained data quality through completeness checks after each home visit. Incomplete data were rechecked before data entry was performed. The researcher also ensured that all measuring instruments were in good condition before being used in the field. Environmental measurements were performed carefully to minimize measurement and recording errors. The collected data were then processed through editing, coding, entry, and cleaning before statistical analysis.

Data analysis was performed using univariate and bivariate analyses. Univariate analysis was used to describe the frequency and percentage distribution of each variable, including pulmonary tuberculosis incidence, house ventilation, natural lighting, air humidity, occupancy density, and room temperature. Bivariate analysis was used to examine the relationship between each residential environmental health factor and pulmonary tuberculosis incidence. The Chi-square test was used for bivariate statistical analysis. The results were considered statistically significant when the p-value was less than 0.05.

This study followed ethical principles in health research, including respect for respondents, confidentiality, beneficence, and non-maleficence. The researcher explained the study objectives, procedures, benefits, and respondent rights before data collection. Respondents were given the opportunity to ask questions and decide their participation voluntarily. The researcher maintained respondent confidentiality by not presenting personal names in the analysis and reporting process. All respondents who agreed to participate signed an informed consent form after receiving the study explanation.

RESULTS AND DISCUSSION

The findings of this study describe the distribution of pulmonary tuberculosis incidence and the residential environmental health conditions among 286 respondents in Batu Belang Jaya Village. The residential environmental factors assessed in this study included house ventilation, natural lighting, air humidity, occupancy density, and room temperature. The analysis was conducted in two stages. The first stage described the frequency distribution of each study variable. The second stage examined the relationship between each residential environmental health factor and pulmonary tuberculosis incidence using the Chi-square test.

Table 1. Distribution of Pulmonary Tuberculosis Incidence and Residential Environmental Health Factors

Variables	Frequency (n)	Percentage (%)
Pulmonary Tuberculosis Incidence		
Pulmonary tuberculosis case	84	29.4
Non-pulmonary tuberculosis case	202	70.6
House Ventilation		
Did not meet the requirement	169	59.1
Met the requirement	117	40.9
Natural Lighting		
Did not meet the requirement	150	52.4
Met the requirement	136	47.6
Air Humidity		
Did not meet the requirement	184	64.3
Met the requirement	102	35.7
Occupancy Density		
Did not meet the requirement	159	55.6
Met the requirement	127	44.4

Room Temperature		
Did not meet the requirement	140	49.0
Met the requirement	146	51.0

Table 1 shows that 84 respondents (29.4%) were identified as pulmonary tuberculosis cases, while 202 respondents (70.6%) were not pulmonary tuberculosis cases. Most respondents lived in houses with residential environmental conditions that did not meet health requirements. Air humidity was the most common environmental problem, with 184 houses (64.3%) categorized as not meeting the requirement. Inadequate house ventilation was found in 169 houses (59.1%), followed by high occupancy density in 159 houses (55.6%) and inadequate natural lighting in 150 houses (52.4%). Room temperature showed a relatively balanced distribution, with 140 houses (49.0%) not meeting the requirement and 146 houses (51.0%) meeting the requirement.

Table 2. Relationship Between Residential Environmental Health Factors and Pulmonary Tuberculosis Incidence

Variables	Pulmonary Tuberculosis Case n (%)	Non-Pulmonary Tuberculosis Case n (%)	Total n (%)	p-value
House Ventilation				0.015
Did not meet the requirement	62 (47.7)	107 (52.3)	169 (100.0)	
Met the requirement	22 (18.8)	95 (81.2)	117 (100.0)	
Natural Lighting				0.038
Did not meet the requirement	55 (36.7)	95 (63.3)	150 (100.0)	
Met the requirement	29 (21.3)	107 (78.7)	136 (100.0)	
Air Humidity				0.014
Did not meet the requirement	66 (35.9)	118 (64.1)	184 (100.0)	
Met the requirement	18 (17.6)	84 (82.4)	102 (100.0)	
Occupancy Density				0.012
Did not meet the requirement	60 (37.7)	99 (62.3)	159 (100.0)	
Met the requirement	24 (18.9)	103 (81.1)	127 (100.0)	
Room Temperature				0.046
Did not meet the requirement	51 (36.4)	89 (63.6)	140 (100.0)	
Met the requirement	33 (22.6)	113 (77.4)	146 (100.0)	

Table 2 presents the relationship between residential environmental health factors and pulmonary tuberculosis incidence. The Chi-square test showed that house ventilation was significantly associated with pulmonary tuberculosis incidence ($p = 0.015$). Respondents living in houses with inadequate ventilation had a higher proportion of pulmonary tuberculosis cases than those living in houses with adequate ventilation. Natural lighting was also significantly associated with pulmonary tuberculosis incidence ($p = 0.038$), indicating that houses with inadequate natural lighting had a higher proportion of cases. Air humidity showed a significant relationship with pulmonary tuberculosis incidence ($p = 0.014$), with a higher proportion of cases found in houses with humidity levels that did not meet the requirement. Occupancy density was significantly associated with pulmonary tuberculosis incidence ($p = 0.012$), indicating that overcrowded houses had a higher proportion of cases. Room temperature also had a significant relationship with pulmonary tuberculosis incidence ($p = 0.046$), showing that unsuitable indoor temperature was associated with a higher proportion of pulmonary tuberculosis cases. These findings indicate that inadequate ventilation, poor natural lighting, unsuitable humidity, overcrowding, and inappropriate room temperature were significantly related to pulmonary tuberculosis incidence in Batu Belang Jaya Village.

The significant relationship between house ventilation and pulmonary tuberculosis incidence indicates that air exchange plays an important role in domestic tuberculosis transmission. Poor ventilation reduces indoor air circulation and increases the retention of infectious droplet nuclei in

household spaces (Hidayat & Lestari, 2024). Inadequate air exchange allows *Mycobacterium tuberculosis* to remain suspended in the air for a longer period in enclosed rooms (World Health Organization, 2022). Houses with limited ventilation can create an indoor environment that increases exposure among household members during daily interaction (Kurniawan et al., 2023). Previous environmental epidemiology studies have shown that poor physical housing characteristics increase the risk of pulmonary tuberculosis transmission in households (Prasetyo et al., 2023). This evidence supports the present finding that respondents living in houses with inadequate ventilation had a higher proportion of pulmonary tuberculosis cases than respondents living in houses with adequate ventilation (Meliyanti, 2026).

The finding on natural lighting shows that insufficient sunlight exposure may strengthen the environmental risk for pulmonary tuberculosis transmission. Poor natural lighting reduces sunlight penetration into indoor spaces and maintains dark room conditions that support bacterial persistence (Ramadhan & Wijaya, 2024). Indoor spaces with low natural lighting can limit the natural disinfection effect of sunlight on airborne microorganisms (Saputra & Wijaya, 2024). Houses with inadequate sunlight exposure may also reflect poor building design, limited window use, and dense settlement patterns in the community (Prasetyo et al., 2023). Environmental studies have reported that poor housing conditions and inadequate indoor environmental quality are associated with pulmonary tuberculosis incidence (Meliyanti, 2026). This explanation supports the present result that respondents living in houses with inadequate natural lighting had a higher proportion of pulmonary tuberculosis cases than respondents living in houses with adequate lighting (Ida Royani et al., 2025).

The significant relationship between air humidity and pulmonary tuberculosis incidence indicates that indoor microclimate conditions influence the survival and transmission of tuberculosis bacteria. High or unsuitable humidity can prolong the viability of airborne particles and maintain infectious aerosols in indoor spaces (Dewi & Subagyo, 2025). Humid indoor conditions often occur together with poor ventilation, poor sunlight exposure, and inadequate housing materials in residential areas (Anwar et al., 2023). Poor humidity control can create an indoor environment that supports the persistence of *Mycobacterium tuberculosis* in household air (World Health Organization, 2022). Previous research has shown that houses with poor physical environmental conditions have higher risks for pulmonary tuberculosis incidence (Meliyanti, 2026). This evidence supports the present result that respondents living in houses with humidity levels that did not meet the requirement had a higher proportion of pulmonary tuberculosis cases than respondents living in houses with adequate humidity (Saputra & Wijaya, 2024).

The finding on occupancy density shows that overcrowding can increase the probability of pulmonary tuberculosis transmission among household members. High occupancy density increases close contact between infectious and susceptible individuals in the same domestic space (Wulandari & Santoso, 2024). Overcrowded rooms reduce personal space and increase the duration of exposure to infectious droplet nuclei during sleeping, resting, and family interaction (Kurniawan et al., 2023). Dense housing conditions can also worsen indoor air quality because many occupants share limited air volume in the same room (Anwar et al., 2023). Previous studies have reported that household crowding contributes to secondary tuberculosis transmission in domestic settings (Arifin et al., 2025). This explanation supports the present finding that respondents living in houses with occupancy density that did not meet the requirement had a higher proportion of pulmonary tuberculosis cases than respondents living in houses with adequate occupancy density (Prasetyo et al., 2023).

The significant relationship between room temperature and pulmonary tuberculosis incidence indicates that thermal conditions contribute to indoor environmental risk. Unsuitable room temperature can interact with humidity and ventilation to create an indoor microclimate that supports the persistence of airborne pathogens (Dewi & Subagyo, 2025). Extreme indoor temperature may reflect poor building materials, inadequate airflow, and limited sunlight exposure in residential houses (Ramli & Utami, 2024). Poor thermal comfort may also encourage residents to close windows and doors, thereby reducing ventilation and increasing indoor air stagnation (Hidayat & Lestari, 2024).

Environmental studies have demonstrated that poor indoor physical conditions can contribute to pulmonary tuberculosis transmission at the household level (Prasetyo et al., 2023). This evidence supports the present finding that respondents living in houses with room temperature that did not meet the requirement had a higher proportion of pulmonary tuberculosis cases than respondents living in houses with appropriate room temperature (Meliyanti, 2026).

The overall findings of this study strengthen the argument that pulmonary tuberculosis prevention should include environmental modification at the household and community levels. Clinical treatment remains essential, but environmental risk reduction is needed to prevent repeated exposure and household transmission (World Health Organization, 2025). Primary health care programs should integrate environmental surveillance, home visits, and healthy housing education into tuberculosis control activities (Kementerian Kesehatan Republik Indonesia, 2025). Community-based healthy village programs can support behavioral changes related to window opening, sunlight exposure, ventilation improvement, and household crowding reduction (Annisa, 2026). Local evidence from this study can help health workers identify priority households that require environmental counseling and sanitation intervention (Dinas Kesehatan Kabupaten Ogan Komering Ulu Selatan, 2025). This integrated approach can strengthen tuberculosis control in Batu Belang Jaya Village by combining case management with residential environmental health improvement (World Health Organization, 2025).

CONCLUSIONS

This study concluded that residential environmental health factors were significantly related to pulmonary tuberculosis incidence in Batu Belang Jaya Village. The findings showed that inadequate house ventilation, poor natural lighting, unsuitable air humidity, high occupancy density, and inappropriate room temperature were associated with a higher proportion of pulmonary tuberculosis cases. These results indicate that the physical condition of houses plays an important role in domestic tuberculosis transmission. The Muaradua Public Health Center should strengthen environmental health surveillance through regular household inspections in tuberculosis-prone areas. Health workers and community cadres should provide continuous education on opening windows, improving sunlight exposure, reducing indoor humidity, arranging sleeping spaces, and maintaining healthy room temperature. The local government should also support healthy housing improvement programs, especially for households with poor physical housing conditions and high tuberculosis transmission risk.

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