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A Case-Control Study of Environmental Risk Factors for Pulmonary Tuberculosis: Housing Density, Indoor Humidity, and Smoking Habits

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Abstract
Pulmonary tuberculosis (TB) remains a major public health problem in urban settings and is strongly influenced by environmental and behavioral factors. This study aimed to examine the effects of housing density, indoor humidity, and smoking behavior on the incidence of pulmonary TB in the working area of the Segiri Health Center, Samarinda. An observational analytic study with a case–control design was conducted involving 50 respondents, consisting of 25 TB cases and 25 matched controls. Data were collected through structured interviews, direct observation, and environmental measurements, and were analyzed using chi-square tests and odds ratios. The results indicated that high housing density was significantly associated with an increased risk of TB (OR = 11.16; p = 0.001), while smoking behavior was also significantly related to TB incidence (OR = 5.63; p = 0.010). High indoor humidity showed an increased risk but was not statistically significant. In addition, a large proportion of TB cases were frequently exposed to secondhand smoke in enclosed spaces. In conclusion, high housing density and smoking, including exposure to secondhand smoke, are key determinants of pulmonary TB incidence, whereas indoor humidity demonstrated a weaker association. These findings highlight the importance of improving housing conditions and strengthening tobacco control efforts as part of TB prevention strategies in urban areas.

Keywords: Environmental Risk Factors, Housing Density, Indoor Humidity, Pulmonary Tuberculosis, Smoking Behavior.

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1. INTRODUCTION

Pulmonary tuberculosis (TB) remains a serious public health concern in Indonesia, which ranks as the country with the second-highest TB burden in the world after India (WHO, 2024). Although TB is a preventable and treatable infectious disease, its prevalence remains high due to a combination of behavioral, social, and environmental factors (Pratiwi, Pramono, & Junaedi, 2020; Rangkoratat, Suhita, & Anggraini, 2024). Transmission of Mycobacterium tuberculosis via airborne droplets is readily facilitated, particularly in densely populated, enclosed environments with poor ventilation. The latest data from the Global Tuberculosis Report 2024, released by the WHO on October 29, 2024, reported 10.8 million new TB cases globally in 2023, with an incidence rate of 134 per 100,000 population (WHO, 2024).

The physical environment of the house and the behaviors of its occupants are known to play a significant role in facilitating the transmission of M. tuberculosis. Crowded, damp houses with poor lighting and inadequate ventilation can prolong the airborne survival of the bacteria, thereby increasing the risk of interpersonal transmission (Coleman et al., 2022; Tosepu et al., 2024). Housing density is one of the most significant factors contributing to TB transmission risk, especially in high-burden countries, as it increases the likelihood of close and prolonged contact between individuals with active TB and susceptible individuals. A study conducted in Canadian First Nations communities revealed that individuals living in high-density housing had a 2.5 times greater risk of developing TB compared to those in less crowded housing conditions (Clark, Riben, & Nowgesic, 2002). Poor environmental conditions, such as high indoor humidity, have also been shown to enhance the survivability of M. tuberculosis in the air, prolonging its infectivity and increasing transmission risk, particularly in areas lacking proper ventilation (Coleman et al., 2022; Krishnan et al., 2022).

Active and passive smoking can impair airways, lowering respiratory defenses and increasing TB risk. Household smoking also contributes to TB transmission and can worsen treatment outcomes (Gupta et al., 2022; Fakhira & Keman, 2024). Samarinda City has the highest TB case detection rate in East Kalimantan Province and a high number of reported TB cases, particularly at Puskesmas Segiri. This study examines the relationship between housing density, indoor humidity, household smoking habits, and the incidence of pulmonary tuberculosis in Puskesmas Segiri's catchment area. Results aim to inform more effective community-level TB interventions.

2. RESEARCH METHOD

This case-control study analyzed how environmental risk factors influenced pulmonary tuberculosis (TB) incidence. The risk factors studied were housing density, indoor air humidity, and household smoking. Research was conducted in the Segiri Public Health Center area, Samarinda City, specifically in the Sidodadi and Dadi Mulya subdistricts, from December 2024 to February 2025, covering coordination, data collection, and analysis.

This study was approved by the Health Research Ethics Committee of STIKES Suaka Insan Banjarmasin (Approval No. 212/KEPK-SI/VI/2025). The study population comprised active TB patients and healthy individuals living in the Segiri Health Center area. The case group included 42 people with active pulmonary TB undergoing treatment, identified in medical records. The control group comprised healthy neighbors of pulmonary TB patients in Sidodadi and Dadi Mulya subdistricts. Groups were matched by gender and domicile. Controls were interviewed about their medical history and whether any TB patients lived in their household. Only those with no history of TB and not living with TB patients were included as controls. After applying the criteria and matching, the final sample included 25 in each group. Inclusion criteria: (1) diagnosed with pulmonary TB, (2) currently in treatment, (3) residing in Sidodadi or Dadi Mulya, and (4) willing to participate. Exclusion criteria: (1) residing outside selected subdistricts, (2) not willing to participate, or (3) completed TB Data were collected through structured interviews and direct observation at respondents' homes. Housing density

was determined by measuring bedroom size with a roll meter and counting occupants. A standard 9 m² bedroom should accommodate no more than two people, except for children under 5 years old. Rooms were scored as standard (1) or not (2). Smoking behavior was measured using a questionnaire adapted from the 2018 Indonesian Basic Health Research (Riskesdas) by the National Institute of Health Research and Development, Ministry of Health. Questions covered the presence and frequency of indoor smoking, as well as indoor smoking restrictions. Humidity was measured with a hygrometer in the main room or bedroom, and categorized as ideal (40%–60%) or not ideal if outside this range. this range.

Data analysis consisted of univariate analysis to describe the frequency distribution of each variable, including respondents' characteristics and environmental risk factors. Bivariate analysis was conducted to assess the association between environmental and behavioral risk factors and pulmonary TB incidence. For 2×2 contingency tables that met the minimum expected count assumption (≥5), the Chi-Square test (χ^2) with continuity correction (Yates correction) was used. For 2×2 tables that violated the assumption (expected count <5), Fisher's Exact Test was applied. For tables larger than 2×2 with small expected counts, the Fisher-Freeman-Halton Exact Test with the Monte Carlo method (10,000 sampled tables) was used. A significance level of $p < 0.05$ was set.

3. RESULTS AND DISCUSSION

Samarinda City is one of the regions in Indonesia experiencing a steadily increasing burden of tuberculosis (TB) over the past three years. According to the Samarinda City Health Office, the number of TB cases recorded in the city increased from 1,464 in 2021 to 2,074 in 2022, and then to 3,455 in 2023. The city comprises 10 districts, 59 sub-districts, and 26 public health centers (Puskesmas), most of which operate in areas with relatively high TB incidence rates. Among these 26 centers, ten have been identified as having the highest TB incidence, including Puskesmas Segiri.

Puskesmas Segiri, located in Sidodadi sub-district, oversees two main service areas: Kelurahan Sidodadi and Kelurahan Dadi Mulya. These areas have consistently recorded a substantial number of TB cases: 48 in 2021, 70 in 2022, 61 in 2023, and 42 as of October 2024. This fluctuating pattern indicates that pulmonary TB remains a serious public health concern requiring interventions targeting environmental and behavioral factors.

Table 1. The Characteristics of Respondents.

Variables	TB Case		Control		Total	
	n	%	n	%	n	%
Sex						
Female	9	36.0	9	36.0	18	36.0
Male	16	64.0	16	64.0	32	64.0
Age						
<20	1	4.0	2	8.0	3	6.0
20-29	9	36.0	9	36.0	18	36.0
30-39	4	16.0	4	16.0	8	16.0
40-49	5	20.0	6	24.0	11	22.0
>49	6	24.0	4	16.0	10	20.0
Education						
Elementary School	5	20.0	1	4.0	6	12.0
Junior High School	5	20.0	3	12.0	8	16.0
Senior High School	12	48.0	16	64.0	28	56.0
Diploma	1	4.0	2	8.0	3	6.0

Bachelor's Degree	2	8.0	3	12.0	5	10.0
Residence Area						
Sidodadi	14	56.0	14	56.0	28	56.0
Dadi Mulya	11	44.0	11	44.0	22	44.0
Employment status						
Employed	13	52.0	14	56.0	27	54.0
Unemployed	12	48.0	11	44.0	23	46.0

In this study, 50 respondents were included: 25 pulmonary TB cases and 25 matched controls without a history or symptoms of TB. Their demographic characteristics, including sex, age group, education level, residence area, and employment status, are summarized in Table 1. The majority of participants were male (64%), aged 20–29 years (36%), and had completed senior high school (56%). A slightly higher proportion of respondents resided in Kelurahan Sidodadi (56%) than in Dadi Mulya, and employment status was relatively balanced between the two groups.

Housing Density as an Environmental Risk Factor

Housing density is one of the physical environmental factors that influences the transmission of infectious diseases, including pulmonary tuberculosis (Lee et al., 2022). Densely populated residential areas with poor ventilation can increase the risk of *Mycobacterium tuberculosis* transmission through airborne droplets. Houses that are occupied beyond their spatial capacity tend to have suboptimal air circulation, facilitating the spread of infection from one individual to another (Jannah et al., 2023).

The study found that among 23 respondents living in high-density housing environments, 17 had pulmonary TB and 4 were in the control group. Most of the TB patients lived in bedrooms with an area of less than 9 m² per person, and the number of occupants exceeded the standard limit set by the Indonesian Ministry of Health Decree No. 2 of 2023, which stipulates a maximum of two persons per bedroom with a minimum area of 9 m² (Kementerian Kesehatan Republik Indonesia, 2023). In addition, the classification of high and low housing density also considered other environmental criteria, such as adequate ventilation, window availability and size, and overall indoor air circulation. These conditions further increase the risk of transmission, as most high-density houses lacked sufficient airflow to prevent airborne droplet transmission of Mycobacterium tuberculosis. This indicates that most dwellings did not meet the proper density and ventilation standards. Conversely, 27 respondents lived in low-density housing, characterized by fewer occupants per room, adequate room area, and better ventilation, and did not suffer from pulmonary TB.

Table 2. Cross-tabulation of Housing Density and Pulmonary TB Cases with Odds Ratio and Chi-Square Analysis.

Housing Density	TB Case		Control		Total		OR	Chi2	p
	f	%	f	%	n	%			
High Density (Risk +)	17	68.0%	4	16.0%	23	42.0%	11.16	11.82	0.001
Low Density (Risk –)	8	32.0%	21	84.0%	27	58.0%	11.16	11.82	0.001
Total	25	100%	25	100%	50	100%	11.16	11.82	0.001

As presented in Table 2, the odds ratio (OR) of 11.16 indicates that individuals living in high-density housing are 11.16 times more likely to develop pulmonary TB than those residing in low-density housing. The 95% confidence interval (CI: 2.864–43.464) reinforces the strength of this association, indicating that the relationship is statistically significant. Although the CI is relatively wide, possibly due to the sample size, even its lower bound suggests a substantially elevated risk. The Chi-square test yielded $\chi^2 = 11.82$ ($p < 0.001$), confirming a significant relationship between housing density and TB incidence.

This finding is in line with several previous studies. Fahdhienie et al. (2024) reported that individuals residing in high-density housing were 3.92 times more likely to develop pulmonary

TB, while. Sulidah et al. (2024) found a 3.81-fold increase in risk under similar conditions. A study by Tesema et al., (2015) in Ethiopia also showed that living in a household with more than four people and less than 4 m² of space per person increased the risk of TB by threefold. Similarly, Wulandari, Nurjazuli, & Sakundarno (2015) found that residential overcrowding increased the risk of TB by 7.8 times. These findings reinforce the strong association between household density and the incidence of pulmonary TB. In addition to the number of occupants and room size, ventilation also plays a crucial role in exacerbating the impact of residential density. Poor ventilation reduces air circulation and allows TB-laden droplets to remain airborne for extended periods in densely populated spaces. This finding supports the theory of infectious disease epidemiology, which states that overcrowded housing increases the risk of infectious disease transmission, particularly pulmonary TB, due to inadequate ventilation and the high frequency of close contact among household members (Clark et al., 2002; Lee et al., 2022, Sulidah et al., 2024)

Of the 50 bedrooms observed, 27 did not meet the standard housing density, while only 23 did. This finding confirms that the majority of residents in the working area of Segiri Health Center still live in overcrowded and unhealthy housing conditions, which have the potential to become transmission hotspots for pulmonary TB. High housing density increases the likelihood of *Mycobacterium tuberculosis* droplet transmission and degrades indoor air quality. The imbalance between the number of occupants and room area contributes to the rising rate of TB transmission (Khan et al., 2016).

Indoor Humidity as an Environmental Risk Factor

Indoor air humidity is a crucial aspect of residential environmental quality, influencing perceptions of indoor air quality and contributing to respiratory health (Wolkoff, 2018). High humidity, especially in poorly ventilated environments, can create living conditions that support the survival of pathogenic microorganisms, including *Mycobacterium tuberculosis*. When humidity exceeds the optimal threshold (>60%), the risk of airborne transmission of infectious diseases, such as pulmonary tuberculosis, increases because infectious droplets remain more stable in the air. Aerosols produced by patients when coughing or speaking may be released in a humid air cloud with upward momentum, allowing even large particles to remain suspended and travel farther in conditions of high humidity and air turbulence. This suggests that transmission of *M. tuberculosis* is highly likely in overcrowded, poorly ventilated environments, as the bacterium has evolved to exploit the characteristics of human-generated aerosols to sustain its chain of infection (Coleman et al., 2022).

Table 3. Cross-tabulation of Indoor Humidity and Pulmonary TB Cases with Odds Ratio and Chi-Square Analysis.

Indoor Humidity Level	TB Cases		Controls		Total		OR	χ^2	p-value
	(n)	(%)	(n)	(%)	(n)	(%)			
High humidity (Risk +)	24	96.0	22	88.0	46	92.0	3.27	0.27	0.602
Normal humidity (Risk −)	1	4.0	3	12.0	4	8.0		–	–
Total	25	100	25	100	50	100	–	–	–

Table 3 showed that among the 46 respondents living in environments with high indoor humidity (>60%), 24 were pulmonary TB cases and 22 were in the control group. In contrast, among the 4 respondents living in environments with normal humidity levels (≤60%), only 1 was a pulmonary TB case. As shown in Table 3, the majority of TB cases occurred in high-humidity environments that did not meet healthy humidity standards. High indoor humidity is commonly caused by inadequate ventilation, limited natural lighting, and building structures that do not support optimal air circulation. According to the Ministry of Health regulation (Kementerian Kesehatan Republik Indonesia, 2023), ventilation openings should ideally

account for at least 10% of the house floor area. However, field observations revealed that some respondents' bedrooms were dark and stuffy, lacking windows or open vents. These conditions allow excessive condensation of water vapor in the air, increasing humidity and creating an optimal environment for bacteria to survive for 1–2 hours in saturated air.

The Odds Ratio (OR) of 3.27 suggests that individuals living in high-humidity environments may be more vulnerable to developing pulmonary tuberculosis than those living in normal-humidity environments. However, this result should be interpreted carefully, as it may just show a trend that needs further testing. However, as shown in Table 3, the Chi-square test yielded $\chi^2 = 0.272$ and p-value = 0.602, indicating that the relationship between indoor humidity and the incidence of pulmonary TB is not statistically significant ($p > 0.050$).

Another study conducted by Fahdhienie et al. (2024) supports this finding, demonstrating that indoor air humidity is a key environmental factor influencing the incidence of pulmonary tuberculosis. The study revealed that individuals living in environments with insufficient humidity had a 6.65 times greater risk of developing pulmonary TB than those living in environments with adequate humidity. A similar result was reported by Sulidah et al. (2024) in a study conducted in Tarakan City, where individuals exposed to low indoor humidity had a 3.5 times higher risk of contracting TB than those living in areas with good humidity. These two studies confirm that humidity significantly affects the incidence of pulmonary TB. Although findings in the Puskesmas Segiri working area were not statistically significant, the trend remains epidemiologically relevant, as high humidity creates an environment conducive to the survival of microorganisms. Coleman et al. (2022) also stated that high humidity in densely populated areas can prolong the viability of infectious droplet particles, especially in conditions with poor air circulation.

High indoor relative humidity, exceeding 80%, significantly increases the risk of TB infection. This occurs because high humidity slows droplet evaporation, allowing infectious particles to remain airborne longer. Conversely, low humidity, particularly during the dry season, is also associated with an increased risk of TB because it can impair the respiratory tract's defense mechanisms, making individuals more susceptible to infection. It is important to note that both extremes of indoor humidity, too high or too low, can pose risks. Humidity levels below 60% can dry out the mucosal surfaces, while levels above 70–80% support the survival of pathogens such as bacteria and fungi, including Mycobacterium tuberculosis (Tosepu et al., 2024). Therefore, these findings emphasize the importance of maintaining optimal indoor air humidity as a part of environmental interventions to reduce TB transmission at the household level. Although existing evidence continues to grow, further research is needed to clearly elucidate the mechanistic relationship between humidity and TB pathogenesis, particularly in urban tropical regions, where climate, housing conditions, and ventilation interact and may amplify the risk.

Smoking Habits as a Behavioral Risk Factor

Smoking is a significant behavioral risk factor for the occurrence of pulmonary tuberculosis (Alavi-Naini, Sharifi-Mood, & Metanat, 2012). Cigarettes contain toxic substances that can impair lung function and weaken the immune system, thereby increasing the body's susceptibility to *Mycobacterium tuberculosis* infection (Quan et al., 2022). Based on the findings presented in Table 4, out of 23 respondents with an active smoking habit (daily smokers), 16 were TB cases, while 6 belonged to the control group. Conversely, among 27 respondents who did not smoke or were categorized as non-smokers, only 9 were TB cases, while the majority, 19 individuals, were part of the control group.

Table 4. Cross-tabulation of Smoking Habits and Pulmonary TB Cases with Odds Ratio and Chi-Square Analysis.

Smoking habits	**TB Case**		**Control**		**Total**		**OR**	**Chi2**	**p**
Smoking habits	f	%	f	%	n	%			
Smoker (Risk +)	16	60.0%	6	24.0%	23	46.0%	5.63	6.57	0.010
Non-Smoker (Risk -)	9	36.0%	19	76.0%	27	54.0%	5.63	6.57	0.010
Total	25	100%	25	100%	50	100%	5.63	6.57	0.010

Table 4 shows that the Odds Ratio (OR) test results indicated that individuals who smoke have a 5.63 times higher risk of developing pulmonary tuberculosis compared to non-smokers (OR = 5.63; 95% confidence interval not reported). Statistical analysis using the Chi-square test yielded $\chi^2 = 6.57$ and $p = 0.010$, indicating a statistically significant association between smoking habits and the incidence of pulmonary tuberculosis ($p < 0.050$). This finding aligns with earlier studies, including a large-scale study by Leung et al. (2004) that examined 42,655 elderly individuals in Hong Kong. The study revealed a higher prevalence of pulmonary tuberculosis among smokers compared to non-smokers.

Based on the smoking behavior survey presented in Table 5, the majority of respondents with pulmonary TB cases (64.0%) were active smokers who smoked daily. This figure is significantly higher than that of the control group, which was only 24.0%. Moreover, most TB case respondents began smoking during adolescence, between the ages of 15 and 17, and primarily used filtered cigarettes. Another important factor is that the majority of TB case smokers reported smoking indoors, such as at home, in public places, or at work, which increases both direct and indirect exposure to cigarette smoke. It was also found that 80.0% of respondents in the TB case group were frequently exposed to secondhand smoke in enclosed spaces, compared to only 32.0% in the control group.

Table 5. Distribution of smoking-related behaviors among TB case and control groups.

1	The respondent has a history of smoking or is currently a smoker.	The respondent has a history of smoking or is currently a smoker.	The respondent has a history of smoking or is currently a smoker.	The respondent has a history of smoking or is currently a smoker.	The respondent has a history of smoking or is currently a smoker.	
		Never smoked	Yes, but not every day	Yes, every day		
	TB Case	36.0%	0.0%	64.0%		
	Control	68.0%	8.0%	24.0%		
2	Age at which the respondent first started smoking	Age at which the respondent first started smoking	Age at which the respondent first started smoking	Age at which the respondent first started smoking	Age at which the respondent first started smoking	
		Never smoked	Under 12 years old	12–14 years old	15–17 years old	15–17 years old
	TB Case	36.0%	4.0%	20.0%	40.0%	40.0%
	Control	68.0%	4.0%	0.0%	28.0%	28.0%
3	The respondent mentioned	The respondent mentioned	The respondent mentioned	The respondent mentioned	The respondent mentioned	

	the type(s) of cigarettes they usually smoke.	the type(s) of cigarettes they usually smoke.	the type(s) of cigarettes they usually smoke.	the type(s) of cigarettes they usually smoke.	the type(s) of cigarettes they usually smoke.	
		Never smoked	Filtered cigarettes	Hand-rolled cigarettes	e-cigarettes	e-cigarettes
	TB Case	36.0%	64.0%	0.0%	0.0%	0.0%
	Control	68.0%	32.0%	0.0%	0.0%	0.0%
4	The respondent reported the average number of cigarettes smoked per day or per week	The respondent reported the average number of cigarettes smoked per day or per week	The respondent reported the average number of cigarettes smoked per day or per week	The respondent reported the average number of cigarettes smoked per day or per week	The respondent reported the average number of cigarettes smoked per day or per week	
		Never smoked	<10 cigarettes	10–15 cigarettes	16–20 cigarettes	16–20 cigarettes
	TB Case	36.0%	28.0%	28.0%	8.0%	8.0%
	Control	68.0%	0.0%	28.0%	4.0%	4.0%
5	The respondent has smoked within the past month.	The respondent has smoked within the past month.	The respondent has smoked within the past month.	The respondent has smoked within the past month.	The respondent has smoked within the past month.	
		Never smoked	Yes, every day	Yes, but not every day	Has quit smoking	Has quit smoking
	TB Case	36.0%	20.0%	4.0%	40.0%	40.0%
	Control	68.0%	28.0%	4.0%	0.0%	0.0%
6	The respondent typically smokes indoors, including in public places, schools, workplaces, or other enclosed spaces.	The respondent typically smokes indoors, including in public places, schools, workplaces, or other enclosed spaces.	The respondent typically smokes indoors, including in public places, schools, workplaces, or other enclosed spaces.	The respondent typically smokes indoors, including in public places, schools, workplaces, or other enclosed spaces.	The respondent typically smokes indoors, including in public places, schools, workplaces, or other enclosed spaces.	
		Never smoked	Yes	No		
	TB Case	36.0%	52.0%	12.0%		
	Control	68.0%	8.0%	24.0%		
7	The respondent regularly	The respondent regularly	The respondent regularly	The respondent regularly	The respondent regularly	

	smokes inside their home.	smokes inside their home.	smokes inside their home.	smokes inside their home.	smokes inside their home.
		Never smoked	Yes	No	
	TB Case	36.0%	52.0%	12.0%	
	Control	68.0%	8.0%	24.0%	
8	The respondent is frequently exposed to secondhand smoke in enclosed spaces, including at home, work, or in public transportation.	The respondent is frequently exposed to secondhand smoke in enclosed spaces, including at home, work, or in public transportation.	The respondent is frequently exposed to secondhand smoke in enclosed spaces, including at home, work, or in public transportation.	The respondent is frequently exposed to secondhand smoke in enclosed spaces, including at home, work, or in public transportation.	The respondent is frequently exposed to secondhand smoke in enclosed spaces, including at home, work, or in public transportation.
		Very often	Sometimes	Never	
	TB Case	80.0%	12.0%	8.0%	
	Control	32.0%	40.0%	28.0%	

Tuberculosis (TB) is primarily transmitted through the air when infected individuals exhale droplets containing *Mycobacterium tuberculosis*. While most infected individuals successfully clear the bacteria without symptoms (known as latent or reactive TB), approximately 5–10% progress to active TB, particularly in the lungs. Small droplets can reach the alveoli and infect alveolar macrophages (AMs), whereas larger droplets are typically trapped and cleared by the upper respiratory tract. However, in smokers, the mucociliary clearance system is impaired, leading to an accumulation of AMs and creating a pulmonary environment more conducive to the growth and persistence of *M. tuberculosis.*

Table 6. Chi-Square Test of TB Incidence in Relation to Smoking Frequency, Type, and Intensity.

Variable	**Chi-square**	**p-value**
TB Case vs. Smoking Frequency	9.01	0.007
TB vs. Age at First Smoking	9.35	0.011
TB vs. Cigarette Type	3.93	0.048
TB vs. Number of Cigarettes Smoked	9.79	0.013

Furthermore, the results of the Chi-square analysis showed a significant association between TB incidence and smoking frequency ($\chi^2 = 9.01$; $p = 0.007$), age at first smoking ($\chi^2 = 9.35$; $p = 0.011$), type of cigarette used ($\chi^2 = 3.93$; $p = 0.048$), and the number of cigarettes smoked per day ($\chi^2 = 9.79$; $p = 0.013$). These findings indicate that, in addition to being an active smoker, specific aspects such as smoking frequency, early exposure to smoking, consumption intensity, and the type of tobacco product used may be more decisive factors in increasing susceptibility to *Mycobacterium tuberculosis* infection. The type of tobacco product indeed shows a significant association with TB incidence. However, in the current era, most smokers tend to use filter cigarettes, while the use of other types of cigarettes has become increasingly rare. This preference is likely influenced by practical factors, product availability

in the market, and public perception that filter cigarettes are "lighter," even though they still contain harmful substances.

One study found that the risk of developing tuberculosis increased among individuals who had ever smoked, with an odds ratio of 1.35; current smokers had an OR of 1.26; and former smokers had an OR of 1.43 when compared to those who had never smoked (Smith et al., 2015). This risk is influenced by factors such as dose, smoking intensity, smoking duration, and the type of tobacco used (Gambhir et al., 2010; Smith et al., 2015). Moreover, exposure to second-hand smoke (SHS) has also been shown to increase the risk of pulmonary tuberculosis. A meta-analysis by Dogar et al. (2015) reported that SHS exposure was significantly associated with an increased risk of active TB (RR = 1.59). Additionally, a cohort study by Leung et al. (2004) in Hong Kong found that elderly women who were routinely exposed to cigarette smoke at home had a 1.5-fold greater risk of developing active TB compared to those who were not exposed. Consistent with these findings, the present study showed that 80.0% of pulmonary TB cases were frequently exposed to cigarette smoke in enclosed spaces, such as at home, workplaces, or public transportation, compared to only 32.0% in the control group. Second-hand smoke (SHS), also referred to as environmental tobacco smoke, involuntary smoke, or passive smoke, is predominantly composed of sidestream smoke, emitted directly from the burning end of a cigarette, which accounts for about 85%, while the remaining 15% comes from mainstream smoke exhaled by the smoker. SHS contains over 7,000 chemical substances, including nicotine, many of which are known toxins and carcinogens. Because sidestream smoke results from incomplete combustion and is unfiltered, it is potentially more hazardous than mainstream smoke in terms of toxic and carcinogenic exposure (Bai et al., 2018).

4. CONCLUSION

This study highlights that environmental and behavioral factors play a significant role in the occurrence of pulmonary tuberculosis in the working area of the Segiri Health Center, Samarinda. High housing density increases the likelihood of transmission by creating conditions that facilitate the spread of Mycobacterium tuberculosis. Suboptimal indoor humidity also contributes to the persistence of airborne pathogens. In addition, smoking behavior—whether active smoking or exposure to secondhand smoke in enclosed spaces—substantially heightens vulnerability to the disease. Various aspects related to smoking habits, including frequency, age at initiation, cigarette type, and daily consumption, further reinforce the strong association between tobacco exposure and tuberculosis risk. These findings emphasize the importance of improving living conditions and strengthening tobacco control measures as essential components of comprehensive TB prevention efforts.

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