Journal Home Page:
https://e-journal.unair.ac.id/JKL

Jurnal Kesehatan Lingkungan
Journal of Environmental Health
Vol. 15 No. 1
DOI: 10.20473/jkl.v15i1.2023.76-83
ISSN: 1829 - 7285 | E-ISSN: 2040 - 881X

ORIGINAL RESEARCH Open Access

THE RELATIONSHIP BETWEEN VENTILATION AND PHYSICAL QUALITY OF HOUSES WITH PULMONARY TUBERCULOSIS CASES IN THE WORKING AREA OF SRAGEN PRIMARY HEALTHCARE CENTER, SRAGEN REGENCY

Radhika Wulandari[1]*, Budiyono Budiyono[1], Sulistiyani Sulistiyani[1], Endah Wahyuningsih[1]

[1]Department of Environmental Health, Undergraduate Public Health Study Program, Faculty of Public Health, Diponegoro University, Semarang 50275, Indonesia

Corresponding Author:
*) radhikawulandari@alumni.undip.ac.id

Article Info
Submitted : 16 August 2022
In reviewed : 19 September 2022
Accepted : 18 January 2023
Available Online : 31 January 2023

Keywords : *House, Tuberculosis, Ventilation.*

Published by *Faculty of Public Health Universitas Airlangga*

Abstract

Introduction: *Pulmonary tuberculosis is ranked the second health problem in the world, including Indonesia with reasonably high mortality rates. This study examined the association between the ventilation, physical condition, and the prevalence of pulmonary tuberculosis in the working area of the Sragen Primary Healthcare Center.* ***Methods:*** *This study used a case-control design and purposive sampling to select 40 patients with positive smear pulmonary tuberculosis as the case group and 40 subjects with negative smear pulmonary tuberculosis as the control group who lived in the same area.* ***Results and Discussion:*** *Ventilation volume per hour (p = 0.007; OR = 3.889; 95% CI = 1.533–9.868), ventilation area (p = 0.014; OR = 3.462; 95% CI = 1.379–8.691), lighting intensity (p = 0.007; OR = 3.955; 95% CI = 1.546–10.114) and a humidity level (p = 0.001; OR = 5.762; 95% CI = 2.065–16.079) were associated with the prevalence of pulmonary tuberculosis in patients of the productive age group who attended the Sragen Primary Healthcare Center. The results of the multivariate analysis conclude that ventilation (OR = 5.900), humidity level (OR = 8.414), and occupancy density (OR = 0.113) had joint influences with a significant contribution of 41.3% to TB prevalence.* ***Conclusion:*** *House' ventilation and humidity are the main factors contributing to the incidence of pulmonary tuberculosis in the working area of Sragen Primary Healthcare Center.*

INTRODUCTION

Tuberculosis (TB) is a gram-positive bacterium-caused infectious disease identified as one of ten common mortality causes (1). In most TB cases, Mycobacterium tuberculosis attacks the lungs, but it can also infect other organs. This disease can be transmitted from TB patients to healthy people who inhale the TB bacteria or come into close contact with them. TB cases were predicted to result in 1.3 million HIV-negative TB deaths in 2020 (2). The number of TB cases reached to 8.9–11 million tuberculosis sufferers worldwide in 2019, expected to be eradicated by 2020. Based on geographical conditions, countries that mostly develop TB cases are in the Southeast Asia regions, including Indonesia which was known as having the second largest TB prevalence in the world or 8.5% of all TB cases in the world after India (26%) (1).

Based on the Indonesian Ministry of Health statistics, the number of detected tuberculosis cases was 397,377 in 2021 and 351,936 in 2020. These trends show a decrease compared to 2019, where the tracked cases numbered to 568,987 cases (3). The entire number of tuberculosis cases in Sragen Regency was 477 cases in 2021, with the highest number of cases at the Sragen Primary Healthcare Center, of which 37 cases had positive BTA results. Meanwhile, the total number of tuberculosis cases was 599 in 2020, and the Sragen Primary Healthcare Center was found to have the highest rate in two consecutive periods. As many as 44 positive BTA cases occurred in 2020 at the Primary Healthcare Center with a Case Notification Rate (CNR) value of 67 per 100,000 population and a Case Detection Rate (CDR) value of 30.6%. A higher number of TB cases were detected in 2020, numbering to 952 cases, and the

Cite this as :
Wulandari R, Budiyono B, Sulistiyani S, Wahyuningsih E. The Relationship between Ventilation and Physical Quality of Houses with Pulmonary Tuberculosis Cases in the Working Area of Sragen Primary Healthcare Center, Sragen Regency. *Jurnal Kesehatan Lingkungan*. 2023;15(1):76–83. https://doi.org/10.20473/jkl.v15i1.2023.76-83

highest number of tuberculosis cases was also found at the same place. As many as 73 cases with positive BTA were found in the period with a Case Notification Rate (CNR) value of 107 per 100,000 population and a Case Detection Rate (CDR) value of 48.6% (4–6).

Several risk factors of pulmonary tuberculosis are malnutrition, indoor air quality, the volume of Air Changes per Hour (ACH), ventilation area, lighting intensity, relative humidity levels, and residential overcrowding (7–10). Houses or buildings are vulnerable places, transmitting airborne diseases, including tuberculosis. A study in Brazil revealed inadequate housing is related to tuberculosis (11). Buildings in humid tropical countries are certainly required to have well-designed ventilation system absorbing fresh air from outside. Inadequate ventilation system in indoor spaces affects the temperatures and humidity levels, contributing to the development of bacteria (12). According to a previous study, there is a relationship between the ventilation system and the transmission of airborne infectious diseases i.e., nosocomial infections (13).

The volume of air changes per hour, commonly expressed in ACH, is one of the important indicators in reducing levels of pathogenic microorganisms such as viruses, bacteria, and fungi in the indoor air. However, there is no information on the relationships between air changes per hour, physical house, and the tuberculosis incidence in Sragen regency. Therefore, the study aimed to analyze air changes per hour, the physical house, and the tuberculosis incidence in Sragen regency.

METHODS

The research was an observational study with a case-control design. It was conducted from February to June 2022. The research population was patients with the smear-positive pulmonary tuberculosis as the case group and patients with smear-negative pulmonary tuberculosis as the control group. All research population lived in the same area as Sragen Primary Healthcare Center. The case and control populations attended services at the Sragen Primary Healthcare Center.

Of the total population, 80 subjects were selected through purposive sampling and grouped into 40 patients as the case group and 40 patients in the control group. According to the inclusion criteria, subjects of the case group were male or female subjects aged 15–64 years, willing to be respondents, living in the working area of the Sragen Primary Healthcare Center, and receiving treatment due to being confirmed positive BTA. The exclusion criteria were that patients suffered from sickness, were died during the research activity and no longer lived in the working area. The exclusion criteria for respondents had other respiratory diseases such as asthma, bronchitis, and others.

This study included the incidence of pulmonary tuberculosis as the dependent variable and the volume of air changes per hour, ventilation area, lighting intensity, humidity level, type of floor, house construction, and occupancy density as the independent variables. The structured questionnaires were employed to evaluate the variables. The research data were divided into two categories, namely secondary data, i.e., reports from related agencies and scientific journals, and primary data obtained from the results of questionnaires, observations, and direct measurements on the conditions of the subjects' houses. The bivariate analysis used a chi-square test with a 5% error rate and a 95% confidence interval. Multiple logistic regression test was used for multivariate analysis, and univariate analysis was used for data evaluation.

RESULTS

Univariate Analysis Results

Table 1 shows that the subjects' characteristics. The majority of the subjects was mostly male (70.0%) in the case group and (57.5%) in the control group. All subjects were of the productive age (15–64 years) (100%) in the case group, and nearly all of the productive age (90.0%) were in the control group; both case and control groups did not have a history of HIV/AIDS (100%). Both case and control groups used liquid petroleum gas/ LPG (100%) as cooking fuel. Some subjects of the case group had normal BMI status and thin status (47.5%), and 80.0% of control subjects had normal BMI status. In terms of smoking habits, 82.5% of case subjects were non-smokers, and so were 67.5% of control subjects. In the next category, more than half of case subjects never smoked (52.5%), and neither did many control subjects (67.5%); controls (67.5%) and case groups (55.0%) mostly had a lower or sufficient level of income.

Table 1. Cross-tabulation between Respondents' Characteristics and Incidence of Pulmonary Tuberculosis in the Work Area of Sragen Primary Healthcare Center

Characteristics of Respondents	Incidence of Pulmonary Tuberculosis			
	Pulmonary TB (person)	(%)	No Pulmonary TB (person)	(%)
Gender				
Man	28	70.0	23	57.5
Woman	12	30.0	17	42.5
Total	**40**	**100.0**	**40**	**100.0**
Age				
Productive Age (15-64 years)	40	100.0	36	90.0
Non-Productive Age (> 64 years)	0	0.0	4	10.0
Total	**40**	**100.0**	**40**	**100.0**

Characteristics of Respondents	Incidence of Pulmonary Tuberculosis			
	Pulmonary TB (person)	(%)	No Pulmonary TB (person)	(%)
History of HIV/AIDS				
HIV/AIDS	0	0.0	0	0.0
No HIV/AIDS	40	100.0	40	100.0
Total	**40**	**100.0**	**40**	**100.0**
Type of Cooking Fuel				
Oil Stove, Firewood	0	0.0	0	0.0
LPG gas	40	100.0	40	100.0
Total	**40**	**100.0**	**40**	**100.0**
BMI Status				
Thin	19	47.5	0	0.0
Normal	19	47.5	32	80.0
Overweight	2	5.0	8	20.0
Total	**40**	**100.0**	**40**	**100.0**
Smoking Status				
Yes Smoking	7	17.5	13	32.5
Do not smoke	33	82.5	27	67.5
Total	**40**	**100.0**	**40**	**100.0**
Smoking Category				
Current smoker	5	12.5	12	30.0
Former smoker	14	35.0	1	2.5
Never smoked	21	52.5	27	67.5
Total	**40**	**100.0**	**40**	**100.0**
Income Level				
Income is less and or sufficient (<Rp 2,000,000.00)	27	67.5	22	55.0
More income (>Rp 2,000,000.00)	13	32.5	18	45.0
Total	**40**	**100.0**	**40**	**100.0**

Bivariate Analysis Results

Table 2 shows correlations between variables. Results show associations between the volume of air changes per hour (p = 0.007; OR = 3.889; 95% CI 1.533–9.868), ventilation area (p = 0.014; OR = 3.462; 95% CI 1.379–8,691), lighting intensity (p = 0.007; OR = 3.955; 95% CI 1.546–10.114) and humidity level (p = 0.001; OR = 5.762, 95% CI 2.065–16.079) with the prevalence of TB cases; meanwhile, there was no relationship between the type of floor (p = 1.000; OR = 2.026; 95% CI 1.620–2.533), type of house construction, type of indoor air pollution (p = 0.156; OR 0.451; 95% CI 0.174–1.168) and residential density (p = 0.050; OR = 0.259; 95% CI 0.075–0.891) with the prevalence of TB cases in the working area.

Table 2. Bivariate Analysis of Ventilation and Physical Quality of Houses with the Incidence of Pulmonary Tuberculosis in the Working Area off Sragen Primary Healthcare Center, Sragen Regency

Independent Variables	Case (n = 40)		Control (n = 40)		p-value	95 % CI
	n	%	n	%		
Ventilation volume per hour*						
Not meet requirements	25	62.5	12	30.0	0.007	1.533–9.868
Meet requirements	15	37.5	28	70.0		
Ventilation area*						
Not meet requirements	25	62.5	13	32.5	0.014	1.379–8.691
Meet requirements	15	37.5	27	67.5		
Lighting Intensity*						
Not meet requirements	24	60.0	11	27.5	0.007	1.546–10.114
Meet requirements	16	40.0	29	72.5		
Humidity Level*						
Not meet requirements	22	55.0	7	17.5	0.001	2.065–16.079
Meet requirements	18	45.0	33	82.5		
Floor Type						
Not meet requirements	0	0.0	1	2.5	1.000	1.620–2.533
Meet requirements	40	100.0	39	97.5		
Type of Building Construction						
Not meet requirements	0	0.0	0	0.0	-	-
Meet requirements	40	100.0	40	100.0		
Types of Indoor Air Pollution						
Not meet requirements	10	25.0	17	42.5	0.156	0.174–1.168
Meet requirements	30	75.0	23	57.5		
Occupancy Density						
Not meet requirements	4	10.0	12	30.0	0.050	0.075–0.891
Meet requirements	36	90.0	28	70.0		

Multivariate Analysis Results

In Table 3, the multivariate analysis results are presented descriptively. This study presents the ideas that the ventilation had an OR of 5.900, meaning non-standard ventilation has 5.900 times greater chances to contribute to TB vases than adequate ventilation. The humidity level variable had an OR of 8.414, indicating that adequate humidity level poses someone at risk of suffering pulmonary tuberculosis as much as 8.414 times greater than inadequate humidity. The occupancy density variable had an OR of 0.113, pointing to 0.113 times greater chances of TB cases caused by high occupancy density. Therefore, if one lives with a ventilation area, humidity level, and occupancy density that do not meet the requirements, the chances to develop TB are higher. Ventilation, humidity level, and occupancy density determine 99.6% of the TB occurrence contribute as much as 41.3% to this disease.

Table 3. Multivariate Analysis of Double Logistics Regression Test on Ventilation and Physical Quality of Houses with the Incidence of Pulmonary Tuberculosis in the Working Area off Sragen Primary Healthcare Center, Sragen Regency

Variables	B	*P-values*	*Exp* B	95 % CI	
				Lower	*Upper*
Ventilation area	1.775	0.002	5.900	1.880	18.517
Humidity level	2.130	0.001	8.414	2.470	26.668
Occupancy density	-2.180	0.005	0.113	0.025	0.514
Constant	-0.601	0.422	0.548		

DISCUSSION

Relationship between Air Change per Hour and Prevalence of Pulmonary Tuberculosis Cases

Air change per hour or air change rate is the number of times at which the total air volume in a room or space is completely removed and replaced in an hour. Air change per hour or commonly expressed in Air Changes per Hour (ACH) is one of the important indicators to assess the quality of ventilation in the environment and is commonly used to design a good ventilation model. According to the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE), on average, a house could receive a minimum of 0.35 ventilations per hour and not less than 425 L per minute (lpm) per person of good indoor air. Then, the ASHRAE guidelines No. 170 of 2008 and the 2005 CDC guidelines recommend a minimum ventilation rate of 12 ACH in isolation rooms of hospitals. Poor ventilation design will affect the hourly ventilation rate at a house. If the airflow rate increases, it will help dilute the pollution concentration better, especially the contaminant sources such as aerosols containing tuberculosis germs. An increase in air flow rate has a small impact on alleviating possibilities of infections while improving ventilation, humidity, temperature, and filtration systems is way better to prevent the prevalence of TB cases.

In this study, an average ACH was 13.58 which met the ACH standard for indoor spaces of >12. The proportion of subjects with ineligible ACH and no pulmonary TB infections was 65%, higher compared to that with qualified ACH and pulmonary TB infections (37.5%). This proves that the number or frequency of air changes per hour is less than 12 times, causing the house occupants to be at risk of pulmonary tuberculosis. House pollutants can be particulate, bacteria, viruses, and fungi (14–15). The air impurities or air pollutants in the house cannot be completely guided to outside the house. TB cases occur due to inadequate ACH which potentially transmit TB bacteria to the house occupants. ACH depends on the speed and movement of air entering and leaving the house (16). Expanding ventilation such as opening windows and doors every day can reduce the number of contaminants at the house (17).

Relationship between Ventilation Area and Prevalence of Pulmonary Tuberculosis Cases

The ventilation area that is exposed to sunlight likely affects the level of humidity in a room and minimizes the concentration of tuberculosis germs or others that exist in the room. According to the requirements from the Regulation of the Indonesian Minister of Health No. 1077 of 2011, the ventilation area is > 20% of the floor area (1). The results of observations on the respondent's houses show that many houses did not have required ventilation areas; the subjects also did not open windows in the morning or afternoon, leading to an increase in humidity levels of the houses. Furthermore, high housing density can cause TB to grow more rapidly and spread quickly.

The research in Tiga Panah District, Karo Regency in 2021 found an association between the ventilation area and the prevalence of pulmonary tuberculosis cases (p = 0.006) (2). Researchers in Kebasen District, Banyumas Regency in the following year discovered a similar finding with a p-value of 0.0001 (3). Ventilation was also associated with symptoms of tuberculosis with a p-value of 0.003 as found in a study at the Bandarharjo Medical Center in 2017 (4). However, research in the working area of the Barengkrajan Primary Healthcare Center in 2020 stated different results that the ventilation area variable was not a factor of pulmonary TB cases with an OR of 1.457 (5).

Relationship between Lighting Intensity and Pulmonary Tuberculosis

Based on the Regulation of the Indonesian Minister of Health number 1077 of 2011, house lighting must be above 60 lux (1). The intensity of lighting that is not optimal or way far from the standard, in this case, can contribute to the development of tuberculosis bacteria in a room. Tuberculosis bacteria cannot die and resist sunlight; they can only be destroyed at 60 lux of light intensity. Optimal lighting intensity, based on the requirements, can prevent TB transmission and proliferation (6). Ultraviolet C light with 200–280 nm of a wavelength can kill microorganisms such as bacteria, viruses, and fungi up to more than 99.9% (18). The source of ultraviolet C lights can come from sunlight or ultraviolet light lamps. The ultraviolet lights also can damage base pairs in the DNA of the bacteria, resulting in irreparable DNA (19).

Research, which was conducted in Tiga Panah subdistrict, Karo regency in 2021, is also in line with this study. The previous research shows that light intensity of less than 60 lux will have a 0.415 times higher risk of pulmonary tuberculosis occurrence (2). Additionally, research in the Kumun Primary Healthcare Center in 2021 also indicated a substantial association between light intensity and pulmonary tuberculosis occurrence with a p-value of 0.001 (20). In 2018, researchers at the Panjang Primary Health Center discovered an association between light intensity and pulmonary tuberculosis occurrence (21). Research in the working area of Korleko Primary Healthcare Center in 2022 found opposite findings with a p-value of 0.926 (22).

Relationship between Humidity Levels and Prevalence of Pulmonary Tuberculosis Cases

According to the Regulation of the Indonesian Minister of Health number 1077 of 2011 concerning air cleanliness in residential areas, room humidity levels at 40%–60% meet the requirements. Humidity level in the house can be a tricky factor that contributes to the growth of *Mycobacterium tuberculosis* (6). Humidity is also related to lighting intensity, the walls, or floors of the houses. Dark and damp rooms may retain *Mycobacterium tuberculosis* even longer. However, exposure to direct sunlight solves the bacteria growth.

Previous research dealing with the Kumun Sungai Primary Healthcare Center supports this study by stating that humidity has a major association with pulmonary tuberculosis occurrence with a p-value of 0.038 (20). Multivariate analysis in Mine district, Kampar regency in 2021, which states that the humidity variable has the most dominant effect on the incidence of pulmonary tuberculosis with a p = 0.017 (23). Researchers in Pakowa Village, Wanea District, Manado City discovered an association between room humidity and the incidence of pulmonary tuberculosis with a p-value of 0.000 (24). In addition to previous studies, previous research in the fishing village Seberang Lingkungan XII, Belawan I village, Medan also shows a similar result (25).

Relationship between Floor Type and Prevalence of Pulmonary Tuberculosis Cases

Based on the Regulation of the Indonesian Ministry of Health Number 829 of 1999 concerning Residential Hygiene Requirements, floor must be waterproof, easy to clean, and comprises of materials such as cement, wood, ceramics, and tiles (21). A dirty and damp floor can cause the proliferation of disease; Hence, the choice of floor material is important to avoid sources of diseases. Based on the results of the survey, the subjects owned houses with waterproof floors that were always dry and easy to clean. The majority of their floors were tiles and ceramics, which are considered not easily moist, thus reducing the proliferation of germs.

The results of this study indicate that the type of floor is not related to the incidence of pulmonary tuberculosis. Where this is supported by research at the Korleko Health Center, which shows the prevalence of pulmonary tuberculosis is not associated with floor type with a p-value of 0.097 (22). According to a study conducted in Semarang City and Manente Primary Healthcare Center, there is no association between floor type and pulmonary tuberculosis (26–27). However, other studies have shown different results, where residents of the Palembang city slums in 2018 found a correlation between floor type and the incidence of pulmonary tuberculosis (28).

Relationship between Types of House or Building Construction and Prevalence of Pulmonary Tuberculosis Cases

This study revealed a result that type of house or building construction was not related to the occurrence of pulmonary tuberculosis as the majority of respondents lived at houses with sufficient walls following the government's guidelines. The Regulation of the Indonesian Minister of Health Regulation Number 1077 of 2011 states that walls are made permanent and waterproof. Based on the research in the working area of the Barengkrajan Primary Healthcare Center in 2022. Type of house wall was determined having an OR of 0.873, and it was not a factor causing the incidence of pulmonary tuberculosis (5). Besides that, research in the working area of the Kumun Sungai Penuh Primary Healthcare Center confirms this current study (p = 1.000) (20).

Relationship between Indoor Air Pollution and Prevalence of Pulmonary Tuberculosis Cases

Indoor air pollution was found to be a risk factor but was not associated with the pulmonary tuberculosis occurrence. The main factors that affect indoor air pollution include physical factors and external factors as outdoor air quality and outdoor pollution contamination can also affect the Heating, Ventilation, and Air Conditioning (HVAC) system. The largest single contributor of indoor air pollution comes from Environmental Tobacco Smoke (ETS); the US Environmental Protection Agency (US EPA) explains that ETS posits a causal correlation with lung cancer in adults who do not smoke. Besides, formaldehyde emissions, which usually come from wooden furniture, are also considered as one source of indoor air pollution. The observations show that some houses were still polluted by cigarette smoke. The relationship between indoor air pollution, especially from exposure to cigarette smoke which contains pollutants such as carbon monoxide, also suggests the inhibition of apoptosis (the removal of dead or unused cells in the body, especially cells that have been infected with tuberculosis bacteria). A literature review in 2021 stated that exposure to cigarette smoke will affect the function of the antigen response, disrupting the lungs to recognize entering foreign materials (29).

Relationship between Occupancy Density and Prevalence of Pulmonary Tuberculosis Cases

Occupancy fluctuation is a risk factor, but it is not associated with pulmonary tuberculosis occurrence. Overcrowding is associated with disease transmission, including tuberculosis bacteria to other family members (30). Based on the Decree of the Indonesian Minister of Health Number 829 of 1999 concerning Housing Hygiene Requirements, housing density is considered to meet the requirements if it exceeds 8 m^2 per person (31). Occupancy fluctuation is a risk factor, but it is not associated with the prevalence of pulmonary tuberculosis cases. Thus, household overcrowding can mediates disease transmission (30).

Research in the Kabila Health Center in 2021 also found no significant relationship between pulmonary tuberculosis and occupancy density with a p-value of 0.136 as shown in the Chi-square analysis (32). A study at the Perak Timur Primary Healthcare Center in 2019 figured out no significant relationship between occupancy density and the presence of tuberculosis bacteria (33). Compared to this study, research in the working area of the Pekalongan Primary Healthcare Center also found no association between fluctuating occupancy density and the incidence of pulmonary tuberculosis with a p-value of 0.743 (34). Research conducted at the Lhok Bengkuang Primary Healthcare Center in Tapaktuan district, South Aceh regency found that residential density was associated with BTA Pulmonary TB (+) with a p-value of 0.001 (35).

ACKNOWLEDGMENTS

The authors would like to thank various parties who have assisted in data collection. Research respondents decided to participate in this study without any coercion from any parties.

CONCLUSION

Air change per hour, ventilation area, lighting level, and humidity level are risk factors of pulmonary tuberculosis for residents of the working area at the Sragen Primary Healthcare Center, Sragen district, Sragen regency. The results of the multiple logistic regression test mentions that the variables of ventilation area, humidity level, and occupancy density had effects on the prevalence of pulmonary tuberculosis cases in the working area of the Sragen Primary Healthcare Center. This study holds some limitation regarding the data measurement. Air changes were measured per hour only in the morning, and the measurement was not subject to before and after the occurrence of pulmonary tuberculosis. It is important to maintain air changes at the house by opening the ventilation facilities and designing a well-thought ventilation system.

REFERENCES

1. Ministry of Health of Republic of Indonesia. Regulation of the Minister of Health of the Republic of Indonesia Number 1077 of 2011 concerning Guidelines for Air Sanitation in Home Rooms. Jakarta: Ministry of Health of Republic of Indonesia; 2011.
2. Manalu SMH, Syaputri D, Tanjung T, Soedjadi TTB. Faktor Risiko Kondisi Lingkungan Fisik Rumah dengan Penderita TB Paru. *Jurnal Ilmiah PANNMED*. 2022;17(1):63–70. https://doi.org/10.36911/pannmed.v17i1.1264
3. Aryani AA, Wardani FLK, Rahardjo S. Lingkungan Fisik Rumah Sebagai Faktor Risiko Kejadian Tuberkulosis Paru di Kecamatan Kebasen, Kabupaten Banyumas. *Jurnal Ilmiah Kesehatan Masyarakat*. 2022;14(2):56–62. https://doi.org/10.52022/jikm.v14i2.333
4. Anggraeni DE, Rahayu SR. Gejala Klinis Tuberkulosis pada Keluarga Penderita Tuberkulosis BTA Positif. *Higeia Journal of Public Health Research and Development*. 2018;2(1):91–101. https://journal.unnes.ac.id/sju/index.php/higeia/article/view/18100/10483
5. Ulprastika ME, Narwati, Ipmawati PA. Analisis Faktor Risiko Kondisi Fisik Rumah terhadap Penyakit TB Paru di Wilayah Kerja Puskesmas Barengkrajan Kabupaten Sidoarjo Tahun 2020. *GEMA Lingkungan Kesehatan*. 2022;20(01):49–53. https://doi.org/10.36568/gelinkes.v20i1.3
6. Sikumbang RH, Eyanoer PC, Siregar NP. Factors Related to the Incidence of Pulmonary Tuberculosis at the Productive Age in the Working Area of Tegal Sari Public Health Center in Medan Denai District in 2018. *Ibnu Sina*. 2022;21(1):32–43. https://www.jurnal.fk.uisu.ac.id/index.php/ibnusina/article/view/196/177
7. Tobing KL, Nainggolan O, Rachmawati F, Manalu HSP, Sagala RD, Kusrini I. The Relationship between Malnutrition and Tuberculosis (TB) at the Age Group more than 18 Years Old in Indonesia (Analysis of the Basic Health Research 2018). *International Journal of Innovation, Creativity and Change*. 2021;15(9):332–348. https://doi.org/10.53333/IJICC2013/15941
8. Narasimhan P, Wood J, MacIntyre CR, Mathai D. Risk Factors for Tuberculosis. *Pulmonary Medicine*. 2013;2013(828939):1–11. https://doi.org/10.1155/2013/828939
9. Muhammad AJ, Lestari P, Widodo ADW. The Ventilation to Area Ratio and House Lighting Relate to the Incidence of Pulmonary Tuberculosis. *Althea Medical Journal*. 2020;7(1):1–5. https://doi.org/10.15850/amj.v7n1.1821
10. Lee JY, Kwon N, Goo G, Cho S. Inadequate Housing and Pulmonary Tuberculosis: A Systematic Review. *BMC Public Health*. 2022;22(622):1–12. https://doi.org/10.1186/s12889-022-12879-6

11. André SR, Nogueira LMV, Rodrigues ILA, Cunha TNd, Palha PF, Santos CBd. Tuberculosis Associated with The Living Conditions in An Endemic Municipality in the North of Brazil. *Revista Latino-Americana de Enfermagem*. 2020;28(e3343):1–10. https://doi.org/10.1590/1518-8345.3223.3343
12. Andualem Z, Gizaw Z, Bogale L, Dagne H. Indoor Bacterial Load and its Correlation to Physical Indoor Air Quality Parameters in Public Primary Schools. *Multidisciplinary Respiratory Medicine*. 2019;14(2):1–7. https://doi.org/10.1186/s40248-018-0167-y
13. Nourmohammadi M, Mirzaei R, Taban E, Yari S. Effect of Ventilation System on Spread and Control of Infections (Covid19) in Indoor Environments: Based on Current Studies. *Asian Pacific Journal of Environment and Cancer*. 2020;3(1):55–58. https://doi.org/10.31557/apjec.2020.3.1.55-58
14. Vardoulakis S, Giagloglou E, Steinle S, Davis A, Sleeuwenhoek A, Galea KS, et al. Indoor Exposure to Selected Air Pollutants in the Home Environment: A Systematic Review. *International Journal of Environmental Research and Public Health*. 2020;17(8972):1–24. https://doi.org/10.3390/ijerph17238972
15. Kumar P, Kausar MA, Singh AB, Singh R. Biological Contaminants in the Indoor Air Environment and their Impacts on Human Health. *Air Quality, Atmosphere & Health*. 2021;14(1):1723–1736. https://doi.org/10.1007/s11869-021-00978-z
16. Bullová I, Kapalo P, Katunský D. Quantification of Air Change Rate by Selected Methods in a Typical Apartment Building. *Buildings*. 2021;11(4):1–20. https://doi.org/10.3390/buildings11040174
17. Escombe AR, Oeser CC, Gilman RH, Navincopa M, Ticona E, Pan W, et al. Natural Ventilation for the Prevention of Airborne Contagion. *PLoS Medicine*. 2007;4(2):309–317. https://doi.org/10.1371/journal.pmed.0040068
18. Khan M, McDonald M, Mundada K, Willcox M. Efficacy of Ultraviolet Radiations against Coronavirus, Bacteria, Fungi, Fungal Spores and Biofilm. *Hygiene*. 2022;2(3):120–131. https://doi.org/10.3390/hygiene2030010
19. Zion M, Guy D, Yarom R, Slesak M. UV Radiation Damage and Bacterial DNA Repair Systems. *Journal of Biological Education*. 2006;41(1):30–33. https://doi.org/10.1080/00219266.2006.9656054
20. Monica T. Relationship of the Physical Home Environment with the Incidence of Pulmonary TB in Adults in the Working Area of the Community Health Center in Kumun Sungai Penuh City. *Manuju: Malahayati Nursing Journal*. 2022;4(1):210–226. https://doi.org/10.33024/mnj.v1i1.5745
21. Perdana AA, Putra YS. Relationship Factors of Physical Environmental to House Against Pulmonary Tuberculosis (TB) Incidence in the Work Area of Panjang Community Health Centre, Lampung. *Jurnal Kesehatan*. 2018;9(1):46–50. https://doi.org/10.26630/jk.v9i1.739
22. Widiati B, Majdi M. Analysis Factor of Enviromental Fisical Houses with Pulmonary Tuberculosis in the Working Area of Korleko Public Health Center, East Lombok Regency. *Afiasi: Jurnal Kesehatan Masyarakat*. 2022;7(1):227–234. https://doi.org/10.31943/afiasi.v7i1.199
23. Putri AN, Zahtamal Z, Zulkifli Z. Hubungan Faktor Lingkungan Fisik, Sosial dan Ekonomi dengan Kejadian Tuberkulosis Paru di Kecamatan Tambang Kabupaten Kampar. *SEHATI: Jurnal Kesehatan*. 2021;1(1):6–15. https://doi.org/10.52364/sehati.v1i1.4
24. Kaligis GI, Pinontonan OR, Joseph WBS. Faktor Kondisi Lingkungan Fisik Rumah yang Berhubungan dengan Kejadian Tuberkulosis Paru di Kelurahan Pakowa Kecamatan Wanea Kota Manado. *Jurnal KESMAS*. 2019;8(6):552–559. https://ejournal.unsrat.ac.id/index.php/kesmas/article/view/25724
25. Lubis FH, Annisa R. Faktor –Faktor yang Berhubungan dengan Penyakit TBC pada Nelayan di Kampung Nelayan Seberang Lingkungan XII, Kelurahan Belawan I, Medan. *Jurnal Kesehatan Masyarakat & Gizi (JKG)*. 2019;2(1):91–100. https://doi.org/10.35451/jkg.v2i1.277
26. Mubarok MNA, Siwiendrayanti A. Mutu Pelayanan Kesehatan Setelah Persalinan yang Berhubungan dengan Kepuasan Pelayanan Ibu Nifas. *Indonesian Journal of Public Health and Nutrition*. 2021;1(3):649–656. https://doi.org/10.15294/ijphn.v1i3.48078
27. Tatangindatu MA, Umboh MJ. House Physical Condition Factors and Incidence of Pulmonary Tuberculosis in Coastal Area. *Jurnal Ilmiah Sesebanua*. 2021;5(1):31–35. https://doi.org/10.54484/jis.v5i1.381
28. Budi DRRA, Amirus K, Perdana AA. The Correlation Between House Physical Environmental Condition with Pulmonary Tuberculosis (TB) Disease in the Work Area of Kuala Tungkal II, Jambi. *Jurnal Kesehatan Saelmakers PERDANA*. 2021;4(2):230–240. https://doi.org/10.32524/jksp.v4i2.270
29. Nur'aini N, Suhartono S, Raharjo M. Faktor-faktor yang Mempengaruhi Kejadian Tuberkulosis: Sebuah Review. *SANITASI: Jurnal Kesehatan Lingkungan*. 2021;13(1):20–25. https://doi.org/10.29238/sanitasi.v13i1.1079
30. Sari D. Gambaran Sanitasi dan Perilaku Penghuni Rumah Penderita Tuberkulosis di Wilayah Kerja Puskesmas Kedaton Kota Bandar Lampung Tahun 2021. *Jurnal Kesehatan Lingkungan Ruwa Jurai*. 2022;15(3):138–143. https://doi.org/10.26630/rj.v15i3.3072
31. Ministry of Health Republic of Indonesia. Decree of the Minister of Health Number 829 of 1999 concerning Residential Health Requirements. Jakarta: Ministry of Health Republic of Indonesia; 1999.
32. Suma J, Age SP, Ali IH. Faktor Determinan Lingkungan Fisik Rumah terhadap Kejadian TB Paru di Wilayah Kerja Puskesmas Kabila. *Jurnal Penelitian Kesehatan Suara Forikes*. 2021;12(4):483–488. http://dx.doi.org/10.33846/sf12423

33. Muslimah DDL. Physical Environmental Factors and Its Association with the Existence of Mycobacterium Tuberculosis: A Study in The Working Region of Perak Timur Public Health Center. *Jurnal Kesehatan Lingkungan*. 2019;11(1):26–34. https://doi.org/10.20473/jkl.v11i1.2019.26-34
34. Rahmawati S, Ekasari F, Yuliani V. Hubungan Lingkungan Fisik Rumah dengan Kejadian Tuberkulosis di Wilayah Kerja Puskesmas Pekalongan Kabupaten Lampung Timur Tahun 2020. *Indonesian Journal of Health and Medical*. 2021;1(2):254–265. http://rcipublisher.org/ijohm/index.php/ijohm/article/view/45/32
35. Mawardi M, Sambera R, Hamisah I. Studi Hubungan antara Faktor Lingkungan Fisik Rumah dengan Penderita TB Paru BTA di Aceh Selatan. *Jurnal Serambi Engineering*. 2019;4(1):406–415. https://doi.org/10.32672/jse.v4i1.851