

## RESEARCH ARTICLE

## Physical Environmental Conditions and Germ Number in Bedroom of Tuberculosis Patients in Kupang City, East Nusa Tenggara Province

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### Abstract

The ability of *Mycobacterium tuberculosis* as the agent of tuberculosis (TB) to live in the air is generally very dependent on environmental factors, which can cause bacteria to last long in the air and increase the risk of transmission of TB. The research purpose was to analyze the relationship between the physical environment condition and the number of germs in the bedroom of TB patients. This cross-sectional research was conducted in Kupang city, East Nusa Tenggara province, in January–June 2022 with 77 TB patients as samples, whose TB patients' rooms would be observed based on research variables for physical environmental conditions. Data were collected directly by observing and measuring directly from the variables studied and then analyzed using a correlation test and linear regression test to see the relationship between variables and the effect of the physical environmental condition on germ number in the bedroom. The correlation test shows the variables related to the bedroom germ number ( $p < 0.25$ ) were the number of people sleeping the TB patients, lighting, humidity, ventilation size, percentage of ventilation compared to room size, and room density. The model equation explains that 28.8% of the germ number variation in bedroom TB patients depends on the constant reduction (789,884) added to 19,217 times the bedroom humidity, then reduced by 9,518 times the percentage of room ventilation and also reduced by 31,185 times the density of the room occupancy. The most significant influence on the germ number in TB patients' bedrooms is the room humidity, which is 0.319.

**Keywords:** Bedroom, germ number, physical environmental, tuberculosis

### Introduction

Tuberculosis (TB) is an infectious disease caused by the bacteria *Mycobacterium tuberculosis* that enters the body through the respiratory tract. This disease is still a public health problem worldwide, and Indonesia has the 2<sup>nd</sup> highest TB cases after India.<sup>1</sup> TB cases in Indonesia have reached 1,000,000, with some deaths yearly.<sup>2</sup> In Kupang city, the number of cases of pulmonary TB for the year 2018–2020 respectively was 670 cases, 667 cases, and 522 cases.<sup>3</sup>

Many factors trigger the occurrence of TB transmission in the community, including the presence of TB germs, individual characteristics, and environmental factors.<sup>4–7</sup> House conditions such as humidity, temperature, lighting, and ventilation conditions, as well as residential density and house floors, are also associated with the incidence of TB transmission and determining factors for the presence of TB germs in people's homes.<sup>5–8–11</sup> Behavior has also been related to the incidence of TB transmission in the community.<sup>12,13</sup>

Environmental factors strongly influence the presence of TB germs.<sup>5,6,9,14</sup> Therefore, it is also necessary to intervene in physical environment risk factors so that the risk of TB transmission in the community can be reduced, especially among family members of TB patients at home.<sup>14</sup> The nature of germs in the air, in general, has similarities with the nature of TB germs, so this research aims to determine the relationship between the physical environmental conditions and the number of air germs in the bedroom of TB patients in Kupang city. Both the community and the government can use the research to prevent the transmission and incidence of TB in Kupang City.

### Methods

This is a cross-sectional study conducted in Kupang city, East Nusa Tenggara province, from January to June 2022. The samples included 77 tuberculosis patients whose bedrooms were observed based on research variables spread over 11 health centers in the working area of the Health

Received: 10 July 2022; Revised: 31 Juli 2022; Accepted: 6 August 2022; Published: 22 August 2022

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Office of Kupang City. They include bedroom size, temperature, number of family members sleeping with TB patients, room occupancy density, lighting, humidity, ventilation size, and airborne germ numbers in the bedroom. All research data except the airborne germs numbers were collected directly by observing and measuring the variables studied using roll Meter and environmental multimeter.

The airborne germ number is the number of pathogenic or non-pathogenic microorganisms floating in the air either together/attached to droplets (water) or particles (dust). We cultured them in the agar media to form colonies that can be observed visually or with magnifying glasses, then calculated based on the colony to be converted into colony-forming units per cubic meter (CFU/m<sup>3</sup>). First, air samples were taken with a microbial air sampler. Then the agar strip was put in an incubator of 30–35°C for 24 hours and repeated for another 24 hours if there was no growth of germs. Finally, the number of germ colonies grew was counted using the colony counter.

The data from the bedroom's TB patients were analyzed statistically using the bivariate test to see the relationship between the variables and the effect of the independent variables on the dependent variable using the multivariate linear regression test. This research has obtained ethical clearance from Politeknik Kesehatan Kemenkes Kupang with the number LB.02.03/1/0008/2022.

**Results**

TB patients' ages here range from 8 to 83 years, with varying physical environmental conditions in their bedroom, as shown in Table 1. The

number of germs in TB patients' rooms ranges from 1 to 2,010<sup>4</sup> CFU/m<sup>3</sup>. It means that not all rooms meet the requirements, such as the germ number should be <700 CFU/m<sup>3</sup>. Table 1 also shows that most TB sufferers sleep with others, and some even share with up to 7 people. Kupang city's temperature is quite hot, with the average temperature of the bedroom being 32.5°C, the average humidity of the bedroom being 69.81% RH, and lighting 59.71 Lux. The average ventilation percentage of the bedroom meets the requirements (19.846% of the bedroom size).

Based on bivariate analysis using a correlation test, the variables related to the germs number in the bedroom (p<0.25) were the number of people sleeping in the same room, lighting, humidity, ventilation size, percentage of ventilation compared to bedroom size, and also bedroom occupancy density (Table 2).

Variables related to the number of bedroom germs (p<0.25) were analyzed using a multiple linear regression test with the backward method. The model summary generated in this analysis shows that the coefficient of determination (R<sup>2</sup>) was 0.288. It meant that the regression model obtained can explain 28.8% of the variation in the number of germs in a room with tuberculosis patients. Therefore, the model generated in the resulting equation is quite good. The results of the F test also show the p value (significance F) is 0.000. The resulting regression model fits the existing data, which means the variables of the bedroom's size per person, humidity, and percentage of ventilation can significantly predict the number of air germs in the bedroom (Table 3).

The regression equations generated in this research are:

$$\text{Total germ number} = -789,884 + 19.217^* \text{bedroom}$$

**Table 1 Description of the Physical Environment Condition and Germ Number of a TB Patients Bedroom in Kupang City in 2022**

Variable for Bedroom (n=77)	Min–Max	Mean	SD
Bedroom germ number (CFU/m <sup>3</sup> )	1–2.104	194.62	417.053
Bedroom size (m <sup>2</sup> )	3–28	8.977	5.4631
Bedroom temperature (°C)	29–35	32.55	1.259
Number of roommates (people)	1–7	2.12	1.235
Bedroom occupancy density (m <sup>2</sup> /person)	1.3–24.0	5.391	4.0338
Bedroom lighting (Lux)	14–196	59.71	36.235
Bedroom humidity (% RH)	60–93	69.81	6.927
Ventilation size (m <sup>2</sup> )	0.0–5.0	1.455	0.8672
Ventilation percentage (%)	0.0–48	19.846	11.8624

**Table 2 Relation between the Physical Environmental Condition with the Germ Number in Bedroom's TB Patients**

Variable for Bedroom (n=77)		Bedroom Germ Number (CFU)
Bedroom size (m <sup>2</sup> )	Pearson correlation	0.025
	Sig. (2-tailed)	0.828
Bedroom temperature (°C)	Pearson correlation	-0.017
	Sig. (2-tailed)	0.886
Number of roommates (people)	Pearson correlation	0.298
	Sig. (2-tailed)	0.009
Bedroom occupancy density (m <sup>2</sup> /person)	Pearson correlation	-0.287
	Sig. (2-tailed)	0.011
Bedroom lighting (Lux)	Pearson correlation	-0.298
	Sig. (2-tailed)	0.009
Bedroom humidity (% RH)	Pearson correlation	0.390
	Sig. (2-tailed)	0.000
Ventilation size (m <sup>2</sup> )	Pearson correlation	-0.319
	Sig. (2-tailed)	0.005
Ventilation percentage (%)	Pearson correlation	-0.284
	Sig. (2-tailed)	0.012

**Table 3 Prediction Model of the Bedroom Germ Number of the TB Patients in Kupang City in 2022**

	Unstd. Coeff.		Std. Coeff.	t	Sig.
	$\beta$	Std. Error	$\beta$		
Constant	-789.889	455.251		-1.735	0.087
Bedroom humidity (% RH)	19.217	6.075	0.319	3.163	0.002
Ventilation percentage (%)	-9.518	3.574	-0.271	-2.663	0.010
Bedroom occupancy density (m <sup>2</sup> /person)	-31.185	10.376	-0.302	-3.006	0.004

humidity - 9.518\*bedroom ventilation percentage - 31.185\*bedroom occupancy density.

This equation also shows that the variable with the greatest influence ( $\beta$ ) in determining the number of germs in the air in the bedroom is bedroom humidity, which is 0.319.

## Discussion

Tuberculosis, where Indonesia ranked 2<sup>nd</sup> after India,<sup>1</sup> was in the world's top 10 leading causes of death.<sup>15</sup> TB cases are decreasing yearly, but the change is still not following the target of the End TB Strategy in 2020. It targeted a decrease in the 2015–2022 period by 20%; however, the reduction achieved is only around 9%.<sup>15</sup>

TB is a disease in which most of the risk factors for its occurrence are environmental and

behavioral factors, so these two factors need special attention in prevention and control so that transmission does not occur. No new cases can become a source of new transmission for people around them.<sup>16</sup>

This research found bedroom occupancy densities ranged from 1.3–24 m<sup>2</sup>/person, which was related to the number of germs in the bedroom. The correlation was negative, i.e., the higher the bedroom size per person, the lower the germ number. The number of people sleeping with TB patients ranged from 1 to 7 people, and it's positively correlated, namely, the more people who sleep in the same bedroom, the more germs number in the bedroom increases. On the other hand, if the number of germs in the room is high or 700 CFU/m<sup>3</sup>,<sup>16</sup> it is also necessary to reduce the number of people sleeping in the room because it

will facilitate the transmission of disease if one of them has a respiratory infection, including TB sufferers.

Decree of the Minister of Health Republic of Indonesia Number 829/Menkes/SK/VII/1999 regarding Housing Health Requirements stated that the minimum bedroom size is 8 m<sup>2</sup> and cannot be more than two people in a bedroom or at least 4 m<sup>2</sup>/person.<sup>17</sup> The average occupancy density of rooms in this research has met the requirements (5.3 m<sup>2</sup>/person), but many still do not meet the criteria. Some even have an occupancy density of only 1.3 m<sup>2</sup>/person, with up to 7 people sleeping in the same bedroom.

TB transmission mainly occurs due to close contact with patients through sputum sprinkling, which is estimated to produce 3,000 sputum sprinklings once a cough, while when clean, it can expel 4,500–1,000 TB germs in the droplets.<sup>18</sup> The more people sleep together and are in close contact with TB patients daily, the transmission of *Mycobacterium tuberculosis* and the TB incidence increases. Previous research in Pontianak found a relationship between bedroom occupancy density and germ number.<sup>19</sup> Based on the Ministry of Health Republic of Indonesia that close contacts are a risk group for TB transmission,<sup>20</sup> a study in Serang city concluded that household contact is associated with the incidence of TB with  $p=0.011$ .<sup>21</sup> and TB patients have a risk of transmitting this disease to 2–3 people of their family members.<sup>22</sup>

Based on these results, TB patients need to have their bedrooms until they are declared cured by the health workers responsible for the examination and treatment. The longer the close contact with the patient, the greater the number of inhaled germs, and the risk of TB transmission increases. If sleeping separately with a TB patient is not possible, other means must be found to prevent TB transmission, for example, wearing a mask or covering the mouth/nose when coughing/sneezing and washing hands with soap and running water.

The bedroom lighting, humidity, and the size of ventilation in this research showed a relationship with the germ number in the bedroom's TB patients. Transmission of TB disease mainly occurs in dark, humid places with less ventilation.<sup>20</sup>

*Mycobacterium tuberculosis* germs will survive a long time in humid conditions and are not exposed to direct sunlight. In a poor

ventilation room, there is less air movement, and TB germs will last a long time in the room, increasing the risk of transmission, especially for close contacts, namely those who sleep in the same bedroom as the TB patient.<sup>20</sup>

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Previous studies have found a relationship between lighting, ventilation, and humidity and TB incidence.<sup>19,23</sup> This condition in Kupang city shows that there are still many housing conditions that do not meet the requirements for healthy housing following the standard of the Ministry of Health Republic of Indonesia, which are room temperature 18–28°C, humidity 40–60% RH, lighting  $\geq 60$  Lux, ventilation area 10% per size floor.<sup>16,17</sup>

The condition of bedrooms in Kupang city allows the risk of transmission and incidence of TB, which is always high in Kupang city. For this reason, it is necessary to take fundamental measures to prevent and control TB from the community and the government, especially by building healthy houses.

Based on this research, TB patients should sleep separately in their bedrooms to decrease the transmission risk to close contact, always wear a mask, or cover the mouth/nose when coughing/sneezing, and wash hands with soap and running water.

The community should keep the sunlight entering the bedroom directly and lower the humidity by adding the ventilation size or placing the room position that allows direct sunlight to enter the room to reduce the risk of TB transmission in the room.

The Kupang City Health Office, the Public Works and Public Housing Office, and other related agencies need to carry out more stringent supervision on housing construction permits to follow the Ministry of Health's Decree for housing building or repairing.

The summary model and the results of the F test show that the higher the bedroom humidity and room density, the higher the germ number will be. Conversely, the greater the percentage of ventilation size, the less germ number.

TB germs are resistant to low temperatures and will survive for a long time at temperatures between 4°C and -70°C. TB germs are susceptible to heat, sunlight, and ultraviolet. Direct exposure to ultraviolet light will cause most TB germs to die within a few minutes, while in sputum at temperatures between 30–37°C, they will die in approximately one week and 5 minutes at 70°C.<sup>18,24</sup> There is a temperature range favored by the *Mycobacterium tuberculosis*, which allows the bacteria to proliferate. *Mycobacterium tuberculosis* is a mesophilic bacterium that grows fast at 25°C–40°C. The bacteria will grow optimally at 31°C–37°C. Humidity plays a role in the growth of microorganisms, including pulmonary tuberculosis (TB) bacteria. High humidity in the house can increase the life of tuberculosis (TB) bacteria.<sup>24</sup>

Based on the results of this research, it is necessary to take measures to ensure healthy home conditions that are not optimal for *Mycobacterium tuberculosis* to survive and grow to reduce the risk of transmission and incidence of TB. These actions include lowering room humidity and increasing natural lighting, namely sunlight entering the bedroom. The simple way to reduce the moisture that the community can take is by adding ventilation.<sup>16</sup> The additional ventilation increases the space for airflow, which allows the release of some germs in the room and to be replaced by fresh air from outside to reduce the risk of TB transmission in the room.

A minimum room lighting needs around 60 Lux.<sup>16</sup> The addition of ventilation can increase the sunlight that enters the bedroom. The morning sun, which contains ultraviolet light, will kill TB germ in minutes. On the other hand, poor air circulation and no sunlight will increase the risk of TB transmission.<sup>18</sup> Ventilation will increase air circulation in the bedroom and reduce the risk of TB transmission for the room's occupants.

One way to control the number of germs in a room is to sterilize the room. Room sterilization with ultraviolet (UV) light is proven to be able to reduce the number of germs in the air.<sup>25</sup> The nature of germs in the air, in general, has similarities with the nature of TB germs, so if the germs in the room are successfully lowered by UV sterilization, the TB germs will also reduce. Sterilization of rooms with ultraviolet can be natural by using sunlight. It is necessary to increase the ventilation area of the room or the placement of the position of the room that allows

direct sunlight to enter. Sterilization of rooms also can be done artificially using UV lamps, so it is necessary to investigate further the effectiveness of UV lamps in reducing the number of germs in the room.

## Conclusions

This study finds the equation model to determine the number of germs. The variation was the germ number in a TB patient's bedroom, the room humidity, room ventilation, and the density of the room occupancy. The most significant influence is the room humidity.

## Conflict of Interest

There was no conflict of interest in this study.

## Acknowledgment

Our gratitude goes to the Ministry of Health, and Poltekkes Kemenkes Kupang has provided financial support. We also thank the leadership and staff at the Kupang City Health Office and health centers throughout Kupang city for collaborating and supporting this research.

## References

1. Kementerian Kesehatan Republik Indonesia. Profil kesehatan Indonesia tahun 2019. Jakarta: Kementerian Kesehatan Republik Indonesia; 2020.
2. Kementerian Kesehatan Republik Indonesia. Apa itu TOSS TBC dan kenali gejala TBC [Internet]. Jakarta: Kementerian Kesehatan Republik Indonesia; 2019 [cited 2022 June 15]. Available from: <https://promkes.kemkes.go.id/apa-itu-toss-tbc-dan-kenali-gejala-tbc>.
3. Dinas Kesehatan Provinsi Nusa Tenggara Timur. Laporan penyelidikan epidemiologi TB paru Provinsi NTT. Kupang: Dinas Kesehatan Provinsi Nusa Tenggara Timur; 2021.
4. Apriliasari R, Hestningsih R, Udiyono A. Faktor yang berhubungan dengan kejadian TB Paru pada anak (studi di seluruh puskesmas di Kabupaten Magelang). JKM. 2018;6(1):298–307.
5. Narasimhan P, Wood J, Macintyre CR, Mathai D. Risk factors for tuberculosis. Pulm



- Med. 2013;2013:828939.
6. Srivastava K, Kant S, Verma A. Role of environmental factors in transmission of tuberculosis. DHH. 2015;2(4):12.
  7. Herdianti, Entianopa, Sugiarto. Effect of patient's personal character on prevention of transmission of pulmonary TB. IJTID. 2020;8(1):9–15.
  8. Indriyani N, Istiqomah N, Anwar MC. Hubungan tingkat kelembaban rumah tinggal dengan kejadian tuberkulosis paru di wilayah Kecamatan Tulis Kabupaten Batang. UJPH. 2016;5(3):214–20.
  9. Wulandari S. Hubungan lingkungan fisik rumah dengan kejadian tuberkulosis paru. UJPH. 2012;1(1):41–4.
  10. Oktavia S, Mutahar R, Destriatania S. Analisis faktor risiko kejadian TB paru di wilayah kerja Puskesmas Kertapati Palembang. JIKM. 2016;7(2):124–38.
  11. Wanti W, Solihah Q, Djapawiji M. Relationship between house condition and tuberculosis incidence in Timor Tengah Utara district. IJSBAR. 2015;21(1):344–9.
  12. Hita PMK, Hariyanto T, Lasri. Hubungan antara konsumsi rokok dengan kejadian penyakit tuberkulosis (TBC) di Puskesmas Kawangu Kecamatan Pandawai Kabupaten Sumba Timur Provinsi Nusa Tenggara Timur. Nurs News. 2017;2(3):240–50.
  13. Utama HI, Riyanti E, Kusumawati A. Gambaran perilaku penderita TB paru dalam pencegahan penularan TB paru di Kabupaten Klaten. JKM. 2019;7(1):491–500.
  14. Laghari M, Sulaiman SAS, Khan AH, Talpur BA, Bhatti Z, Memon N. Contact screening and risk factors for TB among the household contact of children with active TB: a way to find source case and new TB cases. BMC Public Health. 2019;19(1):1274.
  15. Kementerian Kesehatan Republik Indonesia. Profil kesehatan Indonesia tahun 2020. Jakarta: Kementerian Kesehatan Republik Indonesia; 2021.
  16. Peraturan Menteri Kesehatan Indonesia Nomor 1077/Menkes/PER/V/2011 tentang Pedoman Penyehatan Udara dalam Ruang Rumah.
  17. Delyuzir RD. Analisa rumah sederhana sehat terhadap kenyamanan ruang (studi kasus: rumah tipe 18/24, 22/60, 36/72 di DKI Jakarta). Arsitekta. 2020;2(2):15–27.
  18. Peraturan Menteri Kesehatan Indonesia Nomor 67 Tahun 2016 tentang Penanggulangan Tuberkolosis.
  19. Suyatno. Hubungan kondisi fisik lingkungan ruang tidur dan keberadaan penderita TBC dengan angka kuman udara di Kota Pontianak Provinsi Kalimantan Barat [undergraduate thesis]. Semarang: Universitas Diponegoro; 2006.
  20. Kementerian Kesehatan Republik Indonesia. Pedoman nasional pelayanan kedokteran tata laksana tuberkulosis [Internet]. Jakarta: Kementerian Kesehatan Republik Indonesia; 2020 [cited 2022 June 21]. Available from: [https://tbindonesia.or.id/wp-content/uploads/2021/06/UMUM\\_PNPK\\_revisi.pdf](https://tbindonesia.or.id/wp-content/uploads/2021/06/UMUM_PNPK_revisi.pdf).
  21. Mathofani PE, Febriyanti R. Faktor-faktor yang berhubungan dengan kejadian penyakit tuberkulosis (TB) paru di wilayah kerja Puskesmas Serang Kota tahun 2019. JIKM. 2020;12(1):1–10.
  22. Wikurendra EA. Faktor faktor yang mempengaruhi kejadian tuberkulosis paru dan penanggulangannya. INA-Rxiv [preprint]. 2019 INA-Rxiv r3fmg [posted 2019 July 17; revised 2021 February 1; cited 2022 June 27]. Available from: <https://osf.io/preprints/inarxiv/r3fmg>.
  23. Sahadewa S, Eufemia, Edwin, Luh N, Shita. Hubungan tingkat pencahayaan, kelembaban udara, dan ventilasi udara dengan faktor risiko kejadian TB paru BTA positif di Desa Jatikalang Kecamatan Krian Kabupaten Sidoarjo. JIKW. 2019;8(2):118–30.
  24. Kenedyanti E, Sulistyorini L. Analisis *Mycobacterium tuberculosis* dan kondisi fisik rumah dengan kejadian tuberkulosis paru. JBE. 2017;5(2):152–62.
  25. Meiriana LR, Santoso I, Erminawati. Perbedaan angka kuman udara ruang operasi sebelum dan sesudah sterilisasi ultraviolet RSUD Ratu Zalecha. J Kesehat Lingkung J Apl Tek Kesehat Lingkung. 2018;15(1):585–90.