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# EFFECTIVENESS OF HOME AIR SANITATION INTERVENTIONS IN CONTROLLING PULMONARY TUBERCULOSIS IN THE WORKING AREA OF THE TALANG PANGERAN COMMUNITY HEALTH CENTER OGAN ILIR REGENCY

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**Abstract:** All Tuberculosis (*TB*) remains a critical public health challenge, with household environmental conditions, particularly poor air sanitation, significantly contributing to transmission. Previous epidemiological findings in the Talang Pangeran Community Health Center area identified temperature (OR=5.073) and humidity (OR=3.450) as dominant and significant risk factors for TB incidence. This study aimed to analyze the effectiveness of a program management intervention focused on home air sanitation improvements in controlling pulmonary TB, specifically by mitigating these identified temperature and humidity risk factors. This quasi-experimental implementation study focused on executing a healthy home improvement program. The management interventions included intensive health education on ventilation importance, facilitation for installing additional air vents/ventilation, and promotion of greening (*planting*) around the homes of TB cases and at-risk households. Effectiveness was quantitatively measured by comparing indoor temperature, relative humidity (RH), and lighting parameters before and after a 6-month intervention period, alongside monitoring new pulmonary TB case trends. Results showed significant improvements in physical home conditions: the average temperature decreased from an unsatisfactory baseline of 30.5°C to 28.4°C (2.1°C reduction), achieving satisfactory conditions for 80% of houses. Concurrently, average RH decreased by 15% from an unsatisfactory baseline of 78% to 63%, meeting the optimal range (40%-70%) for 92% of houses. Statistically, the intervention successfully reduced the proportion of homes with unhealthy temperature and humidity ($p$-value < 0.05). These findings demonstrate that targeted air sanitation interventions are an effective strategy for creating supportive micro-environments, thereby strengthening pulmonary TB control programs at the community level.

**Keywords**: Pulmonary Tuberculosis, Home Air Sanitation, Temperature, Humidity, Public Health Interventions.

## 1. Introduction

Tuberculosis (TB) remains one of the biggest public health challenges at the global and national levels. According to the WHO Global TB Report, millions of people around the world fall ill with TB every year, and the disease remains one of the leading causes of death from infectious diseases (***WHO, 2020***). Indonesia, as the country with the second highest TB burden in the world, continues to face the urgency of developing more effective and innovative control efforts (***WHO, 2023***). This disease, caused by infection with the Mycobacterium tuberculosis bacterium, not only threatens individual health but also has significant social and economic impacts. The burden of long-term treatment costs, loss of work productivity, and social stigma are heavy consequences that must be borne by patients, families, and ultimately the country. The main mechanism of transmission is through the air (*airborne transmission*), which makes indoor environments, especially homes, a crucial epicenter in the chain of disease transmission.

The physical environment of a home plays a vital role in TB transmission and is one of the most fundamental social determinants of health ***(Budi et al., 2018; Larasati & Wibowo, 2018)***. Factors such as high housing density, inadequate ventilation, and minimal exposure to sunlight can drastically increase the concentration of droplet nuclei containing bacteria in the air. More specifically, microclimate parameters such as temperature and relative humidity (RH) directly affect the viability or survival of bacteria in the environment ***(Nardell, 2016)***. Various studies have shown that hot and excessively humid air conditions, commonly found in tropical regions such as Indonesia, create an ideal habitat for *Mycobacterium tuberculosis* to survive longer. International guidelines stipulate that an optimal healthy home environment should maintain temperature between 18∘C and 28∘C and relative humidity between 40% and 70% to maximize both comfort and pathogen inactivation ***(Kemenkes RI, 2019)***. At the same time, these conditions have the potential to weaken the natural defense mechanisms of the human respiratory tract, such as mucociliary function, thereby increasing susceptibility to infection. More specifically, in tropical and equatorial regions such as Indonesia, two key microclimate parameters play a direct and often detrimental role: indoor temperature and relative humidity (RH). Scientific literature consistently demonstrates that hot and excessively humid conditions create a micro-habitat favorable for micobacterium tuberculosis survival. These conditions not only enhance the viability of the bacteria, allowing them to remain airborne for longer periods, but also concurrently compromise the natural defense mechanisms of the human respiratory tract, such as the mucociliary escalator function, thereby increasing host susceptibility to infection. International guidelines stipulate that an optimal healthy home environment should maintain temperature between 18∘ C and 28∘C and relative humidity between 40% and 70% to maximize both comfort and pathogen inactivation.

The necessity for targeted environmental interventions in this region is highlighted by strong local evidence. Highlighting the importance of these environmental factors, a previous epidemiological study in the Talang Pangeran Community Health Center working area specifically identified high temperatures (OR=5.073) and high humidity (OR=3.450) as the most dominant risk factors for pulmonary TB in the community ***(Amin, 2022)***. These findings provide strong local evidence that environmental interventions are a necessity. However, awareness of these risks is often not followed by concrete corrective actions. There is a clear gap between general guidelines on healthy homes, which are promotional in nature, and the implementation of structured physical interventions to modify these risky environments. Based on these findings and gaps, this study was designed as an implementation study to answer the fundamental question: “How effective is a managed program intervention, focusing on improving household air sanitation, in controlling pulmonary TB through the mitigation of temperature and humidity risk factors?”

## 2. Literature Review

Tuberculosis transmission occurs through the air, where high population density and poor ventilation are strong predictors of transmission ***(Larasati & Wibowo, 2018)***. Adequate natural ventilation can reduce the concentration of droplet nuclei containing bacteria in the air ***(Nardell, 2016)***. Temperature and relative humidity (RH) in homes play an important role in the viability of TB germs. Studies show that the optimal temperature for a healthy home is between 18∘C and 28∘C, with an ideal RH between 40% and 70% ***(Kementerian Kesehatan Republik Indonesia, 2019)***. RH outside this range can affect the stability of droplets and the ability of the respiratory tract's mucocilia.

Effective program management is crucial for the successful implementation of public health interventions. Management principles, often summarized by the POLC framework (Planning, Organizing, Leading, and Controlling), provide a robust structure for designing and implementing community-based health programs ***(Koontz & Weihrich, 2010)***. Planning: Involves setting goals and determining actions. In the context of TB control, planning includes identifying risk factors, such as high temperature and humidity, and designing targeted interventions such as home air sanitation programs. The research question itself, “How effective is program management intervention?” is a product of this planning phase.

Organizing: This phase involves arranging resources to achieve the established goals. For this study, organizing required the mobilization of health workers for intensive education, coordination of physical home improvements (installation of ventilation), and promotion of greening the environment around the home. Leading: This function involves motivation and influence towards people to work towards the program's goals ***(Rowitz, 2013)***. The intensive health education and advocacy components of the intervention exemplify leadership functions, as they aim to change residents' behavior by encouraging them to open windows and maintain a clean home environment. Controlling: Involves monitoring progress and making adjustments as necessary. The effectiveness of the intervention is measured quantitatively by comparing indoor temperature, RH, and lighting before and after the 6-month period, in addition to monitoring new TB cases. The collection and analysis of this data represents the controlling function, which enables assessment of the program's success. This intervention can also be analyzed through various relevant behavioral and health promotion theories.

The Socio-Ecological Model provides a comprehensive lens for understanding TB issues. At the individual level, the success of the ‘Intensive Education’ pillar can be explained through the Health Belief Model (HBM) ***(Rowitz, 2013)***. This model states that health is influenced by dynamic interactions between individuals and their environment at various levels. In this context, TB transmission is not only an individual problem (*micro level*), but is also influenced by the physical condition of the home (*meso level*) and support from public health programs initiated by community health centers (macro level). These interventions simultaneously target the micro level (*behavioral change among residents*) and the meso level (*physical improvements to homes*), creating a holistic approach. At the individual level, the success of the ‘Intensive Education’ pillar can be explained through the Health Belief Model (*HBM*). This theory suggests that a person will take action to prevent disease if they feel vulnerable (*perceived susceptibility*), consider the disease to be serious (*perceived severity*), believe that the action will be beneficial (*perceived benefits*), and face few barriers to doing so (*perceived barriers*). The education provided aims to increase awareness of vulnerability to TB transmission in unhealthy homes, while highlighting the benefits of good ventilation ( *fresher air, reduced risk of illness*). Meanwhile, the ‘Physical Facilitation’ pillar serves to reduce barriers for residents to make physical changes to their homes. Thus, the program management approach applied is not only operationally structured (*POLC*), but also theoretically robust by integrating principles of behavioral change and environmental intervention. This combination of interventions aims to create a microenvironment that is not conducive to the survival of micobacterium tuberculosis and to improve the quality of life of patients and their household contacts.

**Tables and Figures**

**Table 1: Comparison of Average Environmental Parameters Physical Home (Pre-Post Intervention)**

| Parameter | Unit | Standard Healthy | Pre Intv Means | Post- Intv Means | Mean Difference | Paired Test Value |
|---|---|---|---|---|---|---|
| Temperature | °C | 18-28 | 30.5 ± 1.2 | 28.4 ± 0.9 | 2.1 °C (Decrease) | 0.001 |
| Relative Humidity (RH) | % | 40-70 | 78.0 ± 4.5 | 63.0 ± 3.2 | 15.0% (Decrease) | 0.001 |

**Sources:** Field Research Results, 2025

This table shows significant changes in temperature, humidity, and lighting in the homes that were the subject of the study after a 6-month intervention.

**Table 2: Proportion of Houses Meeting Requirements (MS) Temperature and RH (Pre-Post Intervention)**

| Parameter | Condition | Pre Intv Means | Post- Intv Means | p-value (McNemar's Test) |
|---|---|---|---|---|
| Temperature | Qualify (≤28 °C) | 15% (n=6) | 80% (n=32) | 0.001 |
| | Not Qualify (>28 °C) | 85% (n=34) | 20% (n=8) | - |
| Relative Humidity | Qualify (40%-70%) | 8% (n=3) | 92% (n=37) | 0.002 |
| | Not Qualify(<40% OR >70%) | 92% (n=37) | 8% (n=3) | - |

**Sources:** Field Research Results, 2025

## 3. Method

This study was conducted as a quasi-experimental study with a one-group pretest-posttest design over a period of 6 months (February 1, 2025 – August 30, 2025) in the working area of the Talang Pangeran Community Health Center, Ogan Ilir District. A total of 40 houses inhabited by TB patients or close contacts and having unsuitable temperature (>28°C) and humidity (>70%) conditions were selected as samples using purposive sampling. The intervention implemented was an integrated management program covering three pillars: environmental health education, facilitation of physical improvements to homes such as ventilation, and promotion of greening around yards.

The effectiveness of the program was measured by comparing temperature and relative humidity (*RH*) data collected using a digital thermohygrometer before (*pretest*) and after (*posttest*) the intervention. Quantitative data analysis was performed using a paired t-test to determine the difference in means and McNemar's test to analyze changes in the proportion of healthy homes. The level of statistical significance was set at a *p*-value < 0.05. This threshold is a conventional standard in scientific research for rejecting the null hypothesis (the hypothesis that there is no effect from the intervention). This means that if the statistical analysis results show a *p*-value lower than 0.05, it can be concluded that the decrease in temperature and humidity that occurred after the intervention was statistically significant and not caused by mere coincidence.

## 4. Result and Discussion

This study aims to measure the effectiveness of the home air sanitation intervention management program in the working area of the Talang Pangeran Community Health Center, Ogan Ilir District, with a focus on mitigating the risk factors of temperature and humidity. The intervention was carried out for six months in 40 households inhabited by TB patients or close contacts and identified as having unsatisfactory temperature (>28∘C) and humidity (>70%) conditions. Data were collected before (*pretest*) and after (*posttest*) the intervention by measuring temperature and relative humidity (*RH*) using a standardized digital thermohygrometer. Quantitative data analysis was performed using the Paired T-test to compare means and McNemar's test to analyze changes in the proportion of households that met the requirements.

The results of the Paired T-test analysis show a very significant change in the average temperature and RH inside the room after the intervention, as summarized in Table 1. Table 1 Interpretation: The average temperature dropped by 2.1∘C, moving from 30.5∘C to 28.4∘C. The decrease in RH was even more drastic, reaching 15.0%, from 78.0% to 63.0%. Both of these changes had very low (*p*-values = 0.001), indicating that the intervention was the main and effective cause of the improvement in the physical condition of the houses. Changes in the Proportion of Houses Meeting Requirements (Qualify). Table 2, Analysis using McNemar's test (Table 2) confirmed that the program management intervention successfully changed the categorical health status of houses. Table 2 Interpretation: The proportion of homes meeting temperature requirements jumped from 15% to 80%, while the proportion of homes meeting RH requirements soared from 8% to 92%. This dramatic increase in the proportion of healthy homes, which was also statistically significant (*p*-value= 0.001), is strong evidence that this intervention program has a transformative impact on the microenvironment of households. **Effectiveness of Dominant Risk Factor Mitigation** The success of this intervention is rooted in its ability to directly address risk factors previously identified through local epidemiological studies, namely high temperature (OR=5.073) and high humidity (OR=3.450) ***(Amin, 2022)***. This intervention proves that epidemiological findings can be effectively translated into measurable public health actions. Addressing High Temperatures Through Circulation and Shading An average temperature reduction of 2.1°C brought most of the subjects' homes (80%) to the threshold or below the maximum healthy home temperature limit (28°C). An indoor temperature of 30.5°C at baseline is very common in tropical areas, especially in homes with dense designs, low roofs, and a lack of shade. Such high temperatures not only cause thermal discomfort but can also weaken the human respiratory tract's defense mechanisms.

This reduction is the synergistic result of two pillars of intervention: Facilitation of Cross-Ventilation, The installation of new ventilation openings or the widening of windows directly increases the air exchange rate per hour (*Air Changes per Hour -ACH*). Rapid air circulation helps remove trapped hot air masses inside the room, resulting in effective and rapid cooling, especially when the outside air temperature is slightly lower. Promotion of Greening: Planting trees or shade plants around the house acts as an external heat shield. Through the process of evapotranspiration, plants release water vapor that cools the surrounding air, so that the air temperature entering the house through the new ventilation is lower than before. This combined effect significantly reduces the total heat load in the room, transforming the environment from a ‘heat collector’ to a cooler environment.

Relative Humidity (RH) Normalization A more drastic decrease in RH (15.0%) indicates remarkable success in humidity management. The initial humidity of 78.0% was well above the optimal limit of 70%, a condition exacerbated by household activities such as cooking and drying clothes indoors, coupled with inadequate air circulation. A post-intervention RH of 63.0% places 92% of homes within the optimal RH range (40%–70%). In the context of controlling airborne infectious diseases, normalizing RH to this optimal range is crucial. Excessively high RH not only encourages the growth of mold and mites, but also increases the stability of aerosol particles (such as TB droplet nuclei), allowing them to remain airborne for longer periods of time. With lower RH, aerosol particles tend to evaporate and settle more quickly, effectively reducing exposure time for household contacts. Statistically significant results (*p*-value=0.001 on Paired T-test and *p*-value=0.002 McNemar’s test) are scientific confirmation that the program management interventions carried out, including resource mobilization and physical facilitation, consistently produced the desired changes in every home studied.

Analysis of Microbiological Mechanisms and Transmission Prevention Measurable physical success (decrease in temperature and RH) is essentially a step toward achieving the main goal: creating a microenvironment that minimizes the risk of M. tuberculosis transmission. This discussion focuses on the biological and environmental mechanisms that support the effectiveness of interventions. Bacterial Inactivation Based on Microclimate Classic studies on the viability of M. tuberculosis in the air, as synthesized by ***Nardell (2016)***, show that TB bacteria have the worst stability (highest inactivation rate) at moderate RH (40%–70%). Outside this range, especially at high RH (>70%), germ stability increases because aerosol particles are able to maintain a layer of moisture that protects the bacteria from damage by environmental factors such as UV light. Reduction in Viability: By lowering the RH from 78.0% to 63.0%, this intervention has theoretically placed the germs in the fastest inactivation zone. Combined Effects of Temperature and RH: High temperature (>30°C) and high RH (>70%) are a lethal combination that not only supports microbial survival but also disrupts the mucociliary defense system in the human respiratory tract. Mitigating these two factors simultaneously produces a double protective effect: reducing airborne germs and strengthening host resistance. Aerosol Dilution Through Increased Ventilation The most important mechanism of air sanitation interventions is dilution. TB transmission occurs when the concentration of droplet nuclei containing bacteria in the air reaches infectious levels. In other words, a home environment that has been improved is many times safer for household contacts, even if the patient coughs. Therefore, physical facilitation (adding ventilation) serves as the most powerful technical-environmental intervention to break the chain of transmission in the household epicenter.

Success of physical environmental change cannot be separated from the effectiveness of the program management applied, which is based on the POLC (Planning, Organizing, Leading, Controlling) framework and behavioral change theory. **The Relationship between Program Management and Outcomes** This study is an implementation study, which emphasizes how the program is managed. Planning & Organizing: The use of local OR data in the planning phase shows that this program is highly specific (based on local risks, not general guidelines) ***(Pemerintah Kabupaten Ogan Ilir, Dinas Kesehatan, 2021)***. The organizing phase (mobilization of health workers for education, coordination of material facilitation) ensures that the intervention can be implemented effectively in 100% of sample households. Material facilitation serves to eliminate Perceived Barriers (economic barriers) in the Health Belief Model (HBM). Leading & Controlling: The Intensive Education pillar represents the Leading function by changing residents' behavior. The program's success in The controlling function is realized in rigorous pre-post measurements to assess effectiveness quantitatively.

**Contribution to the National TB Control Program (TOSS)** Traditionally, the TOSS (Find, Treat, Cure) program has focused on clinical and biomedical aspects (diagnosis and treatment) ***(Kemenkes RI, 2021)***. This study provides strong evidence that TOSS should be integrated with environmental components (home air sanitation) as an essential secondary and primary prevention measure. Nevertheless, as stated in the literature ***(Larasati & Wibowo, 2018)***, the creation of a healthy physical environment is a non-negotiable prerequisite in the TB transmission prevention chain. Secondary Prevention, Interventions in the homes of TB patients undergoing treatment reduce the risk of reinfection and protect household contacts, who have high perceived susceptibility. Primary Prevention: Changing high-risk environments (hot and humid) into healthy environments is a primary prevention investment against future

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TB cases. Regarding New TB Case Trends Secondary data show a downward trend in new pulmonary TB cases in the Talang Pangeran Community Health Center working area during the 6-month intervention period compared to the previous period. Although this trend provides positive indications, this study cannot definitively establish a direct correlation and causality between this intervention and the decline in new cases. The main reason for this caution is the Single-Group Quasi-Experimental Design: The absence of a control group prevents us from distinguishing the impact of the intervention from other confounding factors (improved case reporting, other treatment interventions). TB Latent Period: The incubation period and the time required for TB bacteria to cause clinical disease are often long. Six months may be too short to see the full impact of environmental improvements on population incidence rates. Nevertheless, as stated in the literature (***Larasati & Wibowo, 2018***), the creation of a healthy physical environment is a non-negotiable prerequisite in the TB transmission prevention chain. Success in mitigating environmental risk factors indicates that the program has successfully addressed critical nodes in the TB transmission chain at the household level.

## 5. Conclusions

Program management interventions in the form of home air sanitation improvements in the Talang Pangeran Community Health Center Working Area proved to be very effective in mitigating the physical environmental risk factors for pulmonary TB, namely temperature and humidity. The main findings show that within 6 months, there was an average decrease in temperature of 2.1°C and relative humidity of 15%, resulting in an increase in the proportion of healthy homes for temperature (from 15% to 80%) and RH (from 8% to 92%), all with high statistical significance ($p$-value=0.001). The implication of this study is that pulmonary TB control programs should expand their focus from only treatment and case finding (*TOSS*) to measurable physical environmental interventions integrated with the Healthy House program. The main limitations of this study are its single-group quasi-experimental design without a control group and the relatively short observation period for new TB case trends. The success of this program validates that local epidemiological findings can be effectively translated into measurable public health actions. A structured program management approach based on the POLC (*Planning, Organizing, Leading, Controlling*) framework and behavioral change theories such as the Health Belief Model (*HBM*) ensures that interventions are implemented efficiently and address behavioral and economic barriers for residents. The main implication is that pulmonary TB control must broaden its focus from purely clinical aspects such as in the TOSS program-Find, Treat Until Cured, to explicitly integrate measurable physical environmental interventions. Improving household air sanitation serves as a secondary prevention measure protecting household contacts and a primary prevention measure creating an environment that is not conducive to future TB cases. Although the limitations of this study are its quasi-experimental single-group design without a control group and a relatively short observation period to see the impact on the incidence of new cases in the population, the proven success in mitigating environmental risk factors shows that this program has successfully addressed a critical node in the TB transmission chain at the household level.

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