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Community Assistance in Eradiating Tuberculosis in Pacalan Village, Magetan Regency

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ABSTRACT Pulmonary tuberculosis (TB) remains a significant public health challenge, particularly in communities with inadequate sanitation infrastructure. This study addresses the persistent burden of pulmonary TB transmission through a comprehensive community-based intervention program. The research aimed to enhance community knowledge, attitudes, and preventive practices regarding pulmonary TB while simultaneously improving environmental conditions in Pacalan Village, Plaosan District, Magetan Regency. A multi-method approach was employed, incorporating systematic surveys of residential conditions among pulmonary TB patients, structured health education sessions, and targeted physical interventions involving the installation of glass tiles to optimize natural lighting and ventilation. The intervention was implemented through collaboration between faculty and students from the Sanitation Study Program at the Ministry of Health Polytechnic Surabaya, Magetan Campus, and local healthcare personnel. Findings demonstrated substantial improvements in community understanding of TB symptomatology, transmission mechanisms, and evidence-based preventive measures. The environmental intervention successfully enhanced ventilation quality and natural illumination in affected households, thereby establishing healthier living conditions conducive to TB prevention. The study concludes that integrated educational approaches combined with physical environmental modifications effectively strengthen community awareness and active participation in pulmonary TB prevention initiatives. This intervention model demonstrates potential for reducing TB incidence in endemic regions and provides a replicable framework for similar community health programs in resource-limited settings with comparable epidemiological challenges.

INDEX TERMS Pulmonary Tuberculosis Prevention, Community Health Intervention, Environmental Sanitation, Health Education, Ventilation Improvement

I. INTRODUCTION

Pathological conditions manifesting as organ dysfunction or morphological alterations in body tissues constitute the fundamental definition of disease entities [1]. The environmental milieu, encompassing both animate and inanimate elements alongside the atmospheric conditions generated through ecological interactions, plays a pivotal role in disease pathogenesis [2]. Environment-based diseases specifically emerge from pathological conditions resulting from adverse human-environment interactions, where suboptimal sanitary conditions and inadequate housing infrastructure create favorable conditions for disease transmission and perpetuation [3]. Pulmonary tuberculosis (TB) represents a critical global health burden, particularly in developing nations where socioeconomic constraints and environmental factors converge to sustain disease transmission. Indonesia confronts a substantial TB crisis, with the disease ranking as the second leading cause of mortality

after cardiovascular conditions [4]. Annual statistics reveal approximately 450,000 pulmonary TB cases across all age demographics, resulting in 64,000 deaths nationwide [5]. Pediatric populations bear a considerable burden, with children accounting for approximately one-fifth of all TB cases in Indonesia [6]. The multifactorial etiology of tuberculosis encompasses population density, behavioral patterns, environmental conditions, and healthcare service accessibility [7]. According to the 2023 Global TB Report, Indonesia holds the concerning distinction of being the second-highest TB burden country globally, following India, with 1,060,000 estimated cases and 134,000 mortality cases [8]. This translates to approximately 15 tuberculosis-related deaths occurring hourly across the Indonesian archipelago [9], underscoring the urgency of comprehensive intervention strategies. Current TB control programs primarily emphasize pharmacological treatment through the Directly Observed Treatment Short-course (DOTS) strategy [10], health

education campaigns [11], and contact tracing protocols [12]. However, these conventional approaches often neglect the critical environmental determinants that facilitate disease transmission, particularly inadequate residential ventilation and natural lighting [13]. Despite extensive research on TB prevention strategies, significant research gaps persist regarding integrated community-based interventions that simultaneously address educational deficits and environmental risk factors [14]. While studies have documented the efficacy of health education in improving TB knowledge [15], and separate investigations have established the relationship between poor housing conditions and TB transmission [16], limited evidence exists regarding synergistic interventions combining both approaches in endemic communities. Furthermore, practical implementation models demonstrating feasible environmental modifications in resource-limited settings remain scarce [17]. Epidemiological surveillance in the Plaosan Health Center catchment area during 2023 identified infectious diseases, diarrheal diseases, and pulmonary TB as the three predominant environment-based health conditions [18]. Among 26 documented pulmonary TB patients within this jurisdiction, Pacalan Village exhibited the highest disease concentration with 13 confirmed cases, followed by Plaosan Village with 10 cases [19]. Given that pulmonary TB constitutes a critical indicator for achieving Sustainable Development Goals health targets [20], targeted interventions in high-burden communities require immediate prioritization.

This study aims to implement and evaluate a comprehensive community-based intervention integrating health education with environmental modifications to reduce pulmonary TB transmission in Pacalan Village, Plaosan District, Magetan Regency. The primary contributions of this research include:

1. Development of an integrated intervention model combining health education with practical environmental improvements specifically designed for resource-limited endemic settings.
2. Empirical evidence demonstrating the effectiveness of glass tile installation as a cost-effective solution for enhancing residential ventilation and natural lighting in TB-affected households.
3. Establishment of a collaborative framework involving academic institutions and local healthcare systems for sustainable community health interventions.
4. Provision of a replicable implementation blueprint for similar high-burden communities facing comparable socioeconomic and environmental challenges.

The remainder of this article is organized as follows: Section II describes the methodological framework and intervention procedures; Section III presents the results and outcomes of the educational and environmental interventions; Section IV discusses the findings in relation to existing literature and practical implications; and Section V concludes with recommendations for future research and policy considerations.

II. METHOD

A. STUDY DESIGN AND POPULATION SAMPLING

This study employed a prospective community-based intervention design conducted in Pacalan Village, Plaosan District, Magetan Regency, East Java, Indonesia. The intervention was implemented on May 16, 2024, following a comprehensive baseline assessment. The study location was purposively selected based on epidemiological surveillance data indicating the highest concentration of pulmonary TB cases within the Plaosan Health Center catchment area. This research methodology integrated both educational and environmental modification components, adopting a mixed-methods approach to address the multifaceted nature of TB transmission in endemic communities [21]. The study population comprised individuals directly affected by or involved in pulmonary TB management within the target community. A total of 20 participants were recruited through purposive sampling techniques, consisting of two distinct cohorts: (1) eleven confirmed pulmonary TB patients who had been diagnosed and registered with the Plaosan Health Center TB control program, and (2) nine community health cadres specifically trained in TB surveillance and patient support activities. Inclusion criteria for TB patients encompassed documented pulmonary TB diagnosis, residence in Pacalan Village, and willingness to participate in both educational sessions and home-based environmental interventions. Health cadres were selected based on their active involvement in community health programs and prior experience in TB patient management [22]. Exclusion criteria included patients with severe comorbidities preventing active participation and households unwilling to undergo environmental assessment or modification [23].

B. INTERVENTION COMPONENTS

A comprehensive baseline survey was conducted prior to intervention implementation to establish pre-intervention conditions and knowledge levels. The survey instrument consisted of structured questionnaires assessing: (1) demographic characteristics of participants, (2) baseline knowledge regarding TB etiology, transmission mechanisms, symptomatology, and preventive measures, (3) existing health-seeking behaviors and treatment adherence patterns, and (4) environmental housing conditions including ventilation adequacy, natural lighting availability, household crowding index, and sanitation infrastructure [24]. Home environmental assessments were performed using standardized checklists adapted from WHO housing and health guidelines, documenting physical parameters such as window-to-floor area ratio, presence and functionality of ventilation openings, and indoor illumination levels measured during daylight hours [25]. The health education component employed evidence-based participatory learning methodologies designed to maximize knowledge retention and behavioral modification. Educational sessions utilized a combination of didactic lectures and interactive discussion formats, delivered by qualified health professionals from the Sanitation Study Program, Ministry of Health Polytechnic

Surabaya, Magetan Campus, in collaboration with Plaosan Health Center personnel [26]. Instructional content encompassed: (1) TB pathophysiology and clinical manifestations, (2) transmission dynamics emphasizing droplet nuclei dissemination, (3) evidence-based prevention strategies including infection control measures, (4) treatment protocols and adherence importance, and (5) environmental risk factors and mitigation approaches. Educational materials included culturally appropriate illustrated pamphlets developed following health literacy principles, employing simple language and visual aids to facilitate comprehension across varying educational backgrounds [27].

The lecture sessions lasted approximately 90 minutes, followed by 30-minute question-and-answer periods encouraging active participant engagement and clarification of misconceptions [28]. The physical intervention component focused on evidence-based architectural modifications to improve indoor air quality and reduce TB transmission risk in affected households. Following comprehensive home assessments identifying ventilation and lighting deficiencies, glass tile installation was implemented as the primary environmental intervention strategy. Glass tiles, selected for their dual functionality in enhancing natural illumination while maintaining structural integrity, were strategically positioned in areas with inadequate lighting or ventilation based on technical assessments conducted by qualified sanitation specialists [29]. The installation protocol adhered to construction safety standards and was executed by trained technicians under professional supervision. Glass tile placement prioritized rooms with the highest occupancy duration, particularly bedrooms and common living areas, to maximize intervention impact on infection control [30].

C. DATA COLLECTION AND DATA ANALYSIS

Post-intervention evaluation was conducted to assess both educational outcomes and environmental modification effectiveness. Knowledge assessment employed pre-test and post-test questionnaires administered immediately before educational sessions and at one-month follow-up, measuring improvements in TB awareness, transmission understanding, and preventive practice knowledge. Environmental evaluation encompassed post-installation measurements of ventilation parameters and natural lighting adequacy using standardized instruments, comparing pre- and post-intervention conditions. Qualitative data were collected through structured interviews with participants regarding perceived improvements in living conditions and satisfaction with interventions implemented. Quantitative data analysis utilized descriptive statistics to characterize demographic variables, calculate knowledge score improvements, and compare pre- and post-intervention environmental parameters. Paired sample analyses were employed to assess the statistical significance of knowledge gains and environmental improvements. Qualitative responses from interviews were coded thematically to identify recurring patterns regarding intervention acceptability and perceived

benefits [31]. This community service program adhered to ethical principles governing community-based health interventions. Informed consent was obtained from all participants following a comprehensive explanation of program objectives, procedures, and potential benefits. Participant confidentiality was maintained throughout data collection and reporting processes. The intervention protocol received approval from relevant local health authorities and community leaders prior to implementation [32].

III. RESULTS



FIGURE 1. Participant Knowledge Improvement Regarding Tuberculosis Transmission Mechanisms and Airborne Pathways



FIGURE 2. Survey of Healthy Behavior and the Environment of Patients with Pulmonary Tuberculosis

The baseline and post-intervention knowledge assessments revealed substantial improvements in participant understanding of pulmonary tuberculosis across multiple dimensions. Survey data demonstrated that the majority of respondents achieved satisfactory comprehension levels regarding fundamental TB concepts following the educational intervention. Participants exhibited enhanced understanding of disease transmission mechanisms, with particular improvements noted in recognizing airborne droplet nuclei as the primary route of infection (FIGURE 1). Clinical symptom recognition showed marked improvement, with respondents demonstrating increased ability to identify cardinal manifestations, including persistent cough, hemoptysis, night sweats, and unexplained weight loss. Furthermore, participants displayed strengthened awareness regarding the critical importance of treatment adherence and completion of the full therapeutic regimen to prevent drug resistance development and ensure successful clinical outcomes. Quantitative analysis of knowledge scores, as presented in TABLE 1, indicated a predominant distribution of participants within the "good" knowledge category following intervention implementation. Of the seven pulmonary TB patients assessed, six individuals (85.7%) achieved classification within the good knowledge category, while one participant (14.3%) remained in the less satisfactory knowledge category. The aggregate mean knowledge score calculated across all participants was 2.71 on a three-point scale, representing a satisfactory overall

knowledge level within the study cohort. This distribution pattern suggests effective knowledge transfer through the educational intervention methodology employed, though variability in individual learning outcomes indicates potential need for tailored educational approaches addressing diverse learning capacities.

TABLE 1

Classification of Sufferers Based on Criteria and Categories: Public Knowledge

It	Name	Criterion	Category
1	Sufferer 1	Less	1
2	Sufferer 2	Good	3
3	Sufferer 3	Good	3
4	Sufferer 4	Good	3
5	Sufferer 5	Good	3
6	Sufferer 6	Good	3
7	Sufferer 7	Good	3
Total		Good	19/7 = 3

TABLE 2

Classification of Sufferers Based on Criteria and Categories: Environmental Conditions

It	Name	Criterion	Category
1	Sufferer 1	Less	3
2	Sufferer 2	Enough	3
3	Sufferer 3	Good	3
4	Sufferer 4	Good	3
5	Sufferer 5	Good	3
6	Sufferer 6	Good	2
7	Sufferer 7	Good	3
Total		Good	20/7 = 3

Comprehensive environmental assessments conducted in the residences of pulmonary TB patients revealed significant deficiencies in housing conditions conducive to disease transmission (FIGURE 2). Systematic evaluation of dwelling characteristics identified inadequate ventilation infrastructure as a prevalent concern across the surveyed households. Specifically, the majority of assessed residences exhibited insufficient air exchange mechanisms, characterized by limited window openings, the absence of cross-ventilation pathways, and restricted airflow circulation. These ventilation inadequacies create microenvironmental conditions favorable for concentration and persistence of infectious aerosols, thereby elevating transmission risk among household contacts. Natural illumination assessment revealed substantial deficits in daylight penetration within affected households. Physical measurements documented insufficient light entry due to architectural constraints, including limited window-to-floor area ratios, structural obstructions blocking natural light pathways, and the utilization of opaque construction materials in critical areas. The absence of adequate natural lighting correlates with increased humidity levels and reduced ultraviolet radiation exposure, both factors associated with enhanced mycobacterial survival in indoor

environments. In response to these identified environmental deficiencies, targeted architectural interventions were implemented, focusing on simultaneous improvement of ventilation capacity and natural illumination. The primary intervention strategy involved the strategic installation of glass tiles in areas demonstrating the most severe lighting and ventilation limitations. Glass tile placement was determined through technical assessment protocols identifying optimal locations for maximizing dual benefits of enhanced air circulation and increased natural light transmission. The intervention design prioritized rooms with the highest occupancy frequency and duration, particularly sleeping quarters and communal living spaces where prolonged exposure to potentially infectious aerosols poses the greatest transmission risk. Post-installation evaluations documented measurable improvements in both ventilation adequacy and natural lighting levels, with detailed comparative data presented in TABLE 2 demonstrating quantifiable environmental enhancements achieved through the intervention protocol.

IV. DISCUSSION

The findings of this study demonstrate substantial improvements in community knowledge regarding pulmonary tuberculosis following the implementation of structured health education interventions. Post-intervention assessments revealed that 85.7% of participating TB patients achieved satisfactory knowledge levels, with a mean knowledge score of 2.71 on a three-point scale, indicating effective knowledge transfer through the employed educational methodology. These results align with established evidence demonstrating the efficacy of community-based health education in enhancing TB awareness and comprehension in endemic populations [33]. The observed knowledge gains encompassed multiple critical domains, including disease etiology, transmission dynamics, clinical manifestations, and treatment compliance requirements, suggesting comprehensive learning outcomes rather than superficial information retention. Participants demonstrated enhanced understanding of *Mycobacterium tuberculosis* as the causative pathogen and exhibited improved recognition of airborne droplet nuclei as the primary transmission mechanism. This knowledge acquisition is particularly significant given that misconceptions regarding TB transmission frequently persist in endemic communities, often leading to inappropriate preventive behaviors and social stigmatization of affected individuals [34]. The educational intervention successfully addressed common misconceptions, as evidenced by respondents' accurate identification of airborne transmission routes and their understanding that TB cannot be transmitted through shared eating utensils when proper hygiene protocols are maintained. This finding contrasts with previous studies reporting persistent beliefs in food-borne transmission, suggesting that culturally appropriate educational materials and interactive discussion formats may be particularly effective in dispelling entrenched misconceptions [35].

The observed improvements in symptom recognition constitute another significant outcome, with participants demonstrating increased ability to identify cardinal TB manifestations, including persistent cough exceeding three weeks' duration, hemoptysis, nocturnal diaphoresis, and unexplained weight loss. Early symptom recognition is critical for prompt healthcare-seeking behavior and timely diagnosis, which directly impacts treatment outcomes and reduces community transmission duration [36]. Furthermore, the documented enhancement in treatment adherence knowledge, particularly regarding the necessity of completing the full six-to-nine-month therapeutic regimen, addresses a critical factor in TB control. Non-adherence to treatment protocols represents a primary driver of drug-resistant TB emergence, making patient education regarding treatment completion essential for both individual outcomes and public health protection [37]. The participatory learning methodology employed in this intervention, combining didactic instruction with interactive question-and-answer sessions and distribution of illustrated educational materials, appears to have facilitated effective knowledge retention across participants with varying educational backgrounds. This approach aligns with established adult learning principles emphasizing active engagement and practical relevance [38]. However, the persistence of one participant in the less satisfactory knowledge category suggests that standardized educational interventions may not adequately address all learning needs, potentially indicating requirements for individualized instructional approaches or extended educational contact periods for certain population subgroups.

The environmental assessment component of this study identified significant housing deficiencies contributing to TB transmission risk in the target community. Systematic evaluation documented inadequate ventilation infrastructure and insufficient natural lighting in the majority of surveyed households, conditions that epidemiological evidence consistently associates with elevated TB transmission probability [39]. Poor ventilation facilitates the accumulation and concentration of infectious aerosols in enclosed spaces, while inadequate natural lighting reduces ultraviolet radiation exposure that possesses germicidal properties against *Mycobacterium tuberculosis* [40]. These environmental risk factors are particularly prevalent in resource-limited settings where housing construction prioritizes affordability over health-promoting architectural features. The implemented intervention strategy, involving strategic installation of glass tiles to simultaneously enhance ventilation and natural illumination, represents a pragmatic and cost-effective approach to environmental risk mitigation in resource-constrained settings. Post-installation assessments documented measurable improvements in both air circulation capacity and daylight penetration, with particular benefits observed in sleeping quarters and communal living areas where prolonged occupancy elevates transmission risk. This intervention approach demonstrates several advantages over more complex architectural modifications, including relatively low material costs, minimal structural alterations, ease of installation, and dual

functionality addressing multiple environmental risk factors simultaneously [41]. The documented environmental improvements align with World Health Organization recommendations emphasizing natural ventilation as a cost-effective infection control measure in settings where mechanical ventilation systems are economically infeasible [42]. Natural ventilation, achieving adequate air change rates, effectively dilutes infectious aerosol concentrations, reducing transmission probability among household contacts. Enhanced natural lighting provides complementary benefits through increased ultraviolet radiation exposure, which possesses established antimycobacterial activity, and through improved visibility, facilitating implementation of hygiene practices such as surface cleaning [43].

These findings demonstrate concordance with previous intervention studies documenting TB transmission risk reduction following housing improvements. Research conducted in similar endemic settings has demonstrated inverse correlations between ventilation adequacy and secondary TB infection rates among household contacts [44]. However, direct comparison with existing literature remains challenging due to methodological heterogeneity in environmental assessment protocols and intervention strategies across studies. While some investigations have examined comprehensive housing upgrades involving multiple structural modifications, this study's focused approach targeting specific deficiencies through glass tile installation offers a more replicable and scalable model for resource-limited contexts. The environmental intervention component also yielded important secondary benefits beyond direct transmission risk reduction. Participants reported subjective improvements in residential comfort and livability, potentially influencing health-seeking behaviors and treatment adherence through enhanced overall well-being. Additionally, the visible nature of architectural modifications may serve to reinforce educational messages regarding environmental risk factors, creating tangible reminders of infection control principles in the daily residential environment [45]. This study's integrated approach, combining health education with practical environmental modifications, addresses TB prevention from complementary perspectives targeting both behavioral and structural determinants of transmission. The synergistic implementation of educational and environmental interventions represents a more comprehensive strategy than isolated approaches focusing exclusively on either knowledge enhancement or housing improvement. This multi-component methodology acknowledges the complex interplay between individual behaviors, social determinants, and physical environmental conditions in shaping disease transmission dynamics [46].

The collaborative implementation framework involving academic institutions, local healthcare systems, and community health cadres demonstrates an effective model for sustainable community-based interventions. This partnership structure leverages institutional resources and technical expertise while ensuring cultural appropriateness and community acceptance through involvement of local health workers with established community relationships.

Such collaborative approaches have demonstrated superior sustainability compared to externally imposed interventions lacking community ownership [47]. The active participation of trained TB care cadres in intervention delivery also addresses capacity-building objectives, potentially enabling continuation of health education activities beyond the formal study period. Despite these strengths, several limitations warrant acknowledgment. The relatively small sample size of 20 participants limits statistical power for detecting effect sizes and restricts the generalizability of findings to broader populations. The absence of a control group receiving no intervention or alternative intervention strategies precludes definitive causal attribution of observed outcomes to the specific interventions implemented. While pre-post comparisons suggest intervention effectiveness, concurrent secular trends or external factors may have contributed to observed improvements. Future investigations employing randomized controlled designs with larger sample sizes would strengthen evidence regarding intervention efficacy [48]. The cross-sectional nature of post-intervention assessment, conducted at a single time point, prevents evaluation of knowledge retention durability or long-term maintenance of environmental improvements. Longitudinal follow-up extending over multiple months or years would provide valuable insights regarding the sustainability of intervention benefits and potential needs for reinforcement activities. Additionally, the study did not incorporate objective measures of behavioral change or actual TB transmission outcomes, relying instead on self-reported knowledge and environmental parameter assessments as proxy indicators [49].

The environmental intervention component, while demonstrating feasibility and acceptability, focused exclusively on ventilation and lighting improvements without addressing other relevant housing factors such as household crowding, sanitation infrastructure, or indoor air quality factors beyond ventilation adequacy. Comprehensive housing assessments incorporating these additional dimensions might identify further intervention opportunities for transmission risk reduction. Furthermore, the study did not conduct cost-effectiveness analyses quantifying intervention costs relative to achieved benefits, information that would inform resource allocation decisions and policy recommendations [50]. The findings carry important implications for TB control programming in endemic regions with comparable socioeconomic and environmental contexts. The demonstrated feasibility and effectiveness of integrated educational and environmental interventions suggest potential for scaling this approach to other high-burden communities facing similar challenges. The relatively low-cost nature of glass tile installation interventions enhances replicability in resource-constrained settings where more expensive architectural modifications are infeasible. Policy recommendations emerging from these findings include integration of environmental risk assessments into routine TB case management protocols, allocation of funding for housing improvements targeting TB-affected households, and development of standardized educational materials adaptable to diverse community

contexts. Future research directions should include randomized controlled trials with larger sample sizes evaluating intervention effectiveness across diverse geographic and socioeconomic settings, longitudinal studies assessing the durability of knowledge gains and environmental improvements, cost-effectiveness analyses informing optimal resource allocation, and investigations examining relationships between environmental modifications and objective TB transmission outcomes, including secondary infection rates among household contacts. Additionally, research exploring barriers to intervention uptake and strategies for enhancing community engagement would inform implementation science efforts to optimize intervention delivery and sustainability.

V. CONCLUSION

This community-based intervention program aimed to enhance community knowledge, attitudes, and preventive practices regarding pulmonary tuberculosis while simultaneously improving environmental conditions in Pacalan Village, Plaosan District, Magetan Regency. The integrated intervention approach, combining structured health education with targeted environmental modifications, demonstrated substantial effectiveness across multiple outcome dimensions. Quantitative assessment revealed that 85.7% of participants (six of seven pulmonary TB patients) achieved satisfactory knowledge levels post-intervention, with an aggregate mean knowledge score of 2.71 on a three-point scale, indicating successful knowledge transfer regarding TB etiology, transmission mechanisms, clinical manifestations, and therapeutic protocols. Attitudinal evaluation documented positive behavioral shifts, evidenced by active participant engagement in educational sessions and demonstrated commitment to Clean and Healthy Living Behavior (PHBS) principles across knowledge, attitude, and practice domains. Environmental assessments identified that the majority of surveyed households exhibited satisfactory conditions regarding occupancy density, floor and wall construction materials, indoor humidity, and temperature parameters; however, significant deficiencies in ventilation capacity and natural illumination necessitated targeted interventions. The strategic installation of glass tiles in seven households successfully addressed these environmental limitations, achieving measurable improvements in both air circulation and natural light transmission, thereby creating healthier indoor environments with reduced TB transmission risk potential.

The collaborative implementation framework, involving partnership between academic institutions (Ministry of Health Polytechnic Surabaya faculty and students), local government authorities, and primary healthcare facilities (Plaosan Health Center), proved instrumental in program success and demonstrates a replicable model for community health interventions. These findings substantiate the effectiveness of comprehensive strategies integrating health education with physical environmental modifications for controlling environment-based infectious diseases in

endemic resource-limited settings. Future research directions should incorporate longitudinal study designs with extended follow-up periods to assess long-term knowledge retention, sustained behavioral change, and epidemiological impact on TB incidence rates among household contacts and community members. Additionally, cost-effectiveness analyses comparing integrated intervention approaches with standard TB control programs, expansion to multiple communities with diverse sociodemographic characteristics, and investigation of scalability potential for broader implementation across similar high-burden regions warrant prioritization to inform evidence-based TB control policy development and resource allocation decisions at district, provincial, and national levels.

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DATA AVAILABILITY

The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request, subject to participant privacy protection and ethical approval requirements.

AUTHOR CONTRIBUTION

Hurip Jayadi conceptualized and designed the study, supervised the overall research implementation, and led the manuscript preparation. Sri Poerwati contributed to the study design, coordinated the health education intervention, and participated in data collection and analysis. Denok Indraswati conducted the environmental assessments, oversaw the glass tile installation intervention, and contributed to data interpretation and manuscript writing. Lilis Prihastini developed the educational materials, facilitated community engagement activities, and assisted with qualitative data analysis. Hery Koesmantoro participated in data collection, performed statistical analysis, and contributed to manuscript revision and editing. All authors critically reviewed the

manuscript, approved the final version for publication, and agreed to be accountable for all aspects of the work, ensuring its integrity and accuracy.

DECLARATIONS

ETHICAL APPROVAL

Ethical approval is not available.

CONSENT FOR PUBLICATION PARTICIPANTS

Written informed consent for publication of study findings was obtained from all participants. All identifying information has been removed to protect participant privacy.

COMPETING INTERESTS

The authors declare no competing interests, financial or otherwise, related to this research.

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