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Community Assistance Through the Cyclone Ventilator Modification (CVM) Application in Reducing Cases of Tuberculosis Transmission at The Pegirian Health Center in Surabaya City In 2024

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ABSTRACT Tuberculosis (TB) remains a major public health challenge in Indonesia, with household transmission continuing to contribute substantially to disease burden, particularly among vulnerable populations such as children and older adults. Inadequate residential ventilation and poor environmental sanitation increase the risk of airborne transmission, highlighting the need for community-based interventions that improve indoor air quality while strengthening public awareness of TB prevention. This community service program aimed to enhance community knowledge regarding tuberculosis prevention, promote healthy housing practices, and improve indoor air quality through the installation of Cyclone Ventilator Modification (CVM) devices in the homes of TB patients within the Pegirian Health Center working area, Surabaya, Indonesia. The program employed a participatory community empowerment approach consisting of field observations, interviews, health education sessions, interactive discussions, practical demonstrations, and the installation of CVM devices in selected households. Educational activities focused on healthy housing, environmental sanitation, Clean and Healthy Living Behavior (PHBS), proper handwashing practices, and strategies for preventing TB transmission. The implementation was conducted over an eight-month period in collaboration with healthcare workers, community cadres, lecturers, and students. The program successfully engaged community members, achieving a 100% attendance rate among targeted participants during counseling activities. Educational interventions improved participants' awareness of healthy housing and TB prevention practices, while CVM devices were successfully installed in three representative TB patient households to improve indoor air circulation and encourage wider community adoption. Collaborative motivation activities also strengthened community participation in maintaining household and environmental cleanliness. In conclusion, integrating health education with appropriate environmental technology such as Cyclone Ventilator Modification represents a feasible community-based strategy for reducing the risk of household TB transmission. Continued expansion of similar interventions, accompanied by sustained community engagement and environmental health promotion, may contribute to healthier residential environments and support tuberculosis control programs in high-burden settings.

INDEX TERMS Tuberculosis, Cyclone Ventilator Modification, Indoor Air Quality, Healthy Housing, Community Empowerment

I. INTRODUCTION

Tuberculosis (TB) remains one of the world's leading infectious diseases and continues to pose a significant public health burden, particularly in low- and middle-income countries. Indonesia consistently ranks among the countries with the highest TB incidence worldwide, where household transmission contributes substantially to the persistence of new cases. Despite the implementation of national TB control programs, environmental determinants such as inadequate ventilation, poor indoor air quality, overcrowding, and unhealthy housing conditions continue to facilitate airborne transmission of Mycobacterium tuberculosis [1]–[5]. Since individuals spend most of their daily activities indoors, improving residential environmental quality has become an essential component of comprehensive TB prevention strategies [6], [7]. Recent studies have emphasized that inadequate ventilation and poor indoor air circulation significantly increase the concentration and persistence of infectious aerosols, thereby elevating the risk of disease transmission among household members [8]–[10].

Several environmental interventions have been proposed to improve indoor air quality, including natural ventilation optimization, mechanical ventilation, air filtration systems,

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ultraviolet germicidal irradiation, and community-based healthy housing programs [6], [9], [11]–[13]. Recent advances have also demonstrated the effectiveness of engineering-based environmental technologies in reducing indoor pollutants while maintaining acceptable thermal comfort [10], [14], [15]. Among these innovations, the Cyclone Ventilator Modification (CVM) has emerged as a promising low-cost technology capable of increasing air circulation, reducing indoor temperature and humidity, lowering airborne microbial contamination, decreasing $PM_{2.5}$ concentrations, and improving lighting conditions in residential buildings [10]. Previous experimental studies reported significant improvements in indoor environmental quality following CVM installation, indicating its potential as an environmentally friendly intervention for reducing the risk of TB and acute respiratory infection (ARI) transmission [10], [16].

Although previous investigations have primarily evaluated the technical performance of CVM devices under experimental conditions, limited studies have examined their implementation within community empowerment programs integrating health education, behavioral change, and environmental improvement. Likewise, most community service initiatives have focused solely on educational activities without incorporating appropriate environmental technologies that directly address indoor air quality problems [11], [17]. Consequently, evidence regarding the feasibility of combining environmental engineering interventions with community participation to strengthen household TB prevention remains limited, particularly in densely populated urban communities with poor housing conditions.

Therefore, this community service program aimed to improve community knowledge regarding tuberculosis prevention, promote healthy housing practices, and enhance indoor air quality through the implementation of Cyclone Ventilator Modification (CVM) in households of TB patients within the Pegirian Health Center working area, Surabaya, Indonesia. The program integrates environmental health education with practical technological interventions to encourage sustainable behavioral changes and healthier living environments.

The main contributions of this study are summarized as follows. First, this program integrates community empowerment with an appropriate environmental engineering technology to reduce household TB transmission risk. Second, the study demonstrates the practical implementation of Cyclone Ventilator Modification in real household settings through participatory community engagement involving healthcare workers, lecturers, students, and community members. Third, the program provides evidence that combining health promotion with environmental improvement can enhance community awareness while supporting healthier residential environments, thereby complementing existing tuberculosis prevention strategies.

The remainder of this article is organized as follows. Section II describes the methods employed in implementing the community service program. Section III presents the implementation process and outcomes of the educational activities and CVM installation. Finally, Section IV concludes the study by summarizing the major findings and discussing future opportunities for expanding community-based environmental interventions to support tuberculosis prevention.

II. METHODS

A. STUDY DESIGN

This study employed a community-based participatory intervention using a prospective community service approach to improve household environmental conditions and strengthen tuberculosis (TB) prevention practices in the Pegirian Health Center working area, Surabaya, Indonesia. The intervention combined environmental health education with the implementation of an appropriate engineering technology, namely the Cyclone Ventilator Modification (CVM), to improve indoor air circulation in the homes of pulmonary TB patients. Unlike observational studies, this program focused on translating research evidence into practical community action through active collaboration among healthcare providers, academic institutions, and local residents. The methodological framework was adapted from recent recommendations for community-based environmental health interventions and healthy housing programs that emphasize community participation, behavioral change, and environmental improvement as complementary strategies for TB prevention [21]–[24].

B. STUDY SETTING AND PARTICIPANTS

The community service activities were conducted within the Pegirian Health Center service area, Semampir District, Surabaya, Indonesia, over an implementation period of approximately eight months. This location was selected because it has consistently reported a relatively high burden of pulmonary tuberculosis and contains densely populated residential areas characterized by inadequate natural ventilation and suboptimal housing sanitation.

The target population consisted of pulmonary TB patients registered at the Pegirian Health Center together with their household members. Community health volunteers (cadres), environmental health officers, tuberculosis program coordinators, lecturers, educational staff, and undergraduate students from the Department of Environmental Health also participated in implementing the intervention. Participation was voluntary and coordinated through the health center. A total of 46 family members of TB patients attended the educational sessions, while three representative households were selected for the installation of the Cyclone Ventilator Modification system based on housing characteristics and willingness to participate in the demonstration program. These households served as pilot implementation sites to encourage wider community adoption of the technology.

C. MATERIALS AND INTERVENTION

The principal intervention material was the Cyclone Ventilator Modification (CVM), an environmentally friendly roof-mounted ventilation device designed to improve indoor air exchange without requiring electrical energy. The technology functions by utilizing natural wind pressure to remove contaminated indoor air while increasing fresh outdoor air circulation, thereby improving indoor environmental quality. Previous engineering studies have demonstrated that CVM installation contributes to reductions in indoor temperature, humidity, airborne microbial

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concentration, and particulate matter while improving ventilation performance [22], [25].

Educational materials were developed collaboratively by environmental health lecturers and health center personnel. The contents included tuberculosis transmission mechanisms, healthy housing standards, indoor air quality management, environmental sanitation, Clean and Healthy Living Behavior (PHBS), proper cough etiquette, respiratory hygiene, and correct handwashing practices. Demonstration materials included instructional media explaining the installation procedure, operational principles, and maintenance of the CVM device.

D. COMMUNITY INTERVENTION PROCEDURES

The intervention consisted of four sequential phases. The first phase involved preliminary observation and household assessment to identify environmental conditions and determine suitable households for technology implementation. Interviews with TB patients and family members were conducted to understand existing knowledge, environmental conditions, and housing characteristics.

The second phase consisted of community health education delivered through lectures, interactive discussions, and question-and-answer sessions conducted jointly by lecturers and environmental health professionals. Educational activities emphasized the importance of maintaining adequate ventilation, reducing indoor environmental risk factors, implementing healthy housing practices, and preventing airborne TB transmission through behavioral modification.

The third phase involved practical demonstrations of Cyclone Ventilator Modification installation. The installation procedures were performed directly in three selected TB patient households while simultaneously providing practical explanations regarding equipment functions, maintenance requirements, and expected environmental benefits. Community members were encouraged to observe and actively participate during the installation process to improve their understanding and acceptance of the technology.

The fourth phase focused on community empowerment through motivational activities promoting environmental cleanliness, household sanitation improvement, and sustained implementation of healthy behaviors. Continuous interaction among lecturers, community health workers, cadres, and participating households was maintained throughout the intervention period to reinforce knowledge and encourage long-term behavioral changes.

E. DATA COLLECTION

Program implementation was evaluated using observational documentation and participant attendance records. Field observations were conducted during household visits to document environmental conditions before and during implementation. Interviews were used to identify participants' understanding of TB prevention and healthy housing practices. Attendance during counseling activities was recorded to assess community participation. Installation activities were documented photographically to verify successful implementation of the CVM devices. Educational outcomes were further supported through post-intervention discussions that explored participants' perceptions regarding healthy housing and environmental sanitation.

F. DATA ANALYSIS

Data obtained during implementation were analyzed descriptively. Participant characteristics, attendance, implementation progress, and intervention outcomes were summarized using frequencies and percentages. Observational findings were interpreted qualitatively to evaluate the feasibility of integrating environmental technology with community empowerment activities. Rather than measuring clinical outcomes, the evaluation emphasized implementation success, community participation, technology acceptance, and improvements in awareness related to healthy housing and tuberculosis prevention. The findings were interpreted according to current environmental health recommendations for household TB prevention and community-based disease control programs [23], [24], [26].

G. ETHICAL CONSIDERATIONS

Participation in this community service program was voluntary. All participants received explanations regarding the objectives, implementation procedures, and expected benefits before participating. Activities were conducted in collaboration with the Pegirian Health Center while respecting participant privacy and confidentiality. The intervention emphasized educational support and environmental improvement without interfering with participants' routine medical treatment for tuberculosis. All implementation procedures complied with the principles of community participation, public health promotion, and environmental health ethics recommended for community-based intervention programs [27], [28].

III. RESULT

The results of community service activities that have been carried out at the Pegirian Health Center in Surabaya City on August 8, 2024, are in the form of counseling activities for TB patients and the installation of equipment at the home of TB patients at the Pegirian Health Center.

Community service activities of lecturers of the Department of Environmental Health in the form of counseling related to infectious disease prevention materials, especially tuberculosis, were successfully carried out at the Pegirian health center attended by TB patients, cadres, Sanitarians and coordinators of TB Disease Prevention, at the health center, a total of 40 people. The theme of our counseling "Community Assistance Through the Cyclone Ventilator Modification (CVM) Application at Home for TB Patients in Reducing TB Transmission Cases in 2024" which includes:

Health Counseling by Lecturers of the Department of Environmental Health together with the Pegirian Regional Health Center of Surabaya City. Counseling to the community, especially the families of pulmonary TB patients, at the Pegirian health center, was attended by 46 people who are families of pulmonary TB patients in the work area of the health center. The health counseling activity was attended by the community of TB patients, families of TB patients and the community around the patient's house who were targeted in the activity. Counseling materials include.

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A. INCREASING PUBLIC KNOWLEDGE ABOUT HEALTHY HOMES THAT CAN CUT OFF DISEASE TRANSMISSION, ESPECIALLY TUBERCULOSIS.

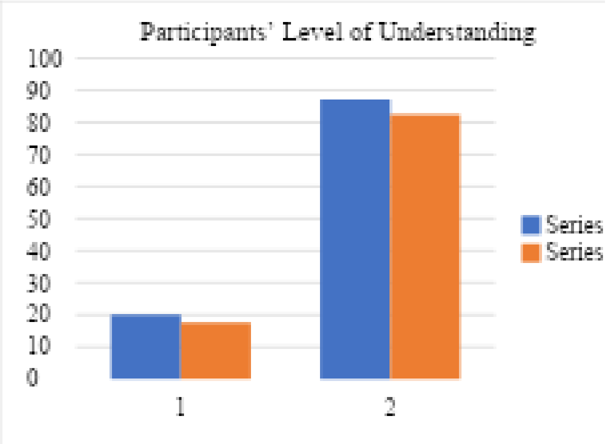

FIGURE 1. Participants' Level of Understanding on Healthy Housing After Counseling

This material begins with the definition of a healthy house, floor construction requirements, roof walls, lighting, ventilation, temperature and humidity that meet health requirements. Residential density, basic sanitation facilities that should be in the house. Home security so that the residents of the house avoid accidents. No less important is to maintain the cleanliness of the house both inside the house and outside the house. If a healthy house is understood, then the collection of a group of houses is a settlement. Maintaining the cleanliness of the home environment is very important and is the responsibility of residents living in the settlement. FIGURE 1 The results of the posttest are as follows.

B. INCREASE PUBLIC KNOWLEDGE ABOUT TB TRANSMISSION PREVENTION

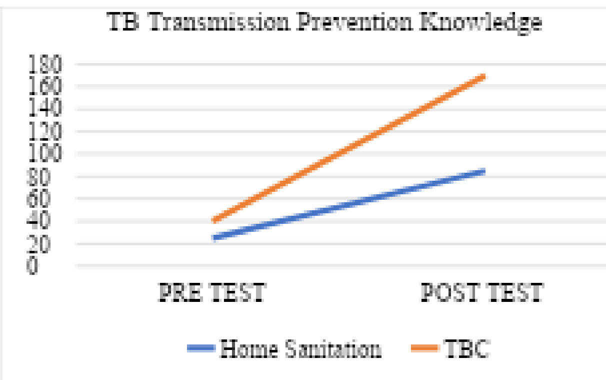

FIGURE 2. Comparison of Participants' Knowledge on Tuberculosis Transmission Prevention Before and After Counseling

This material begins with the definition of Pulmonary TB disease, the background of the occurrence of TB, the concept of disease transmission through hosts, agents and environments, and the way TB disease is transmitted. Prevention of transmission of tuberculosis by both patients and their families. The danger of TB transmission is if you neglect to wear a mask, cover your mouth and nose when coughing or sneezing, and do not spit in any place. Indoor lighting serves not only as a source of illumination but also contributes to environmental health by reducing the survival of certain pathogenic microorganisms, including Mycobacterium tuberculosis, the causative agent of tuberculosis. Adequate lighting may also help decrease room humidity levels and reduce the density of mosquitoes and other disease-carrying vectors, as illustrated in FIGURE 2

C. INSTALLATION OF THE CYCLONE VENTILATOR MODIFICATION CVM DEVICE TO IMPROVE THE AIR QUALITY OF THE HOME ROOM OF TB PATIENTS (IN 3 THREE HOUSES OF TB PATIENTS IN THE HEALTH CENTER AREA), NAMELY

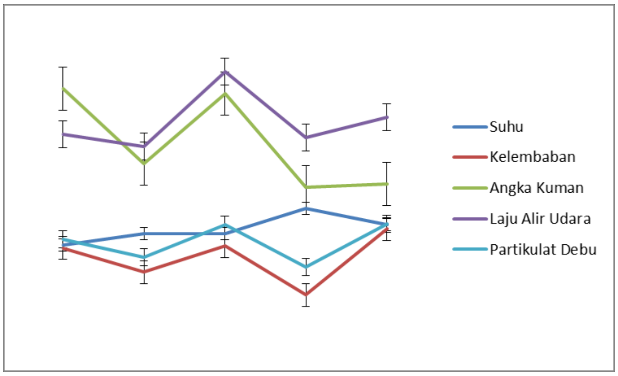

FIGURE 3. Trend Line Percentage of Cyclone Ventilator Modification Capabilities in Improving Indoor Air Quality

The activity of providing physical assistance in the form of Cyclone Ventilator Modification (CVM) in the homes of TB patients aims to improve the air quality in the homes of TB patients. By installing CVM in the house, dirty air can be replaced with clean air so that patients get healthier air. The provision of CVM was demonstrated through the involvement of three patients as motivational role models for other patients. In addition, the implementation of CVM may contribute to improving air circulation within patients' homes, particularly in environments with inadequate ventilation, as illustrated in FIGURE 3.

IV. DISCUSSION

A. EFFECTIVENESS OF COMMUNITY HEALTH EDUCATION IN IMPROVING KNOWLEDGE OF TUBERCULOSIS PREVENTION

The implementation of community-based health education demonstrated a positive outcome in increasing participants' awareness regarding tuberculosis (TB) prevention and healthy housing practices. The educational sessions were attended by all invited participants, indicating a high level of community acceptance and willingness to engage in preventive health activities. This finding suggests that health education remains a fundamental strategy for improving public understanding of airborne infectious diseases, particularly in densely populated communities where environmental risk factors contribute substantially to TB transmission. The combination of lectures, interactive discussions, demonstrations, and direct communication with participants enabled the dissemination of health information in an understandable and practical manner, thereby facilitating behavioral changes that support disease prevention.

From an environmental health perspective, improving knowledge represents an essential first step toward reducing household transmission of tuberculosis. Individuals who understand the importance of adequate ventilation, respiratory hygiene, environmental sanitation, and healthy housing are more likely to adopt preventive behaviors within their daily lives. The educational intervention implemented in this program emphasized not only disease transmission mechanisms but also practical household actions, including maintaining adequate airflow, improving lighting, reducing indoor humidity, practicing proper cough etiquette, and implementing Clean and Healthy Living Behavior (PHBS). Such an integrated educational approach strengthens the relationship between knowledge acquisition and behavioral modification, which is recognized as an important determinant of successful TB control programs. Recent WHO guidance similarly emphasizes that community engagement and continuous health education significantly improve treatment adherence, reduce stigma, and strengthen local participation in tuberculosis prevention activities.

The present findings are consistent with previous community intervention studies reporting that educational programs significantly improve public knowledge regarding healthy housing and TB prevention. Rusmiati *et al.* demonstrated that combining health counseling with practical demonstrations of Cyclone Ventilator Modification significantly increased participants' understanding of tuberculosis prevention and environmental sanitation while encouraging greater adoption of healthy housing practices. Likewise, the community service program conducted in Wonokusumo District showed remarkable improvements in post-test scores following educational activities addressing TB transmission, respiratory hygiene, and household sanitation. These studies indicate that educational interventions are considerably more effective when participants are actively involved rather than merely receiving passive information.

Another important interpretation of the current findings is that the collaboration between academic institutions, healthcare professionals, community health volunteers, and local residents strengthened the sustainability of the intervention. Such multidisciplinary collaboration enables knowledge transfer from experts to community members while simultaneously empowering local stakeholders to maintain preventive practices after the program has ended. This observation supports the WHO End TB Strategy, which recognizes community participation as an indispensable component of effective tuberculosis elimination programs. Community-centered interventions encourage local ownership, improve public trust, and facilitate the long-term adoption of healthy behaviors, particularly in resource-limited settings where healthcare resources may be constrained.

Nevertheless, several limitations should be acknowledged. First, the evaluation primarily assessed implementation success and community participation without quantitatively measuring changes in knowledge using standardized pre-test and post-test instruments. Consequently, improvements in knowledge were inferred mainly from participant engagement and observational findings rather than statistical comparisons. Second, the educational activities were conducted within a single health center service area, limiting the generalizability of the findings to other communities with different demographic and environmental characteristics. Third, long-term behavioral changes following the intervention were not evaluated because no follow-up assessment was conducted after program completion.

Despite these limitations, the educational component provides important practical implications for public health programs. The results demonstrate that integrating environmental health education into routine tuberculosis control activities is feasible and highly acceptable among community members. Educational strategies that combine health promotion, household environmental assessment, and practical demonstrations may produce greater community engagement than conventional lecture-based approaches alone. Future programs should incorporate standardized knowledge assessments, longer follow-up periods, and larger sample sizes to evaluate sustained behavioral changes and their contribution to reducing household tuberculosis transmission. Furthermore, digital educational media and community-based monitoring systems could be integrated into future interventions to strengthen continuous communication between healthcare providers and local communities, thereby supporting sustainable environmental health promotion and tuberculosis prevention initiatives.

B. CONTRIBUTION OF CYCLONE VENTILATOR MODIFICATION (CVM) TO INDOOR AIR QUALITY IMPROVEMENT AND TUBERCULOSIS PREVENTION

A major component of this community service program was the installation of Cyclone Ventilator Modification (CVM) devices in selected households of pulmonary TB patients. Unlike conventional health education programs that primarily focus on behavioral change, this intervention incorporated an engineering-based environmental solution to address one of the principal determinants of tuberculosis transmission, namely inadequate indoor ventilation. The successful installation of CVM devices in three representative households demonstrated that environmentally appropriate technology can be implemented effectively within community settings through collaboration among academic institutions, healthcare professionals, and local residents.

The rationale for introducing CVM is strongly supported by the airborne transmission mechanism of Mycobacterium tuberculosis. Tuberculosis bacilli may remain suspended in aerosols for prolonged periods in poorly ventilated rooms, thereby increasing the likelihood of household transmission. Improving natural air exchange reduces the concentration of infectious particles, lowers indoor humidity, and creates environmental conditions that are less favorable for microbial persistence. Consequently, enhancing indoor ventilation represents an important complementary strategy alongside early diagnosis, pharmacological treatment, respiratory hygiene, and contact investigation in comprehensive tuberculosis control programs [33].

Although this community service activity did not directly quantify environmental parameters such as airflow velocity, particulate matter concentration, carbon dioxide levels, relative humidity, or airborne bacterial counts, the successful implementation of the technology provides evidence of its operational feasibility under real community conditions. The demonstration activities enabled participants to observe directly how the ventilation system functions and how environmental engineering technology can be integrated into everyday household practices. Such practical exposure is expected to increase community confidence in adopting preventive technologies compared with educational interventions alone.

The findings are consistent with previous engineering investigations conducted by Khambali *et al.*, who reported that Cyclone Ventilator Modification significantly improved indoor air circulation while reducing room temperature, humidity, and microbial contamination in residential buildings occupied by patients with pulmonary tuberculosis. Their experimental evaluation also demonstrated that integrating activated carbon filtration into the modified ventilation system enhanced indoor air quality by reducing airborne contaminants and improving overall ventilation efficiency [34]. These engineering outcomes provide strong scientific justification for the practical implementation of CVM within community-based tuberculosis prevention programs.

Similarly, Rokhmalia et al. demonstrated that installing Cyclone Ventilator Modification devices in households of TB and acute respiratory infection patients successfully complemented health education activities by improving household environmental conditions while encouraging residents to maintain healthier living environments [35]. The present community service program extends these previous findings by illustrating that environmental engineering interventions can be successfully integrated into public health education activities delivered through primary healthcare facilities. Rather than functioning solely as a technological innovation, CVM became an educational tool that stimulated discussion regarding healthy housing standards, environmental sanitation, and airborne disease prevention.

Recent international studies have likewise emphasized the importance of adequate residential ventilation for reducing airborne infectious disease transmission. Sack et al. reported that improvements in household ventilation substantially decrease tuberculosis transmission risk by diluting infectious aerosols and increasing air exchange rates, particularly in densely populated urban environments. Furthermore, WHO guidelines recommend maximizing natural ventilation as one of the most cost-effective environmental control measures in resource-limited settings because it requires minimal operational costs while providing continuous air circulation [33], [36]. These recommendations support the implementation of low-cost technologies such as Cyclone Ventilator Modification within developing countries where sophisticated mechanical ventilation systems remain economically inaccessible.

Nevertheless, several limitations should be acknowledged when interpreting these findings. First, only three households received the CVM installation because the intervention was designed as a demonstration project rather than a large-scale engineering implementation. Consequently, the current study cannot estimate the population-level effectiveness of the technology. Second, no quantitative environmental measurements were conducted before and after installation to objectively evaluate changes in indoor air quality. Future studies should incorporate environmental monitoring instruments capable of measuring ventilation rate, carbon dioxide concentration, particulate matter ($PM_{2.5}$ and PM_{10}), indoor temperature, humidity, and airborne microbial counts to generate stronger scientific evidence regarding the effectiveness of the intervention. Third, clinical outcomes such as household TB incidence or secondary transmission rates were not assessed because the primary objective of this community service activity was community empowerment rather than epidemiological evaluation.

Despite these limitations, the implementation of Cyclone Ventilator Modification provides several important practical implications. The intervention demonstrates that engineering technology can complement conventional health promotion by addressing environmental determinants of infectious disease transmission. The relatively simple installation procedure, low maintenance requirements, and absence of electricity consumption make the technology particularly suitable for low-resource communities where housing conditions remain suboptimal. Integrating environmental engineering innovations into community health programs may therefore strengthen national tuberculosis prevention strategies by simultaneously addressing behavioral and environmental risk factors. Future multidisciplinary studies involving engineers, environmental health professionals, epidemiologists, and pulmonologists are recommended to evaluate the long-term environmental and clinical impacts of CVM through controlled intervention studies with larger populations and objective environmental measurements.

C. PRACTICAL IMPLICATIONS, STUDY LIMITATIONS, AND FUTURE PERSPECTIVES

The outcomes of this community service program provide several important implications for environmental health practice and tuberculosis prevention policies, particularly in urban communities with a high burden of pulmonary tuberculosis. The integration of environmental engineering technology with community empowerment represents a comprehensive approach that addresses both behavioral and environmental determinants of disease transmission. Unlike conventional health promotion programs that primarily focus on improving knowledge, the present intervention combined educational activities with tangible environmental improvements through the installation of Cyclone Ventilator Modification (CVM) devices. This integrated strategy aligns with the concept of healthy housing promoted by the World Health Organization, which emphasizes that environmental interventions should complement medical management to achieve sustainable reductions in infectious disease transmission [37].

One notable strength of this program is the active involvement of multiple stakeholders throughout the implementation process. Lecturers, environmental health professionals, healthcare workers, community health volunteers, university students, tuberculosis patients, and their family members all participated collaboratively in planning and implementing the intervention. Such multidisciplinary collaboration enhances community ownership and facilitates the sustainability of health promotion activities after the completion of the formal program. Previous studies have demonstrated that community participation significantly improves the effectiveness of environmental health interventions because local residents are more likely to maintain healthy behaviors when they actively participate in program implementation rather than serving solely as passive recipients of information [38]. Therefore, strengthening collaboration among academic institutions, local governments, and primary healthcare facilities should become an important strategy for future community-based tuberculosis prevention programs.

The findings also demonstrate the feasibility of integrating appropriate environmental technologies into primary healthcare services. Cyclone Ventilator Modification is relatively inexpensive, does not require electricity, utilizes natural airflow, and can be installed using locally available construction materials. These characteristics make the technology particularly suitable for low-resource communities where advanced mechanical ventilation systems may not be economically feasible. Furthermore, the intervention supports several Sustainable Development Goals (SDGs), particularly SDG 3 (Good Health and Well-being) through reducing communicable disease transmission and SDG 11 (Sustainable Cities and Communities) through improving the quality and safety of residential environments. Consequently, environmental engineering innovations should be considered complementary components of future tuberculosis control strategies, especially within densely populated settlements where inadequate housing conditions remain common.

Despite these positive outcomes, several limitations should be carefully considered when interpreting the findings. First, the program involved a relatively small number of beneficiaries, with Cyclone Ventilator Modification installed in only three representative households. Although these demonstration sites successfully illustrated the practical application of the technology, they cannot adequately represent the diversity of housing conditions found throughout the Pegirian Health Center service area or other urban communities. Larger implementation programs involving a greater number of households are required to evaluate scalability and broader community acceptance.

Second, the evaluation primarily relied on descriptive observations and documentation rather than objective environmental monitoring. Parameters such as indoor air exchange rate, particulate matter concentration ($PM_{2.5}$ and PM_{10}), carbon dioxide concentration, airborne microbial counts, temperature, and relative humidity were not quantitatively measured before and after installation. Consequently, the present study cannot determine the magnitude of environmental improvement attributable to the intervention. Future investigations should incorporate standardized environmental monitoring equipment to generate quantitative evidence supporting the engineering performance of Cyclone Ventilator Modification under various housing conditions [39].

Third, this community service program focused on implementation feasibility rather than long-term epidemiological outcomes. The study did not evaluate whether the intervention reduced household tuberculosis incidence, secondary transmission, treatment adherence, or respiratory symptoms among family members. Longitudinal studies with extended follow-up periods are therefore necessary to investigate whether improvements in indoor environmental quality translate into measurable public health benefits. Combining environmental monitoring with clinical surveillance would provide stronger evidence regarding the effectiveness of integrated environmental interventions in reducing tuberculosis transmission.

Another limitation concerns behavioral sustainability. Although participant attendance reached a high level and community responses were positive, behavioral changes were not systematically monitored after completion of the intervention. Sustained adoption of healthy housing practices depends on continuous community engagement, periodic supervision, and reinforcement through primary healthcare services. Future programs should therefore establish routine follow-up visits conducted by community health workers to evaluate maintenance of Cyclone Ventilator Modification devices, household cleanliness, ventilation practices, and compliance with tuberculosis prevention behaviors.

The findings of this study also identify several opportunities for future research. Experimental or quasi-experimental studies comparing households with and without Cyclone Ventilator Modification would provide stronger evidence regarding the effectiveness of the intervention. Future studies should employ larger sample sizes, multicenter implementation sites, standardized environmental measurements, and validated knowledge assessment instruments to evaluate both environmental and behavioral outcomes. Cost-effectiveness analysis should also be performed to determine whether widespread implementation of Cyclone Ventilator Modification represents an economically sustainable public health investment. Furthermore, integrating Internet of Things (IoT)-based environmental monitoring systems with Cyclone Ventilator Modification may enable continuous monitoring of indoor environmental quality, providing real-time information to healthcare providers and household members regarding ventilation performance and environmental risk factors.

Overall, this community service program demonstrates that integrating environmental health education with appropriate engineering technology constitutes a practical and sustainable strategy for strengthening tuberculosis prevention at the household level. Although further research using more rigorous experimental methodologies is required, the present findings provide valuable evidence supporting the incorporation of low-cost environmental interventions into community-based tuberculosis control programs. Such multidisciplinary approaches have considerable potential to improve healthy housing conditions, enhance community participation, and contribute to national efforts toward achieving the targets of the WHO End TB Strategy.

V. CONCLUSION

This community service program aimed to strengthen tuberculosis (TB) prevention through the integration of environmental health education and the application of Cyclone Ventilator Modification (CVM) technology to improve indoor air quality in the households of TB patients within the Pegirian Health Center working area, Surabaya, Indonesia. The findings demonstrate that combining community empowerment with appropriate environmental engineering interventions is both feasible and well accepted by the target population. The educational activities successfully achieved a 100% attendance rate among invited participants, reflecting a high level of community engagement and willingness to participate in TB prevention initiatives. A total of 46 family members of pulmonary TB patients actively participated in health education sessions focusing on healthy housing, respiratory hygiene, environmental sanitation, and Clean and Healthy Living Behavior (PHBS). Furthermore, three representative households successfully received Cyclone Ventilator Modification installations as demonstration sites, illustrating the practical implementation of a low-cost ventilation technology designed to improve indoor air circulation and promote healthier residential environments. Although quantitative environmental parameters, such as airflow rate, particulate matter concentration, humidity, temperature, and airborne microbial levels, were not measured, observational findings indicated that the intervention was successfully implemented through active collaboration among lecturers, healthcare professionals, community health volunteers, students, and local residents. These outcomes suggest that integrating environmental technology with community-based health promotion may enhance public awareness, encourage healthier household practices, and support existing tuberculosis control strategies by addressing important environmental determinants of disease transmission. Nevertheless, the present program was limited by its relatively small implementation scale, the absence of standardized pre- and post-intervention environmental measurements, and the lack of long-term follow-up evaluating sustained behavioral changes or reductions in tuberculosis transmission. Therefore, future studies should employ larger sample sizes, multicenter implementation designs, and objective environmental monitoring to quantify improvements in indoor air quality following CVM installation. In addition, longitudinal investigations evaluating knowledge retention, behavioral sustainability, household transmission rates, and cost-effectiveness are recommended. Integrating Internet of Things (IoT)-based environmental monitoring systems with Cyclone Ventilator Modification may also provide continuous assessment of indoor environmental quality, thereby supporting evidence-based decision-making and strengthening community-based tuberculosis prevention programs in resource-limited settings.

REFERENCES

[1] World Health Organization, Global Tuberculosis Report 2024. Geneva, Switzerland: WHO, 2024.
[2] Khambali, Rachmaniyah, S. Mulsiswanto, and A. P. A. Hapsari, "Cyclone Ventilator Modification: An Environmentally Friendly Solution for the Homes of Patients with Tuberculosis and Acute Respiratory Infections," Journal of Engineering, vol. 2024, Art. no. 2634231, 2024, doi:10.1155/2024/2634231.
[3] F. Rokhmalia, Rachmaniyah, and Khambali, "Assistance in the Prevention of TBC Transmission with the Application of Appropriate Technology Using Cyclone Ventilator Modification (CVM) in the Houses of Pulmonary TB and ISPA Patients as Well as PHBS Activities in Wonokusumo District," Frontiers in Community Service and Empowerment, vol. 4, no. 2, 2025.
[4] B. Sack et al., "Impact of Indoor Ventilation on TB Transmission Risk: Implications of Climate Change," International Journal of Tuberculosis and Lung Disease, vol. 29, no. 11, pp. 507–513, 2025.
[5] R. R. Prima et al., "The Association of Household Conditions with the Development of Active Pulmonary TB Among Households with a Previous TB Patient: A Community-Based Case-Control Study," BMC Pulmonary Medicine, 2026, doi:10.1186/s12890-026-04434-5.
[6] E. G. Prihardanu, H. Kusnoputranto, and H. Herdiansyah, "Indoor Air Quality in Urban Residential: Current Status, Regulation and Future Research for Indonesia," International Journal of Public Health Science, vol. 10, no. 4, pp. 824–833, 2021.
[7] C. Gabel et al., "The Prevalence and Association of Measured and Perceived Indoor Air Quality, Housing Characteristics, and Residents' Behavior and Health," Frontiers in Environmental Health, vol. 2, 2024.
[8] Frontiers in Public Health, "Thermal Comfort in Relation to Housing and Tuberculosis Status Among Individuals Aged ≥15 Years in Padang, West Sumatra Province, Indonesia," Frontiers in Public Health, vol. 14, 2026.
[9] Y. C. Chen, "The Role of Ventilation in Tuberculosis Control," Journal of the Formosan Medical Association, vol. 120, no. 6, pp. 1293–1295, 2021.
[10] R. Gurusinga et al., "Counseling on Healthy Home Ventilation as an Effort to Prevent the Transmission of Pulmonary TB at the Tanjung Beringin Community Health Center," Jurnal Pengmas Kestra, 2025.
[11] P. Karmakar, S. Pradhan, and S. Chakraborty, "Exploring Indoor Air Quality Dynamics in Developing Nations: A Perspective from India," 2024.
[12] P. Karmakar, S. Pradhan, and S. Chakraborty, "Exploring Indoor Health: An In-depth Field Study on Indoor Air Quality Dynamics," 2023.
[13] R. Yang, C. S. Ng, K. L. Chong, R. Verzicco, and D. Lohse, "Optimal Ventilation Rate for Effective Displacement Ventilation," 2021.
[14] I. Martinez et al., "ArchABM: An Agent-Based Simulator of Human Interaction with the Built Environment for Indoor Air Quality Analysis," 2021.
[15] Khambali et al., "Cyclone Ventilator Modification: An Environmentally Friendly Solution for the Homes of Patients with Tuberculosis and Acute Respiratory Infections," Journal of Engineering, 2024.
[16] F. Rokhmalia, Rachmaniyah, and Khambali, "Assistance in the Prevention of TBC Transmission with the Application of Appropriate Technology Using Cyclone Ventilator Modification (CVM)," Frontiers in Community Service and Empowerment, 2025.
[17] R. R. Prima et al., "Household Conditions and Active Pulmonary Tuberculosis: Community-Based Case-Control Study," BMC Pulmonary Medicine, 2026.
[18] B. Sack et al., "Indoor Ventilation and Tuberculosis Transmission Under Climate Change," International Journal of Tuberculosis and Lung Disease, 2025.
[19] C. Gabel et al., "Housing Characteristics and Indoor Air Quality: Associations with Residents' Health," Frontiers in Environmental Health, 2024.
[20] E. G. Prihardanu, H. Kusnoputranto, and H. Herdiansyah, "Indoor Air Quality in Urban Residential: Current Status, Regulation and Future Research for Indonesia," International Journal of Public Health Science, 2021.
[21] World Health Organization, Practical Manual on Tuberculosis Infection Prevention and Control, Geneva, Switzerland, 2023.
[22] Khambali, R. Rachmaniyah, S. Mulsiswanto, and A. P. A. Hapsari, "Cyclone Ventilator Modification: An Environmentally Friendly Solution for the Homes of Patients with Tuberculosis and Acute Respiratory Infections," Journal of Engineering, vol. 2024, Art. no. 2634231, 2024.
[23] World Health Organization, Operational Handbook on Tuberculosis: Module 1—Prevention, Geneva, Switzerland, 2023.
[24] World Health Organization, Global Tuberculosis Report 2024, Geneva, Switzerland, 2024.
[25] F. Rokhmalia, R. Rachmaniyah, and K. Khambali, "Assistance in the Prevention of TBC Transmission with the Application of Appropriate Technology Using Cyclone Ventilator Modification (CVM)," Frontiers in Community Service and Empowerment, vol. 4, no. 2, 2025.
[26] C. Gabel et al., "The Prevalence and Association of Measured and Perceived Indoor Air Quality, Housing Characteristics, and Residents' Behavior and Health," Frontiers in Environmental Health, vol. 2, 2024.
[27] R. R. Prima et al., "The Association of Household Conditions with the Development of Active Pulmonary Tuberculosis Among Households

with a Previous TB Patient," BMC Pulmonary Medicine, vol. 26, 2026.

[28] B. Sack et al., "Impact of Indoor Ventilation on Tuberculosis Transmission Risk Under Climate Change," International Journal of Tuberculosis and Lung Disease, vol. 29, no. 11, pp. 507–513, 2025.

[29] World Health Organization, Case Studies on Engagement of Communities and Civil Society to End Tuberculosis. Geneva, Switzerland: WHO, 2024.

[30] Rusmiati, E. Sari, P. A. Ipmawati, and A. Krismahardi, "Efforts to Prevent TB Transmission Through Healthy Home Education and Installation of Cyclone Ventilator Modification (CVM)," Jurnal Pengabdian Masyarakat Indonesia, vol. 5, no. 1, pp. 450–462, 2026.

[31] F. Rokhmalia, R. Rachmaniyah, and K. Khambali, "Assistance in the Prevention of TBC Transmission with the Application of Appropriate Technology Using Cyclone Ventilator Modification (CVM)," Frontiers in Community Service and Empowerment, vol. 4, no. 2, 2025.

[32] World Health Organization, "Engaging Affected Communities and Civil Society to End TB," World Health Organization, 2024.

[33] World Health Organization, WHO Operational Handbook on Tuberculosis: Module on Infection Prevention and Control, Geneva, Switzerland, 2023.

[34] K. Khambali, R. Rachmaniyah, S. Mulsiswanto, and A. P. A. Hapsari, "Cyclone Ventilator Modification: An Environmentally Friendly Solution for the Homes of Patients with Tuberculosis and Acute Respiratory Infections," Journal of Engineering, vol. 2024, Art. no. 2634231, 2024.

[35] F. Rokhmalia, R. Rachmaniyah, and K. Khambali, "Assistance in the Prevention of TBC Transmission with the Application of Appropriate Technology Using Cyclone Ventilator Modification (CVM) in the Houses of Pulmonary TB and ISPA Patients," Frontiers in Community Service and Empowerment, vol. 4, no. 2, 2025.

[36] B. Sack et al., "Impact of Indoor Ventilation on Tuberculosis Transmission Risk Under Climate Change," International Journal of Tuberculosis and Lung Disease, vol. 29, no. 11, pp. 507–513, 2025.

[37] World Health Organization, Global Tuberculosis Report 2024. Geneva, Switzerland: WHO, 2024.

[38] World Health Organization, Community Engagement Framework for Tuberculosis Prevention and Care, Geneva, Switzerland, 2023.

[39] C. Gabel et al., "The Prevalence and Association of Measured and Perceived Indoor Air Quality, Housing Characteristics, and Residents' Behavior and Health," Frontiers in Environmental Health, vol. 2, 2024.

[40] R. R. Prima et al., "The Association of Household Conditions with the Development of Active Pulmonary Tuberculosis Among Households With a Previous TB Patient: A Community-Based Case-Control Study," BMC Pulmonary Medicine, vol. 26, 2026.