

Development of IoT-Based Monitoring Technology for Humidity, Lighting, and Temperature in the Homes of Tuberculosis Patients in the Working Area of the Penyengat Olak Community Health Center, Muaro Jambi Regency

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ABSTRACT

Pulmonary tuberculosis (TB) remains a major public health problem in Indonesia, including in Muaro Jambi Regency, where TB transmission continues to increase despite integrated treatment efforts. Environmental factors such as humidity, lighting, and temperature play an important role in supporting TB transmission within household environments. This study aimed to develop an Internet of Things (IoT)-based monitoring technology prototype for measuring humidity, lighting, and temperature in the homes of TB patients in the working area of the Penyengat Olak Community Health Center, Muaro Jambi Regency. The study employed a Research and Development (R&D) approach consisting of four stages, including needs analysis, system design, prototype development, and testing. The developed prototype integrates environmental sensors with a web-based monitoring system to enable real-time recording and monitoring of household environmental conditions. The expected outcome of this research is an IoT-based monitoring device capable of supporting early prevention and environmental control of pulmonary TB transmission

INTRODUCTION

In Indonesia, pulmonary tuberculosis remains a major public health problem. Indonesia ranks fourth in the world in terms of tuberculosis (TB) cases after India, China, and South Africa, with a TB prevalence of 285 per 100,000 population, or 302,861 cases in 2010 (WHO, Global Tuberculosis Control, 2010). Tuberculosis, also known as TB, is a disease that affects many Indonesians, ranging from children to adults (Ministry of Health of the Republic of Indonesia, 2018). The transmission of pulmonary tuberculosis in the community of Muaro Jambi Regency continues, with new cases increasing despite the implementation of integrated and controlled treatment services.

The home environment can contribute to the high incidence of pulmonary tuberculosis, including unhealthy housing conditions such as inadequate ventilation, poor lighting and humidity, overcrowding, and poor building materials. In addition to the home environment influencing the incidence of tuberculosis, poor physical, biological, and social environmental conditions can also negatively affect health and contribute to the high incidence of tuberculosis (Muaz, 2014). A healthy home must fulfill health requirements, including psychological needs, prevention of disease transmission, and prevention of accidents (Soesanto, 2000). Fresh air circulation and adequate lighting within a house are essential for human health. The transmission of tuberculosis is closely related to ventilation and lighting conditions in the home (Achmadi, 2000). Therefore, a healthy home environment is essential to prevent the transmission of tuberculosis.

This disease is transmitted through droplets, where bacteria can travel up to 100 meters in the air and spread rapidly through wind movement. Consequently, the number of infections becomes very high, and healthcare workers often face difficulties in identifying the exact source of infection. Therefore, monitoring environmental conditions that potentially support TB transmission is highly important as part of disease prevention efforts.

The Internet of Things (IoT) has become a major trend in the Industry 4.0 era and offers significant opportunities for technological advancement and human development goals. IoT is defined as the integration of interconnected devices that can be managed through web-based systems, providing real-time information and enabling user interaction (Gomez, 2013). Among various applications, the Internet of Medical Things (IoMT) has gained considerable attention in the healthcare sector because it assists healthcare workers in diagnosing diseases and monitoring patients remotely through wearable and sensor-based devices (Hsu, 2016). The use of IoT-based technology that is practical, effective, and affordable for monitoring home environmental conditions is highly needed. However, IoT-based home environmental monitoring systems developed specifically for the prevention of infectious diseases remain very limited, particularly systems that are user-friendly and suitable for developing countries such as Indonesia.

Based on these conditions, the research problem is formulated as follows: "How is pulmonary tuberculosis (TB) transmitted using sensory methods in monitoring the physical environment of homes of pulmonary tuberculosis

patients in the working area of the Penyengat Olak Community Health Center, Muaro Jambi Regency?" Therefore, this study aims to develop a prototype sensor system for monitoring humidity, lighting, and temperature as part of tuberculosis prevention efforts through environmental monitoring. This research is important because tuberculosis prevention should not only focus on reducing morbidity and mortality rates, but also on breaking the chain of transmission so that tuberculosis no longer becomes a public health problem.

LITERATURE REVIEW

Pulmonary Tuberculosis as a Public Health Problem

Pulmonary tuberculosis (TB) remains one of the major infectious diseases worldwide and continues to be a serious public health problem, particularly in developing countries such as Indonesia. The World Health Organization (WHO) reported that Indonesia remains among the countries with the highest TB burden globally, with environmental and socioeconomic factors contributing significantly to disease transmission. Environmental conditions such as inadequate ventilation, poor lighting, high humidity, overcrowding, and unhealthy housing structures have been identified as important determinants influencing TB transmission within households. Recent studies have demonstrated that household environmental quality is closely associated with the incidence of pulmonary tuberculosis, especially in densely populated residential areas.

Research conducted by Rahmatullah et al. (2025) found that environmental risk factors, including ventilation, humidity, and room temperature, significantly contribute to tuberculosis transmission in household settings. Similarly, Isworo et al. (2026) reported that air humidity and room temperature were significantly associated with pulmonary TB incidence in community health center areas. These findings indicate that physical environmental conditions inside houses play a critical role in supporting or suppressing airborne transmission of *Mycobacterium tuberculosis*.

In addition, studies conducted in several Indonesian regions demonstrated that poor lighting and inadequate ventilation increase the risk of pulmonary tuberculosis transmission because insufficient sunlight exposure and poor air circulation create favorable conditions for bacterial survival indoors. Aisyah et al. (2026) reported that environmental factors such as lighting, humidity, and ventilation had significant relationships with pulmonary tuberculosis cases in residential environments. These findings emphasize the importance of improving environmental health conditions as part of tuberculosis prevention strategies.

Physical Environmental Factors and Tuberculosis Transmission

The physical environment of a house has an important influence on the transmission dynamics of airborne infectious diseases, including pulmonary tuberculosis. Ventilation, lighting, humidity, and temperature are among the most important environmental determinants associated with TB transmission. Poor ventilation reduces air circulation and increases the concentration of airborne pathogens inside rooms, while high humidity and unstable temperature

conditions may support bacterial persistence and negatively affect respiratory health.

Recent epidemiological studies have shown that humidity and temperature fluctuations significantly influence tuberculosis incidence across different geographical regions. Meliyanti et al. (2026) explained that meteorological factors such as humidity and temperature are closely associated with respiratory disease transmission and tuberculosis epidemiology. Furthermore, environmental exposure to poor indoor air quality may increase vulnerability to pulmonary infections.

Research by Mardanila et al. (2025) also found significant relationships between humidity, temperature, lighting, and ventilation with pulmonary TB incidence. Their findings showed that houses with poor humidity conditions, inadequate ventilation, and insufficient lighting had higher risks of tuberculosis transmission compared to houses meeting environmental health standards. Similarly, another study found that residential density, humidity, lighting, and temperature significantly influenced pulmonary TB occurrence in communities.

Environmental conditions inside houses not only influence bacterial survival but also affect patient comfort and recovery. Patients with respiratory disorders are particularly vulnerable to changes in room temperature and humidity because extreme environmental conditions can trigger breathing difficulties and reduce quality of life. Therefore, continuous monitoring of environmental conditions is essential to support respiratory health management and reduce the risk of tuberculosis transmission within households.

Internet of Things (IoT) Technology in Environmental and Health Monitoring

The rapid development of Internet of Things (IoT) technology has created new opportunities for healthcare monitoring systems, particularly in environmental and preventive health management. IoT refers to interconnected devices capable of collecting, transmitting, and processing real-time data through internet-based systems. In healthcare applications, IoT technology enables remote monitoring, real-time environmental observation, and early detection of health-related risks.

Recent studies have highlighted the growing importance of IoT-based environmental monitoring systems for indoor health management. Simamora et al. (2025) developed an IoT-based indoor air quality detection system capable of monitoring humidity, temperature, and air quality in real time through web-based platforms. Their study demonstrated that sensor-based monitoring systems can provide accurate and continuous environmental data to support healthcare decision-making.

Similarly, Anik et al. (2021) developed a scalable and portable IoT infrastructure for indoor environmental sensing capable of monitoring multiple environmental parameters, including humidity, lighting, and temperature. Their findings showed that IoT-based environmental sensing systems are cost-effective, practical, and highly useful for monitoring indoor environmental conditions in residential settings.

In the context of healthcare, IoT technology has become increasingly important for disease prevention and environmental monitoring because it

enables real-time observation of environmental risks that may influence disease transmission. IoT-based systems also support data recording, historical environmental analysis, and automated notifications when environmental parameters exceed safe thresholds. Therefore, integrating IoT technology into household environmental monitoring systems offers significant potential for improving tuberculosis prevention strategies in communities.

Humidity, Lighting, and Temperature Sensors in IoT Systems

Sensors are essential components in IoT-based monitoring systems because they function as data collection devices capable of measuring environmental conditions automatically and continuously. In environmental health monitoring systems, humidity, lighting, and temperature sensors are commonly used to observe indoor environmental quality and identify potential health risks.

Recent technological developments have improved the performance and sensitivity of humidity sensors used in IoT applications. Ma et al. (2024) explained that modern humidity sensors have become increasingly accurate, stable, and suitable for smart healthcare and smart home applications. Humidity sensors play an important role in detecting environmental conditions that may contribute to microorganism growth and respiratory disease transmission.

Temperature and lighting sensors are also widely applied in environmental monitoring systems because room temperature stability and adequate lighting significantly influence indoor environmental quality and respiratory health. IoT-based monitoring systems integrating humidity, temperature, and lighting sensors enable continuous real-time observation and automatic environmental analysis. These technologies provide practical solutions for monitoring physical environmental conditions in patients' homes and supporting preventive healthcare interventions.

IoT-Based Environmental Monitoring for Tuberculosis Prevention

The application of IoT technology for tuberculosis prevention remains relatively limited, particularly in developing countries. Most existing TB prevention programs still rely on manual observation and conventional environmental assessments, which are often inefficient and unable to provide real-time environmental information. Consequently, there is a growing need for affordable, user-friendly, and web-based environmental monitoring systems capable of supporting tuberculosis prevention at the household level.

A study conducted by Chandra (2025) developed an IoT-based humidity monitoring system for the homes of pulmonary TB patients and demonstrated that sensor-based monitoring technologies can assist healthcare workers in identifying unhealthy environmental conditions associated with tuberculosis transmission. The study emphasized that continuous environmental monitoring can improve disease prevention strategies and support environmental health surveillance in communities with high TB incidence.

Furthermore, recent studies indicate that integrating IoT technology into public health systems can strengthen preventive healthcare services by enabling continuous monitoring, automated notifications, and remote data access. IoT-

based environmental monitoring systems also support evidence-based interventions because environmental data can be recorded and analyzed over time to identify risk patterns and improve public health responses.

Based on the literature reviewed, it can be concluded that humidity, lighting, and temperature are important environmental determinants influencing pulmonary tuberculosis transmission. At the same time, IoT technology provides significant opportunities for developing real-time, affordable, and effective environmental monitoring systems capable of supporting tuberculosis prevention efforts. However, empirical studies specifically focusing on IoT-based monitoring systems for the physical environments of TB patients' homes in Indonesian community health center settings remain limited. Therefore, this study is important to develop and evaluate an IoT-based monitoring technology for humidity, lighting, and temperature in the homes of tuberculosis patients in the working area of the Penyengat Olak Community Health Center, Muaro Jambi Regency.

METHODOLOGY

This study employed a Research and Development (R&D) approach to develop an IoT-based monitoring system for humidity, lighting, and temperature in the homes of tuberculosis patients. The research phase began with a needs analysis, followed by an analysis of educational activities related to tuberculosis transmission within the community. The implementation phase consisted of the system design and construction process, while the final phase involved prototype development through validation by experts and practitioners.

The research design and instruments used for data collection included observations of humidity, lighting, and temperature conditions in the homes of tuberculosis patients. The population of this study consisted of tuberculosis patients within the working area of the Penyengat Olak Community Health Center, Muaro Jambi Regency.

Data collection techniques included observation, interviews, and documentation. During the observation process, the researcher monitored the results displayed by the sensor device and recorded the environmental data generated by the system. Interviews were conducted to obtain supporting information related to environmental conditions and tuberculosis transmission, while documentation was used to support and validate the research findings.

RESEARCH RESULT AND DISCUSSION

The results of this study were obtained through expert validation, product testing, and environmental observations conducted in the homes of pulmonary tuberculosis (TB) patients in the working area of the Penyengat Olak Community Health Center, Muaro Jambi Regency. The study focused on developing an Internet of Things (IoT)-based monitoring system capable of measuring humidity, lighting, and temperature conditions as environmental factors associated with TB transmission risk.

Expert Validation Results

The developed monitoring prototype was evaluated by experts and practitioners to assess its feasibility based on the Theory-Intervention-Impact

framework. The behavioral science and health promotion expert validator was Dr. Toto Sudargo, M.Kes., from the Faculty of Medicine, Universitas Gadjah Mada (UGM). The information technology expert validator was Ahmad Fadhil N., B.Sc.IT., M.Sc., Ph.D. (c), from the Keluarga Bunda Jambi Health College, while the community empowerment practitioner validator was Dr. Hendriyanto, S.K.M., S.IP., M.Kes.

The validation results indicated that the IoT-based monitoring system for humidity, lighting, and temperature was considered feasible and appropriate for monitoring the physical environment of TB patients' homes. Experts emphasized that integrating environmental monitoring with web-based data recording can support early prevention efforts and strengthen environmental health surveillance systems in communities with high TB incidence. These findings are consistent with the study conducted by Alshamrani et al. (2021), which explained that IoT-based health monitoring systems provide effective real-time environmental monitoring and improve preventive healthcare management through continuous sensor-based data collection.

One-to-One Product Evaluation

The one-to-one evaluation phase involved direct testing with 1–5 users to assess product usability, user understanding, attractiveness, and operational functionality. This evaluation was conducted to identify technical errors, evaluate the clarity of operational procedures, and obtain initial feedback regarding the practicality of the monitoring system.

Table 1. One-to-One Product Evaluation Results

Product Assessment	es	Score (1)	o	Score (0)
Assessment Result	1	61	3	0

$$\frac{65}{61} \times 100\% = 93,85\%$$

Criteria: Very Feasible

Based on the evaluation results, the product obtained a feasibility score of 93.85%, indicating that the monitoring system was categorized as “very feasible” for implementation. The high feasibility score demonstrates that users were able to understand and operate the monitoring system effectively. This finding suggests that the developed prototype has strong potential for application in community-based health monitoring systems. Similar findings were reported by Alwan et al. (2022), who found that IoT-based monitoring tools achieved high usability and acceptance levels because real-time monitoring systems are considered practical and easy to operate in healthcare environments.

Lighting Conditions of TB Patients' Rooms

Lighting conditions were evaluated because inadequate natural lighting can increase humidity and create environmental conditions favorable for the survival of *Mycobacterium tuberculosis*. Proper sunlight exposure is important

because ultraviolet rays can help reduce bacterial survival in indoor environments.

Table 2. Distribution of Respondents Based on Lighting Conditions of Patients' Rooms

Lighting Condition	Frequency	Percentage (%)
Meets Requirements	12	40
Does Not Meet Requirements	18	60
Total	30	100

The findings showed that 18 out of 30 respondents (60%) lived in houses with lighting conditions that did not meet health standards, while only 12 houses (40%) had adequate lighting conditions. These results indicate that most TB patients lived in environments with insufficient lighting, potentially increasing the risk of disease transmission and reducing indoor environmental quality. This finding is supported by research conducted by Manaf et al. (2021), which reported that poor household lighting is significantly associated with increased pulmonary tuberculosis transmission because limited sunlight exposure allows bacteria to survive longer indoors.

Ventilation Conditions of TB Patients' Rooms

Ventilation is an important environmental factor because adequate air circulation reduces indoor humidity and supports healthy air exchange. Poor ventilation may increase the concentration of airborne bacteria in closed environments.

Table 3. Distribution of Respondents Based on Ventilation Area

Ventilation Area	Frequency	Percentage (%)
≥ 10%	8	26.66
< 10%	22	73.34
Total	30	100

The results demonstrated that 22 houses (73.34%) had ventilation areas below the recommended standard of 10% of floor area, while only 8 houses (26.66%) met the recommended ventilation requirements. These findings indicate that most respondents lived in houses with inadequate air circulation. Poor ventilation increases the persistence of airborne pathogens and creates unhealthy indoor environmental conditions. This result aligns with the study conducted by Rahman et al. (2022), which found that inadequate household ventilation significantly contributes to pulmonary tuberculosis transmission in densely populated communities.

Humidity Conditions of TB Patients' Rooms

Humidity levels were monitored because excessive humidity creates environmental conditions favorable for bacterial survival and may worsen respiratory health conditions.

Table 4. Distribution of Respondents Based on Room Humidity

Humidity Condition	Frequency	Percentage (%)
Meets Requirements	12	40
Does Not Meet Requirements	18	60
Total	30	100

The findings showed that 18 houses (60%) had humidity levels that did not meet health requirements, while only 12 houses (40%) had acceptable humidity conditions. High humidity levels may increase discomfort and create conditions supportive of microorganism growth. These findings are supported by research conducted by Ningsih et al. (2023), which demonstrated that excessive indoor humidity contributes to increased respiratory disease risk and creates environmental conditions favorable for bacterial growth, including tuberculosis bacteria.

Temperature Conditions of TB Patients' Rooms

Room temperature was assessed because extreme temperature conditions may affect respiratory comfort and contribute to poor indoor environmental quality.

Table 5. Distribution of Respondents Based on Room Temperature

Temperature Condition	Frequency	Percentage (%)
Meets Requirements	12	40
Does Not Meet Requirements	18	60
Total	30	100

The results showed that 18 respondents (60%) lived in houses with room temperatures that did not meet recommended standards, while only 12 respondents (40%) had acceptable room temperatures. Poor temperature conditions may reduce patient comfort and worsen respiratory disorders. These findings are consistent with research by Putri et al. (2021), which stated that unstable indoor temperature conditions significantly influence respiratory discomfort and reduce environmental quality for patients with pulmonary diseases.

Development of the IoT-Based Monitoring System

Based on these findings, this study successfully developed an IoT-based monitoring system using DHT22 and LDR sensors capable of measuring temperature, humidity, and lighting conditions in real time. The system utilized a microcontroller connected to a web-based platform for continuous environmental monitoring and data recording. In addition, the system was equipped with a notification feature that alerts users when environmental parameters exceed safe thresholds, allowing rapid intervention and environmental adjustment.

The developed system also provides historical environmental data storage, enabling healthcare personnel and researchers to analyze environmental

patterns associated with patient comfort and potential tuberculosis transmission risks. This finding is supported by research conducted by Sharma et al. (2023), which emphasized that IoT-based environmental monitoring systems can improve disease prevention strategies by providing continuous, real-time environmental data for healthcare monitoring and early intervention.

Academically, this research contributes to the development of IoT applications in public health and environmental monitoring. Practically, the system can support healthcare workers, community health centers, and families in monitoring household environmental conditions more effectively. Socially, this technology is expected to improve the quality of life of patients with respiratory disorders, support early prevention strategies, and reduce the risk of tuberculosis transmission within the community.

CONCLUSIONS AND RECOMMENDATIONS

This study successfully developed an Internet of Things (IoT)-based monitoring tool for measuring humidity, lighting, and temperature in the physical environment of tuberculosis patients' homes using the A-DD-IE development stages adapted from the Dick and Carey design model. The development process included needs analysis, system design, prototype development, implementation, and evaluation to ensure that the monitoring system could function effectively in supporting environmental health monitoring and tuberculosis prevention efforts.

The results of expert and practitioner validation demonstrated that the developed monitoring tool was feasible and appropriate for community use. In addition, one-on-one testing involving five users showed that the system was practical, understandable, and easy to operate. The implementation of educational activities regarding the use of the monitoring tool also contributed to increased community knowledge and awareness about the importance of maintaining healthy environmental conditions, particularly humidity, lighting, and temperature, as part of efforts to prevent tuberculosis transmission within household environments.

ADVANCED RESEARCH

Future research is recommended to develop the IoT-based monitoring system by integrating additional environmental parameters, mobile applications, and real-time notification features to improve tuberculosis prevention and environmental monitoring. Further studies with larger samples and wider research locations are also needed to evaluate the effectiveness of the system in reducing tuberculosis transmission risks.

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REFERENCES

- Aggarwal, R., & Lal Das, M. (2012). RFID security in the context of Internet of Things. In Proceedings of the First International Conference on Security of Internet of Things (pp. 51-56). ACM. <https://doi.org/10.1145/2490428.2490435>
- Aisyah, S. N., et al. (2026). The relationship between physical quality of the house, smoking behavior, and pulmonary tuberculosis incidence. *International Journal of Health Environment and Social Sciences*, 8(2), 1307-1314. <https://jurnal.unismuhpalu.ac.id/index.php/IJHESS/article/download/10346/7169>
- Alshamrani, A., Bahattab, A., & Alqarni, M. (2021). Internet of Things (IoT)-based smart healthcare monitoring systems: A review. *International Journal of Advanced Computer Science and Applications*, 12(2), 497-504. <https://doi.org/10.14569/IJACSA.2021.0120262>
- Alwan, A. A., Kareem, S. A., & Abdullah, R. (2022). Design and implementation of IoT healthcare monitoring systems using environmental sensors. *Sensors*, 22(14), 5318. <https://doi.org/10.3390/s22145318>
- Anik, S., Gao, X., Meng, N., Agee, P., & McCoy, A. (2021). A cost-effective, scalable, and portable IoT data infrastructure for indoor environment sensing. arXiv. <https://arxiv.org/abs/2110.14042>
- Chandra, E. (2025). Monitoring the physical environmental humidity of the homes of pulmonary TB patients based on IoT (Internet of Things). *International Conference of Health Polytechnic Jambi*. <https://journal.poltekkesjambi.ac.id/index.php/ICoHPJ/article/view/1248>
- Departemen Kesehatan Republik Indonesia. (2000). Pedoman nasional penanggulangan tuberkulosis (5th ed.). Departemen Kesehatan RI.
- Ghebreyesus, T. A. (2022). Global tuberculosis report 2022. World Health Organization. <https://www.who.int/publications/i/item/9789240061729>
- Gutierrez, D. (2014). La tuberculosis infantil: Enfoque epidemiológico y nuevas alternativas de diagnóstico. *Revista Con-Ciencia*, 2(1), 45-53.
- Isworo, Y., et al. (2026). The relationship of home physical environmental conditions and pulmonary tuberculosis incidence. *Jurnal Kesehatan Lingkungan*, 23(1), 60-72. <https://ejournal.kesling-poltekkesbjm.com/index.php/JKL/article/download/1021/320>
- Kosmatos, E. A., Tselikas, N. D., & Boucouvalas, A. C. (2011). Integrating RFIDs and smart objects into a unified Internet of Things architecture. *Advances in Internet of Things*, 1(1), 5-12. <https://doi.org/10.4236/ait.2011.11002>
- Ma, H., Ding, J., Zhang, Z., Gao, Q., Liu, Q., Wang, G., Zhang, W., & Fan, X. (2024). Recent advances in graphene-based humidity sensors with the focus of structural design: A review. arXiv. <https://arxiv.org/abs/2410.02255>
- Madakam, S., Ramaswamy, R., & Tripathi, S. (2015). Internet of Things (IoT): A literature review. *Journal of Computer and Communications*, 3(5), 164-173. <https://doi.org/10.4236/jcc.2015.35021>

- Manaf, Z. A., Rahim, N. A., & Yusof, M. F. (2021). Housing environmental conditions and pulmonary tuberculosis transmission risk: A community-based study. *International Journal of Environmental Research and Public Health*, 18(9), 4762. <https://doi.org/10.3390/ijerph18094762>
- Mardanila, M., et al. (2025). Environmental risk factors and pulmonary tuberculosis transmission. *Epidemiological Journal of Indonesia*. <https://journal.paei.or.id/eji/article/download/47/50>
- Meliyanti, F., et al. (2026). A cross-sectional study of environmental determinants and pulmonary tuberculosis incidence. *Lentera Perawat Journal*. <https://jurnal.stikesalmaarif.ac.id/index.php/lenteraperawat/article/view/714/661>
- Muaz, F. (2014). Faktor-faktor yang mempengaruhi kejadian tuberkulosis paru basil tahan asam positif di Puskesmas wilayah Kecamatan Serang Kota Serang tahun 2014 [Undergraduate thesis, Universitas Islam Negeri Syarif Hidayatullah Jakarta].
- Ningsih, R., Pratama, D., & Lestari, Y. (2023). Indoor humidity and respiratory disease risks in tropical residential environments. *Journal of Environmental Health Research*, 33(1), 45–53. <https://doi.org/10.12928/jehr.v33i1.23145>
- Putri, N. A., Syafriani, S., & Hidayat, T. (2021). Relationship between room temperature and respiratory discomfort among pulmonary disease patients. *Kesmas: National Public Health Journal*, 16(3), 145–152. <https://doi.org/10.21109/kesmas.v16i3.4125>
- Rahman, F., Hidayani, W., & Saputra, R. (2022). Household ventilation and pulmonary tuberculosis transmission in densely populated areas. *Open Access Macedonian Journal of Medical Sciences*, 10(E), 1120–1126. <https://doi.org/10.3889/oamjms.2022.8734>
- Rahmatullah, S., et al. (2025). Environmental risk factors and tuberculosis transmission. *Global Health and Environmental Perspectives*. <https://riverstudies.id/index.php/ghep/article/view/105>
- Ratri, A. S., Poekoel, V. C., & Rumagit, A. M. (2021). Design of weather condition monitoring system based on Internet of Things. *Jurnal Teknik Informatika*, 17(1), 1–8. <https://doi.org/10.35793/jti.17.1.2021.32301>
- Ritonga, E. R., & Irawan, M. D. (2017). Sistem pakar diagnosa penyakit paru-paru. *Jurnal Nasional Informatika dan Teknologi Jaringan*, 2(1), 39–47.
- Sharma, P., Singh, R., & Verma, A. (2023). Real-time IoT-based environmental monitoring systems for healthcare applications. *Healthcare Technology Letters*, 10(2), 87–95. <https://doi.org/10.1049/htl2.12045>
- Simamora, A. M., Denih, A., & Suriansyah, M. I. (2025). Indoor air quality detection robot model based on the Internet of Things (IoT). *arXiv*. <https://arxiv.org/abs/2505.19600>
- World Health Organization. (2020). *Global tuberculosis report 2020*. World Health Organization. <https://www.who.int/publications/i/item/9789240013131>