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Design and Development of An Integrated Monitoring System for Nebulizer and Infusion for Lung Disease Patients Based on IoT

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ABSTRACT

This research develops an Internet of Things (IoT)-based monitoring system for nebulizers and infusion devices for patients with lung diseases, specifically Acute Respiratory Infections (ARI). The aim is to improve nursing efficiency and minimize the risk of complications due to delayed patient care by enabling remote monitoring and providing real-time information on the status of nebulizers and infusion devices via a website. The system is designed to stop the infusion fLow when the required amount is reached and to automatically turn off the nebulizer when there is no liquid. It uses an ESP32 microcontroller to control IR obstacle sensors, relays, and a servo motor for the infusion clamp, as well as an LCD display for digital information and feature displays. The system is also equipped with an alarm to indicate when the infusion liquid or nebulizer is depleted and a website to provide real-time status information to medical personnel. Testing shows that the system has a high accuracy of 98.7% and minimal error of approximately 1.82% in monitoring and controlling nebulizer and infusion fluids. In conclusion, the system successfully improves nursing efficiency and patient safety while reducing the workload of nurses through the automation of medical devices that were previously managed manually.

Keywords: *Internet of Things (IoT)*, *Nebulizers*, *Infusion*, *ESP32 Microcontroller*

1. INTRODUCTION

Lung and respiratory diseases have become one of the major global health problems. Pulmonary diseases are among the leading causes of morbidity and mortality worldwide, including Acute Respiratory Infections (ARI). ARI is divided into two types: upper ARI and lower ARI. Upper Acute Respiratory Infections are infections that occur in the respiratory tract above the larynx (voice box), including rhinitis, pharyngitis, tonsillitis, and sinusitis. Meanwhile, lower ARI includes infections that occur in the respiratory tract below the larynx, such as epiglottitis, bronchitis, bronchiolitis, and pneumonia [1].

This research aims to develop an IoT-based monitoring tool that integrates a nebulizer and infusion system to optimize the treatment of ARI patients. The tool is designed to assist nurses in monitoring the use of nebulizers and infusion systems in real-time, helping prevent complications such as respiratory irritation due to inhaling dry air from an empty nebulizer and preventing blood from flowing back into the infusion line due to delayed infusion bag replacement [2]. This development is expected to enhance medical staff performance by enabling fast and accurate decision-making.

The system consists of two main components, a nebulizer and an infusion system. In certain cases, the condition of the nebulizer can affect the quality of care. When the nebulizer runs empty, inhaling air without medication particles can worsen the patient's respiratory condition [3]. Therefore, the developed system is equipped with automatic nebulizer monitoring. Additionally, this tool is integrated with the infusion system to prevent blood clotting caused by delayed infusion replacement.

Previous research on similar tools, such as the journal "Compressor Nebulizer Modification by Adding a Timer and Drug Detector as a Time Limit for Drug Therapy in Asthma Patients" and "IoT-Based Infusion Fluid Drop Monitoring System," has produced devices with timers for drug administration via relays [4] and infusion monitoring using the TCRT5000 sensor connected to a website-based system. However, previous research had limitations, such as the absence of a real-time nebulizer monitoring system directly connected to nurses and the infusion monitoring website requiring manual refreshing to obtain updated data.

In this research, an IoT-based monitoring system will be developed using Firebase, enabling real-time data monitoring without the need for manual refreshing. This allows sensor information to be directly accessed by nurses in the central room. The system will help medical personnel ensure more optimal and efficient care for ARI patients, particularly in avoiding potential complications caused by equipment misuse.

2. LITERATURE REVIEW

2.1 Acute Respiratory Infection (ARI)

Acute Respiratory Infection (ARI) occurs when microorganisms enter and proliferate in the body, affecting the respiratory tract, which includes organs from the nose to the alveoli, as well as the adnexal organs such as the sinuses and middle ear cavities. ARI can last up to 14 days, although some cases may persist longer, and is typically caused by infectious agents transmitted from person to person. This infection is divided into upper ARI, often caused by viruses, and lower ARI, which can be caused by bacteria, viruses, or mycoplasma. In lower ARI, particularly pneumonia, clinical symptoms can be more severe, such as cyanosis, tachycardia, and dyspnea, leading to impaired gas exchange and ineffective breathing patterns [2]. Common symptoms of ARI include fever, cough, runny nose, and difficulty breathing, with more severe conditions, such as pneumonia, potentially causing thick secretions and disrupted physical activity.

2.2 Intravenous (IV) Therapy

Intravenous therapy is a method of delivering medication directly into the body through the bloodstream. It is the fastest way to distribute fluids and medications throughout the body because it utilizes the efficient cardiovascular system. An intravenous setup consists of an IV bag, drip chamber, drip tube, and roller clamp [5]. The drip chamber is connected to the IV bag at its opening. The roller clamp allows the regulation of the flow rate, measured in drops per unit of time.

The flow of IV fluids into the body must be controlled in the form of drops. The volume of IV fluid to be administered should be adjusted according to the required fluid volume per minute. When the fluid in the IV bag is depleted, it must be replaced with a new IV bag [6]. If a person loses a significant amount of bodily fluids and the IV is administered too quickly, it can lead to toxicity and seizures because brain cells experience changes in fluid concentration more rapidly than other cells. Additionally, rapid fluid administration can cause swelling of brain cells. Therefore, healthcare professionals must understand fluid and electrolyte needs and how to calculate IV drops quickly and accurately [6].

The calculation of IV drops must be done correctly. There are two types of IV sets: macro, which is typically used for intravenous therapy in adults and children for rehydration therapy, and micro, which is usually used for pediatric and infant patients but can also be used in adults with specific conditions such as chronic kidney failure. Below is a simple way to calculate IV drops per minute:

There are two options frequently used by healthcare providers depending on the diagnosis and dosage prescribed by the doctor:

1. Macro: 20 drops/min for adults
2. Micro: 60 drops/min for children

The simple formula is:

$$\frac{Amount\ of\ IV\ fluid(ml)\ x\ (Drop\ factor\ for\ adults)}{tPrescribed\ drops\ x\ 60(minutes)}$$

Example:

For 0.9% NaCl solution, 500 cc, with a drop factor of 20 drops per minute. How many hours will it take for the fluid to be completely infused?

Given:

1. Amount of fluid = 500 ml
2. Drop factor = 20 drops
3. Drops per minute (DPM) = 20 drops/min

Insert these values into the formula:

$$Time\ (minutes) =\ 20drops\ per\ minute\ 500ml\ \times\ 20drops$$
$$=\ 10000/20\ =\ 500minutes$$

Convert the time from minutes to hours:

$$Time\ (hours) = 60minutes/hour500minutes = 8.33hours$$

Thus, 500 cc of 0.9% NaCl solution will take approximately 8.33 hours to be fully infused.

3. METHODS

Figure 1 shows the block diagram of a lung disease patient monitoring system based on the Internet of Things (IoT), consisting of three main components: Input, Process, and Output.

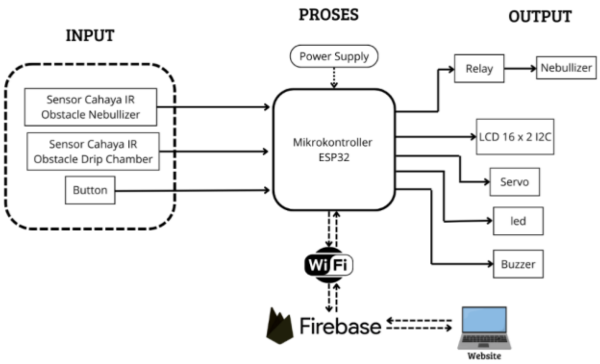


Figure 1. System Block Diagram

The Input section includes an IR Light sensor, which functions to detect the fluid levels in the nebulizer and drip chamber, as well as a button for manual input. The data obtained from these sensors is sent to the ESP32 microcontroller, which acts as the data processing center. The microcontroller processes the information received from the sensors and controls various Output components such as a relay to control the nebulizer, a 16x2 I2C LCD to display system status, a servo to stop the infusion fluid flow, an LED as a visual indicator, and a buzzer as an alarm. Additionally, the ESP32 is equipped with a WiFi module to send real-time data to Firebase, enabling remote monitoring by healthcare workers via a website. This system enhances the efficiency of medical staff and patient safety through real-time information on the status of the nebulizer and infusion system.

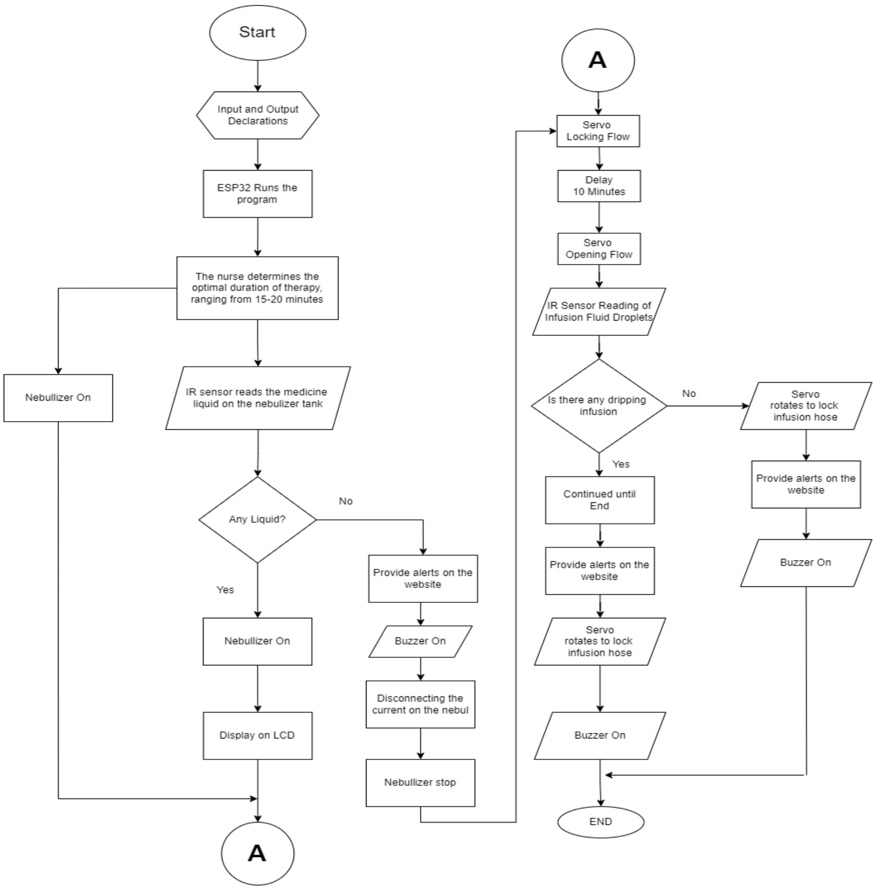


Figure 2. System's Flowchart

Figure 2 shows the system's flowchart, illustrating the workflow of the IoT-based patient monitoring system. The process begins with the declaration of input and output on the ESP32 microcontroller, which will control the sensors and actuators such as the servo and buzzer. After the declaration, based on the clinical diagnosis, the therapy duration is set, typically ranging from 15 to 20 minutes. The nebulizer is then activated, and the IR sensor monitors the fluid level in the nebulizer. If the sensor detects fluid, the nebulizer remains on, and information is displayed on the LCD screen. However, if the fluid runs out, the system issues a warning via the website, activates the buzzer, and cuts power to the nebulizer. Following this, the servo locks the infusion flow, reopening it after a 10-minute delay. The IR sensor in the infusion system checks for fluid drops. If flow is detected, the process continues until the fluid is depleted, and the system sends a warning. If no drops are detected while fluid is still present, the servo locks the tube, activates the buzzer, and the system issues a warning on the website for further action.

4. RESULTS AND DISCUSSION

4.1 The result of hardware development

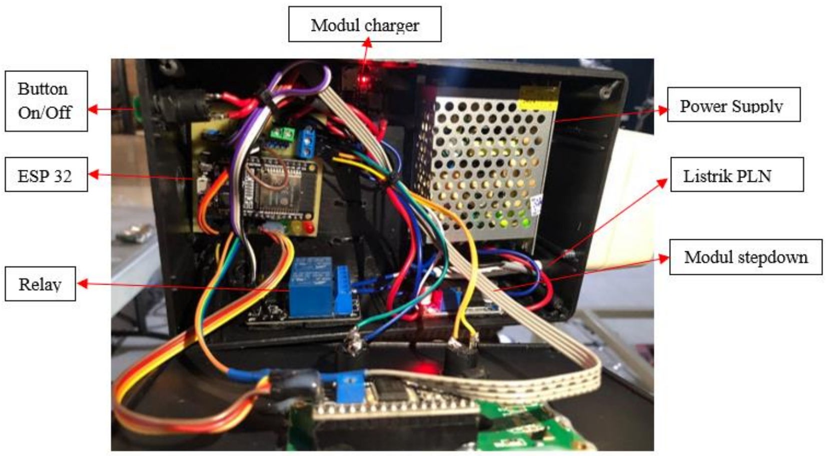


Figure 3. Control Box

Figure 3 shows the interior of the control box, which serves as the control center for the nebulizer and infusion monitoring system. The key components visible include a charger module for charging the battery, a power supply that converts AC voltage from the main power grid into the appropriate DC voltage, a step-down module to adjust the voltage, an ESP32 as the main microcontroller, a relay to control the nebulizer's timer duration, and an on/off button to power the system on or off.

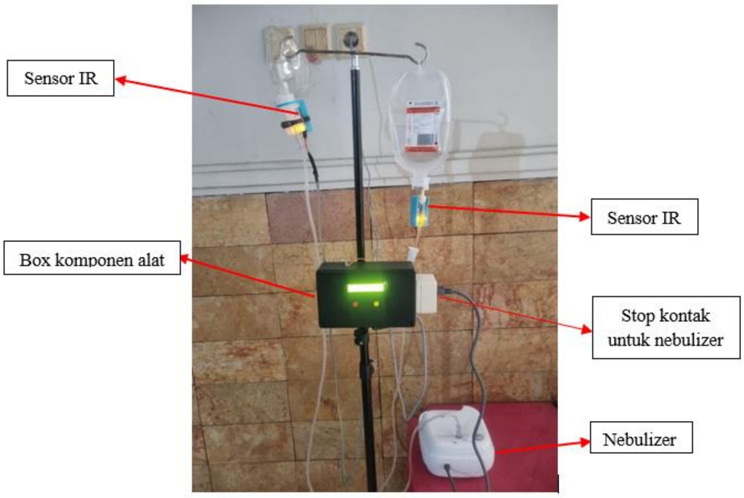


Figure 4. Complete System

Figure 4 shows the complete system setup with the IR sensors placed on the nebulizer's medication tank and the infusion drip chamber to detect fluid levels. Additionally, the image highlights the component control box that houses the main controls, the power socket connected to the nebulizer, and the nebulizer itself, which is used to convert liquid medication into vapor as part of patient therapy. This figure also illustrates how the system functions in detecting the fluid conditions of both the infusion and nebulizer, providing efficient remote monitoring.

4.2 The result of website development

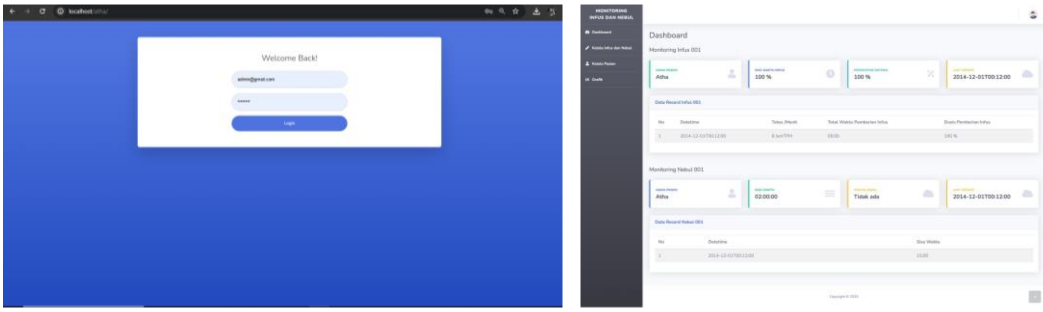


Figure 5. Login page and the Monitoring Dashboard page

Figure 5 shows the Login page and the monitoring dashboard page. The Login page ensures access is restricted to authorized users, while the dashboard displays the real-time status of the nebulizer and infusion, retrieved from Firebase.

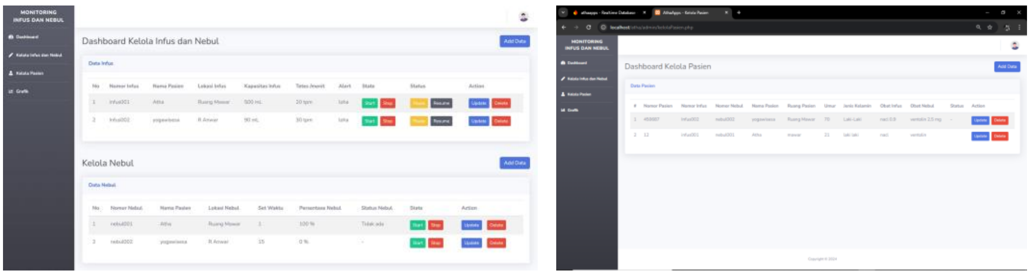


Figure 6. Manage Infusion, Nebulizer, and Patient Management pages

Figure 6 shows the Manage Infusion, Nebulizer, and Patient Management pages. On this page, nurses can manage information related to the devices and patient data, such as dosage settings, device numbers, and patient status, to ensure accurate medication administration.

Figure 6. Monitoring Graph Page

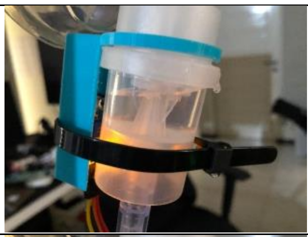
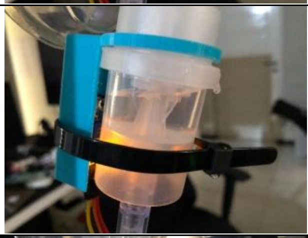
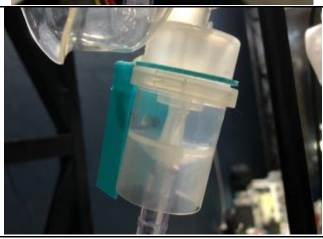
Figure 7 shows the monitoring graph page, which displays data visualizations in graphical form. This feature helps nurses analyze data more easily and supports decision-making based on real-time data from Firebase.

4.3 The result of IR Obstacle Sensor functionality testing

1. Functional Testing of the IR Sensor on the Nebulizer

The test was conducted to ensure that the IR sensor can accurately and responsively detect the presence or absence of liquid in the nebulizer tank.

Table 1. IR Sensor Testing on the Nebulizer

Experiment	Image	Tank Condition	Sensor Output	Reliability
1		Liquid present	1	100%
2		Liquid present	1	100%
3		No liquid	0	100%

The test results showed that the sensor functioned according to specifications, providing a logic output of 1 when liquid was present and a logic output of 0 when no liquid was detected. From the three trials conducted, the sensor proved to have 100% reliability in detecting the nebulizer's liquid condition, making it dependable for controlling medication delivery in the nebulizer.

2. Functional Testing of the IR Sensor on the Infusion:

The testing of the IR sensor in the infusion drip chamber aimed to measure the accuracy in detecting infusion fluid drops at settings of 20 DPM and 30 DPM.

Table 2. IR Sensor Testing on the Infusion

Experiment	Drops/Minute	IR Sensor Reading	Sensor Result	Manual Calculation Difference	Error
1	20	20	1	0 drops/minute	0%
2	20	20	1	0 drops/minute	0%
3	20	20	1	0 drops/minute	0%
4	20	20	1	0 drops/minute	0%
5	20	19	1	0 drops/minute	5%
6	30	30	1	0 drops/minute	0%
7	30	28	1	2 drops/minute	6.6%
8	30	30	1	0 drops/minute	0%
9	30	28	1	2 drops/minute	6.6%
10	30	30	1	0 drops/minute	0%
		Average error		1.82%	

The test results showed an average error rate of 1.82% in reading infusion drops and an average accuracy of 98.7% based on manual calculations using a stopwatch.

Table 3. Experiment Table over 10 Minutes

No	Command				Sensor Reading										Manual Calculation Difference (Drops)		Accuracy (%)
					Drops/Minute												
	Volume	Time (hours)	Drops/ Minute	Drops/Second	Minute										Drops	Time (seconds)	
					1	2	3	4	5	6	7	8	9	10			
1	500 ml	8.3 hours	20 TPM	3	20	20	20	19	20	20	20	20	20	20	1	3	99,5%
2	500 ml	8.3 hours	20 TPM	3	20	20	20	20	20	19	20	20	18	20	3	9	98,5%
3	500 ml	8.3 hours	20 TPM	3	20	19	20	20	20	20	20	20	19	20	2	6	99%
4	500 ml	8.3 hours	20 TPM	3	20	20	20	20	20	19	20	20	20	19	2	6	99%
5	500 ml	8.3 hours	20 TPM	3	18	20	19	20	20	20	20	20	19	20	4	12	98%
6	500 ml	5.5 hours	30 TPM	2	30	30	30	29	30	30	29	30	30	28	4	8	98,6%
7	500 ml	5.5 hours	30 TPM	2	30	29	30	30	28	30	28	30	30	30	5	10	98.3%

Average Accuracy	98,7%

The sensor demonstrated consistent performance in reading drops, with an average drop-per-minute difference of 2.5 drops at 20 DPM and 4.5 drops at 30 DPM, along with a time difference of 7-9 seconds. This sensor proved to be reliable in monitoring the infusion flow.

4.4 Test Results for Automation and Control

1. Relay Testing Results on the Nebulizer

The relay testing on the nebulizer was conducted to ensure an appropriate response to digital logic control signals.

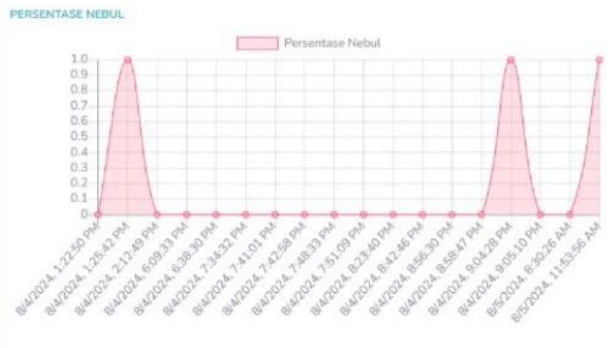


Figure 7. Relay Testing

Based on the test results, the relay operated according to the specifications. When a High logic signal was applied, the relay successfully activated the nebulizer by supplying a stable voltage of 2.32-2.33 V. Conversely, when a Low logic signal was applied, the relay successfully cut off the power supply with a voltage of 0 V, indicating that the nebulizer was turned off. These results demonstrate that the relay functions reliably to control the ON and OFF states of the nebulizer according to the control signals provided.

2. Servo Motor Testing Results

Figure 8. Servo Motor Testing

The servo motor was tested to measure its accuracy and precision in controlling the degree of movement used to stop the infusion flow. A position of 0° indicates the servo motor is in the central position, while various other angles are used to control the infusion flow. Based on the test results, the servo motor demonstrated a high level of accuracy with no measurement errors (0% error). At 0°, 10°, and 20° positions, the infusion flow continued, while at 30°, the infusion flow was successfully stopped. This test confirms that the servo motor operates accurately and precisely in regulating the infusion flow.

CONCLUSION

Based on the research conducted, the integrated nebulizer and infusion monitoring system for lung disease patients was successfully designed with real-time access capabilities via a website. This system enhances patient safety by detecting the fluid condition in the nebulizer using an IR obstacle sensor with a 100% success rate and detecting infusion fluid drops with an average error of 1.82%. The servo motor was able to accurately stop the infusion flow with 0% error. The overall system testing demonstrated that the automation and control accuracy functioned well, achieving a system accuracy of 98.7% and providing reliable performance in web-based medical applications.

REFERENCES

[1] M. Gonzales *et al.*, "Pneumonia is the Leading Cause of Death from Respiratory Diseases at High Altitude In La Paz, Bolivia," *Sci. Res. e-Library*, pp. 109–116, 2024.

[2] S. A. Sondakh, F. Onibala, and M. Nurmansyah, "Pengaruh Pemberian Nebulisasi Terhadap Frekuensi Pernafasan Pada Pasien Gangguan Saluran Pernafasan," *J. Keperawatan*, vol. 8, no. 1, pp. 75–82, 2020.

[3] S. K. Katiyar *et al.*, "Indian Guidelines on nebulization therapy," *indian J. Tuberc.*, vol. 69, pp. S1–S191, 2022.

[4] G. R. Muhammad, A. Allenidekania, and Y. Rustina, "Terapi Nebulasi pada Pasien Anak dengan Bronkiolitis," *J. Telenursing*, vol. 6, no. 1, pp. 1689–1696, 2024.

[5] A. F. Shinta, "Rancang bangun sistem monitoring volume dan laju tetes infus pasien menggunakan NodeMCU Esp8266," *Skripsi Univ. Negeri Semarang*, vol. 500, 2020.

[6] T. P. Vidanti and D. L. C. Pardede, "SISTEM PEMANTAU KETERSEDIAAN CAIRAN INFUS BERBASIS IoT," in *Prosiding Seminar SeNTIK*, 2022, pp. 105–111.