Automatic Usage of IoT-based Dehumidifiers in High-humidity Spaces

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***Abstract*—Students are arriving in Malang City more significantly yearly due to the city's growing number of colleges and universities. The growing need for student boarding homes is partially compensated by changes in the purpose of residential houses into boarding houses, and some ignore the health factors of inhabitants, such as humidity in rooms. The purpose of this study is to monitor the temperature and humidity of several boarding rooms that are suspected of having above average humidity. Rooms with high humidity should incorporate an IoT-based dehumidifier to minimize it. This study introduces an innovative application of IoT-based dehumidifiers specifically designed to optimize air quality in high-humidity boarding houses. By leveraging smart breakers for automated control, the system ensures energy efficiency and consistent indoor humidity levels, distinguishing it from conventional dehumidification solutions. This study employed a qualitative method with a design thinking approach. The temperature in the three boarding rooms was pretty consistent and somewhat over normal, according to data acquired from monitoring the three rooms. Temperature fluctuations are typically stable and not very significant. Meanwhile, the humidity in the three rooms was relatively high, ranging from 6.85% to 15.1% over the average. The author suggests installing a dehumidifier on a smart breaker to reduce high humidity. The tool will activate automatically if the humidity in the room exceeds 60%, which is the upper average level, and will switch off automatically if the humidity is below 60%.**

Keywords—Boarding House, Dehumidifier, Humidity, Internet of Things

I. INTRODUCTION

Malang City is known as a city of education because it is home to numerous schools and institutions [1]. The demand for housing for students from outside Malang grows yearly [2]. Boarding house accommodations are used for pupils and students' housing. Boarding house owners have responded to the growing demand for boarding rooms by transforming regular private homes into boarding houses [3]. Transitioning from a typical residence to a boarding house rarely includes sufficient ventilation and lighting evaluations. As a result, some boarding houses are considered unhealthy for people to stay in. As a result, the lighting and ventilation systems must be monitored.

A ventilation system attempts to replace old air with new air in a room using artificial or natural ventilation in the best possible configuration to accomplish indoor health and comfort goals [4, 5]. Natural and artificial ventilation are the two methods of air conditioning. Singlesided ventilation systems, cross ventilation, and stack effect ventilation can all provide natural ventilation [6–9]. Apart from natural ventilation, there is mechanical ventilation, a type of ventilation that is easy to control manually by humans or automatically [10]. The size of a room's ventilation system can be determined by its volume. The air quality in a space will be healthier and better if it has a good ventilation system [11]. Physical and chemical factors can impact the Indoor Air Quality (IAQ) [12]. Physical factors influencing IAQ are temperature, air humidity, and air velocity. On the other hand, the mechanical factors that influence IAQ are CO, CO2, HCHO, TVOC, PM 2.5 and PM 10 [13].

The primary challenge addressed in this study is the high humidity levels in boarding houses, which traditional ventilation systems fail to manage effectively. Unlike existing solutions that rely on manual adjustments, our IoT-based dehumidification system offers automated, real-time control, ensuring consistent indoor air quality without user intervention.

This research aims to analyze boarding rooms by monitoring temperature and humidity using measuring devices based on the Internet of Things (IoT). By knowing the condition of a room, boarding house owners and users can assess whether there are any deficiencies in the room. If problems occur in the boarding room, residents can take preventive action to avoid situations that endanger the safety of the residents in the long term.

A. Related work

Despite various studies on ventilation and air quality management, there is limited research on the integration of IoT-based automated dehumidifiers in residential settings, particularly in boarding houses, to maintain optimal humidity levels. This study addresses this gap by proposing a smart dehumidification system tailored for high-humidity environments. Previous works have explored the use of natural and mechanical ventilation for improving indoor air quality [4, 5], but these approaches often lack the automation and real-time responsiveness provided by IoT-based solutions

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[10, 13]. This study builds on these foundations by incorporating smart technology to enhance efficiency and user convenience.

II. Methodology

This research employs a design thinking approach, starting with empathy to understand the problems faced by boarding house residents. This is followed by defining the problem, ideating solutions, prototyping the smart dehumidification system, and testing its effectiveness. Data on temperature and humidity were collected using IoT sensors and analyzed using statistical tools.

The author began with the phenomenon that Malang's boarding houses are expanding quickly due to the city's growing student and college population. This stage is empathy, which is the initial stage in design thinking. Defining a problem that arises is the next step in the design thinking process. From the existing problems, the author goes further to the next step to find a solution. This stage, which is known as ideate, is the third in the design thinking process. If a solution is discovered, prototyping must be used as a practical stage in problem-solving. This prototyping must be tested to determine whether it solves the problem. The design thinking process ends with the testing phase.

In this research, the research object was in a boarding house in Malang City, East Java, Indonesia. The author used smart temperature and humidity in this research, which has a data logging feature. This device will send data every hour to the cloud server. The author also installed the Smart Life application on an Android smartphone to monitor room conditions and ensure the equipment worked during the research. Apart from that, using the same software, the author pulls logging data from the cloud in the form of a spreadsheet file (.xls). Temperature and humidity measurement datasets can be accessed through this link https://doi.org/10.7910/DVN/37QCBT. Next, the author processed the data in graphic form using Microsoft Excel software.

III. Result and Discussion

A. Determine the Research Object

The research object is a boarding house that is integrated with the owner's house, also called the main house. The author took three bedroom samples, namely a bedroom of the owner's child in the main house, a room on the 1st floor of the boarding house, and a bedroom on the 2nd floor. Samples were taken on different days in each room. We labeled the owner's child's bedroom as room A, and data collection was carried out on 7-9 January 2023. The following measurements were on 9-11 January 2023 in Room B, located in a room on the 1st floor of the boarding house. We took the third measurement on 12-14 January 2023 in the third boarding room on the 2nd floor of the boarding house and labeled it room C.

Bedroom A on the site has an area of 10.5m2, with a length of 3.5m and a width of 3m. This bedroom has a dead window with an area of 4.56m2 or 2.4m wide and 1.9m long. The condition of the interior aspects in this bedroom area includes the ceiling and floor areas, which do not have problems, but the wall areas have problems. The problem with walls is that the walls are damp, giving rise to mold spots caused by water absorption from the ground. The layout plan for bedroom A as represented in Fig. 1.

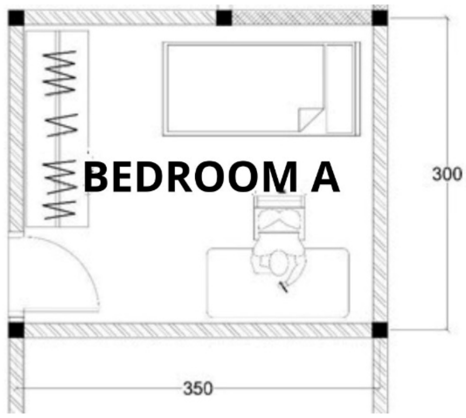

Fig. 1. *Layout plan of Bedroom A*

Bedroom number 115 in boarding house two on the site has an area of 9m2, with a length of 3m and a width of 3m. This bedroom has a window with an area of 1.6m2 or 0.6m wide and 1m long. The condition of the interior aspects of the bedroom area, including the ceiling, floor, and walls, has no problems. However, the problem lies in the air circulation in the room, which tends to be stuffy, thus affecting the user's comfort, health, and psychological conditions. Fig. 3 represents the layout plan and position of rooms on the 1st floor.

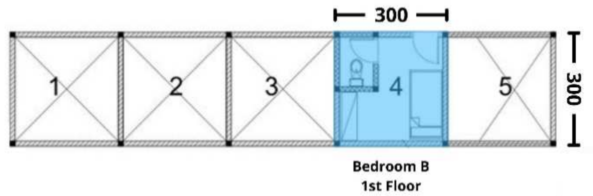

Fig. 2. *Layout plan of Bedroom B and its location in the first floor*

Located on the 2nd floor of the building, bedroom number 215 in boarding house two on the site has an area of 9m2, with a length of 3m and a width of 3m. This room is close to the foyer area, which has an open space concept (the foyer area does not have a roof), so the room area may be directly exposed to heat from the sun, which can affect the temperature and humidity of the room. This bedroom has a window with an area of 1.6m2 or 0.6m wide and 1m long. The condition of the interior aspects of the bedroom area, including the ceiling, floor, and wall areas, has no problems. However, the problem lies in the air circulation in the room, which tends to be stuffy, thus affecting the user's comfort, health, and psychology. The layout plan for Bedroom C looks like in Fig. 3.

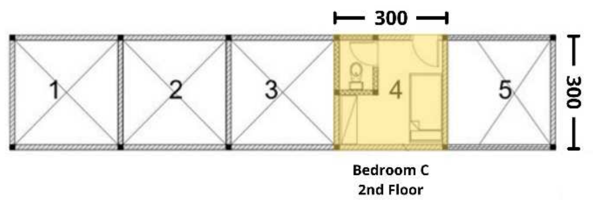

Fig. 3. *The position and the layout plan of Bedroom C in the second floor*

B. Data Collection

The author used a digital temperature and humidity monitoring tool to measure the room based on the Internet of Things (IoT). This device has a data logging feature, which will send temperature and humidity data every hour via the internet. Because this tool is IoT-based, the author can also access temperature and humidity remotely via a cellphone application. In this research, the author used Smart Life, which runs on the Android operating system.

Data collection in the three rooms was carried out on different days and at different times. In bedroom A, data was collected on 7-9 January 2023. On the same date at a different time, namely on 9-11 January 2023, measurements were taken in bedroom B. We took the third measurement in the Bedroom C boarding room on 12-14 January. The details of the date and time of measurement can be seen in Table 1

TABLE I. ROOM NAME, DATE, AND TIME OF DATA COLLECTION

Room's name	Date	Time
Bedroom A	7th January 2023	15:00 - 24.00
Bedroom A	8th January 2023	01:00 - 24:00
Bedroom A	9th January 2023	01:00 - 15:00
Bedroom B	9th January 2023	21:00 – 24:00
Bedroom B	10th January 2023	01:00 – 24:00
Bedroom B	11th January 2023	01:00 – 21:00
Bedroom C	12th January 2023	22:00 – 24:00
Bedroom C	13th January 2023	01:00 – 24:00
Bedroom C	14th January 2023	01:00 – 10:00

C. Data Collection

The measurement results from the three rooms show different temperature and humidity results between day and night. Differences in measurement results between rooms also vary from one room to another. Various factors, such as different room positions, window placement, window area, and window type, cause it. Fig. 4 represents a temperature and humidity measurement results graph in Bedroom A.

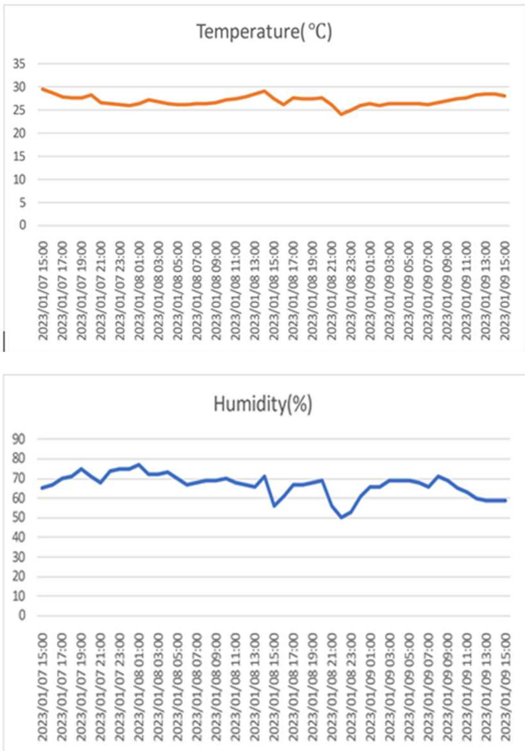

Fig. 4. *Temperature and humidity in Bedroom A*

Based on the image above, it can be seen that measurements in bedroom A began to be recorded on January 7, 2023, at 15.00, with a temperature of 29.5°C and humidity of 65%. The temperature touched its lowest figure for two days, namely 24.2°C on January 8, 2023, at 22.00. It is due to the influence of the Air Conditioner (AC) used at 22.00 by the user, thus affecting the room humidity, which decreased by 15°C from the initial humidity, which was 50°C. The temperature reached the highest figure, namely 29.5°C on January 7, 2023, at 15.00 WIB, so the humidity obtained was 65%. It is known that at 15.00, the weather is hot and hot, affecting the bedroom temperature.

The average ($\bar{x}$) temperature on 7-9 January 2023 is 27.05°C. Meanwhile, the average humidity on January 7-9, 2023, is 66.85%. Based on the average humidity results ($\bar{x}$), it can be concluded that the room humidity is relatively higher when compared to the standard, which is 6.85% different. The standard humidity for a room is 40% -60% [14]. High humidity in a room can affect the comfort of the occupants and affect their health in the long term.

After the measurements in Bedroom A were completed, the author continued to take measurements in Bedroom B. The locations of bedrooms A and B were both on the 1st floor. Temperature and humidity measurements in Bedroom B began on January 10, 2023, at 24.00 WIB, with a temperature of 26.3°C and humidity of 74%, as represented in Fig. 5. During two days of data collection, the temperature reached its lowest figure, namely 26.2°C in the early morning to morning on January 10 and 11 2023. Meanwhile, from afternoon to evening, the temperature increased by 26.5° C on January 10 and 26.6°C on January 11. The increase in room temperature was not significant on both dates. The rise and fall of temperature is relatively stable in the room. The rising graph shows no change of up to 1 degree Celsius.

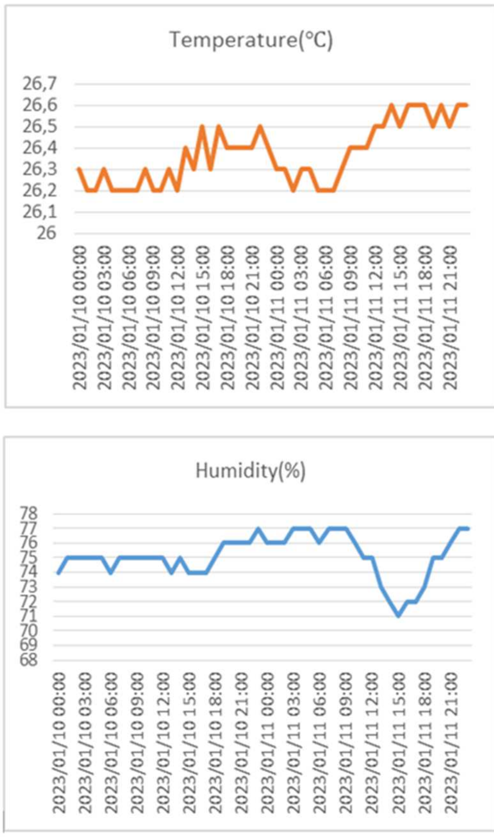

Fig. 5. *Temperature and humidity in Bedroom B*

Based on the graph data above, the lowest humidity of 71% occurred on January 11, 2023, at 15.00 WIB, with a temperature of 26.5 °C. This lowest humidity has a comparison that is not too far from the initial humidity and only has a difference of 3%. Humidity reaches the highest figure at 77% at various times and temperatures. Based on the average humidity results ($\bar{x}$), it can be concluded that the room humidity is relatively high compared to the standard, namely 15.1% percent higher. This condition can affect the health of residents in the long term. Also, too humid conditions will damage furniture, especially those made from plywood or particle board.

The third measurement was carried out in Bedroom C, which is located on the 2nd floor, on January 12 and 13, 2023. Data begins on January 12, 2023, at 24.00 WIB, with a temperature of 26.5°C and humidity of 76%. During two days of data collection, the temperature touched the lowest figure, namely 26.2°C at 05.00 to 06.00 WIB, January 12, 2023. This significant figure was not caused by anything in particular because the temperature data was relatively constant, so the temperature drop was not too significant. , which is 0.3°C from the initial temperature. On the other hand, the temperature touched the highest figure, namely 29.2°C at 15.00 WIB, January 13, 2023, as seen in Fig. 6

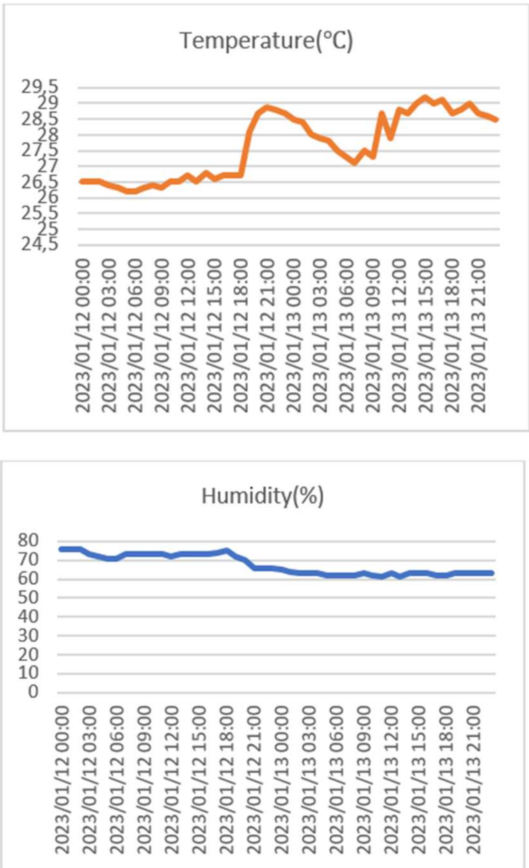

Fig. 6. *Temperature and humidity in Bedroom B*

Meanwhile, based on the data that has been taken, humidity reached its highest figure at 76% from 24.00 to 02.00 WIB, January 12, 2023. The lowest humidity at 61% occurred on January 13, 2023, at 13.00 WIB, with a temperature of 28.7 °C. This lowest humidity is quite far from the initial humidity and has a difference of 15%. It is because the temperature on different days and times dramatically influences the temperature, so it also impacts the humidity in the room.

The average ($\bar{x}$) temperature on January 10-11 2023 is 27.6°C. Meanwhile, the average ($\bar{x}$) humidity on January 10-11, 2023 is 67.4%. Based on the average humidity results ($\bar{x}$), it can be concluded that the room humidity is relatively high when compared to the standard.

D. Problem Solving to Address Space Issues

The temperature in the three research objects is relatively stable, but the problem is that the air humidity is above average. Based on the problem, location, and analysis results, a solution was found that could make things easier for the occupants, namely by applying a dehumidifier with the help of smart breaker technology. The dehumidifier itself removes moisture from the air in the room to make it more comfortable. The system itself works by moist air entering the dehumidifier and passing through the coolant cooled coil, causing the moisture in the air to condense on the coil in the machine. Through this, the moisture will be collected in a container for disposal while the air passes through a warm condenser or heat recovery coil. The slightly warm air from the dehumidifier is dry and warm [15].

This dehumidifier will then be combined with a smart breaker device, which, if the input data orders the relay to be on, the smart breaker will activate the dehumidifier. On the other hand, if the relay is off, it will turn off the dehumidifier. This dehumidifier, combined with a smart breaker, has a system where when the humidity reaches more than the maximum humidity (60%), the smart breaker can automatically turn on the dehumidifier; meanwhile, if the humidity in a room is in neutral or ideal conditions (40%-60 %), then the smart breaker automatically turns off the dehumidifier. With the help of a smart breaker, the dehumidifier becomes more energy efficient, and indoor humidity is controlled.

The effectiveness of the proposed IoT-based dehumidification system was validated through a series of experiments in different boarding house rooms. The system consistently maintained humidity levels within the optimal range, demonstrating superior performance compared to traditional manual dehumidifiers.

E. Contribution and Threats to Validity

The specific contribution of this paper is the development of an IoT-based smart dehumidification system that offers automated control of humidity levels in high-humidity residential settings, significantly improving indoor air quality and energy efficiency. Potential threats to the validity of this study include the limited sample size and the specific environmental conditions of the boarding houses studied. Future research should consider larger sample sizes and varied settings to validate the generalizability of the results.

IV. CONCLUSION

The measurements of temperature and humidity in the three rooms revealed that there were issues with room humidity. According to our research on the humidity levels of the three bedrooms, the average bedroom in the first location had a humidity level of 6.85% higher than the optimal humidity threshold. The second location also had a higher average humidity of 15.1% than the optimal norm. Furthermore, the third location has an average humidity 7.4%

higher than the optimal humidity standard. This study presents a novel IoT-based solution for controlling humidity in residential settings, demonstrating its effectiveness through empirical testing. Compared to recent works [4, 10], our system offers enhanced automation and energy efficiency, contributing significantly to the field of indoor air quality management.

According to these findings, the average humidity level in the bedrooms we studied is relatively high compared to optimal humidity levels. As a result, the solution to this problem is to link a dehumidifier to a smart breaker. Smart temperature and humidity monitor the temperature and humidity in the room. If the humidity in the room rises over the average, the dehumidifier will activate automatically. When the humidity level in the room reaches an acceptable level, the dehumidifier will turn off automatically.

AUTHOR CONTRIBUTORSHIP

Anastasya Krisna Putri: Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Resources, Software, Visualization, Writing – Original Draft Preparation, Writing –Review and Editing; Andi Pramono: Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Resources, Validation, Funding Acquisition, Project Administration, Supervision, Resources, Validation, Writing –Review and Editing; Nadya Anthony: Data Curation, Formal Analysis, Investigation; Muhamad Julfan Firnandi: Data Curation, Investigation, Software, Visualization; Felix Franklin Zebua: Data Curation, Writing – Original Draft Preparation; Ida Bagus Ananta Wijaya: Conceptualization, Methodology.

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