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Development of Real-Time Air Quality Monitoring Device with Graphical User Interface (GUI)

Siti Zaimah Atiqah Zaherman[1], Mohd Arif Rosli [1]*, Amirul Syafiq Sadun[1]

[1] *Department of Civil Engineering Technology, Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, 84600 Pagoh, Johor, MALAYSIA*

*Corresponding Author: mohdarif@uthm.edu.my
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Abstract

Air is one of the most significant elements of the environment humans live in. Rapid industrialization, urbanization, and commercial activity are harming the once-beautiful natural environment. The "digital revolution" is bringing significant changes to building design concepts, transforming design culture, and increasing the demand for a renewed link between technology and the environment. The biggest, heaviest, and most costly characteristics of conventional monitoring equipment, such as the E-Sampler tool, are their disadvantages. This study aims to develop a real-time air quality monitoring device with a Graphical User Interface (GUI) to monitor ambient air quality and test its functionality in an indoor location at UTHM Pagoh. The new device will upload data to a database accessible via LabVIEW software, incorporating ten characteristics: humidity, temperature, light intensity, air pressure, carbon dioxide, carbon monoxide, alcohol, acetone, ammonia, and toluene. Two tools will be used simultaneously for testing: the new device operating for 24 hours and the Delta Ohm Datalogger (HD37AB1347) operating for 7 hours. Testing will be conducted in two indoor laboratories: Student Residential College A1 Universiti Tun Hussein Onn, Malaysia, Manufacturing and Assembly Technology Laboratory (Block B), and Concrete Technology Laboratory (Block F). The results and analysis will focus on the functionality of the new device by comparing data from the newly developed IoT device with traditional indoor air quality devices across different locations. The study will conclude with findings and recommendations for future improvements in air quality monitoring technology.

1. Introduction

The study highlights the critical role of air quality in human health. Air, composed of essential gases such as oxygen (O_2), nitrogen (N), and carbon monoxide (CO), becomes hazardous when polluted with particulate matter (PM), nitrogen dioxide (NO_2), and sulphur dioxide (SO_2). According to the World Health Organization (WHO), air pollution is responsible for approximately seven million deaths annually, affecting both indoor and outdoor environments [1]. Pollutants exacerbate respiratory health issues and impair visibility, underscoring the urgency for effective air quality monitoring systems. The pressing need for strategies and procedures for data collection and analysis is vital to mitigate the health risks associated with air pollution [2]. The lack of efficient real-time monitoring systems for indoor air quality presents a significant challenge. Traditional monitoring equipment, such as the E-Sampler tool, is often bulky, expensive, and limited in scope [3]. This study seeks to address these limitations by developing a real-time air quality monitoring device equipped with a

Graphical User Interface (GUI). The innovative device integrates sensors to measure ten parameters: humidity, temperature, light intensity, air pressure, carbon dioxide (CO_2), carbon monoxide (CO), alcohol, acetone, ammonia, and toluene. This comprehensive approach ensures a more accurate and holistic understanding of indoor air quality. The collected data will be uploaded to a database accessible through LabVIEW software, providing users with immediate insights and enabling prompt action to ensure a safe indoor environment. In the broader context, air pollution originates from various sources, including industrial activities, vehicle emissions, and natural events. Indoor air pollution, specifically, arises from household activities, building materials, and external pollutants entering indoor spaces [4]. These sources contribute to a complex mix of contaminants that can significantly affect human health. The proposed solution, by integrating advanced sensors, aims to detect and measure these pollutants accurately, thereby facilitating effective monitoring and control. The use of real-time monitoring systems and the Internet of Things (IoT) enhances the capability to track and manage air quality data efficiently [5]. Integrating these technologies with user-friendly interfaces like LabVIEW demonstrates the potential for significant advancements in air quality monitoring [6].

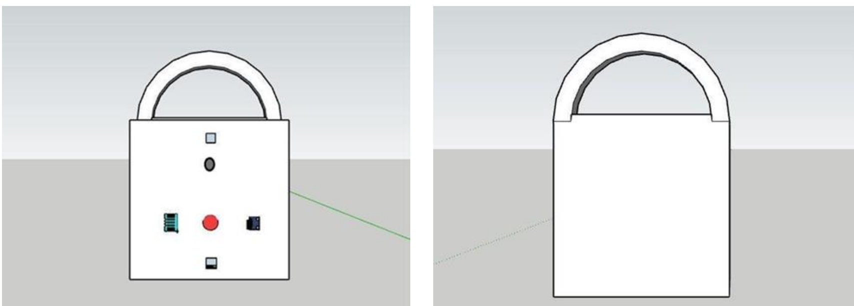
The application of real-time monitoring systems is particularly crucial in environments such as homes, schools, and workplaces, where individuals spend a significant portion of their time. Poor indoor air quality can lead to a range of health issues, from minor irritations to serious respiratory conditions. By continuously monitoring indoor environments, the proposed system can alert users to dangerous levels of pollutants and suggest timely interventions [7]. This proactive approach to managing air quality not only helps in maintaining a healthy living environment but also reduces the long-term health costs associated with exposure to pollutants. Moreover, the study explores the advantages of using the Laboratory Virtual Instrument Engineering Workbench (LabVIEW) for air quality monitoring. LabVIEW offers a versatile platform for developing custom monitoring solutions that can interface with various sensors and data acquisition systems. Its flexibility and scalability make it an ideal choice for implementing comprehensive air quality monitoring systems. By leveraging IoT capabilities and advanced data analytics, the study aims to create a robust framework for real-time monitoring and analysis. This approach not only contributes to improved health outcomes but also supports proactive environmental management and policymaking [8].

The integration of IoT technologies into air quality monitoring systems represents a significant technological advancement. IoT-enabled sensors can collect vast amounts of data from multiple locations in real-time, providing a detailed and dynamic picture of indoor air quality. This data can be analyzed to identify trends, predict future air quality issues, and develop targeted interventions. The use of LabVIEW in this context enhances the system's capability to process and visualize data, making it accessible and actionable for users. The combination of real-time data collection, advanced analytics, and user-friendly interfaces ensures that the proposed system will be an effective tool in the fight against air pollution. Ultimately, this study underscores the importance of continuous innovation in air quality monitoring technologies. As air pollution continues to pose significant challenges to public health, the development of advanced monitoring systems is essential. By providing real-time data and actionable insights, these systems empower individuals and organizations to take proactive measures to improve air quality. The proposed system, with its comprehensive sensor array and robust data processing capabilities, represents a significant step forward in achieving cleaner, healthier indoor environments. The study's findings highlight the potential for technology to address one of the most pressing environmental health issues of our time.

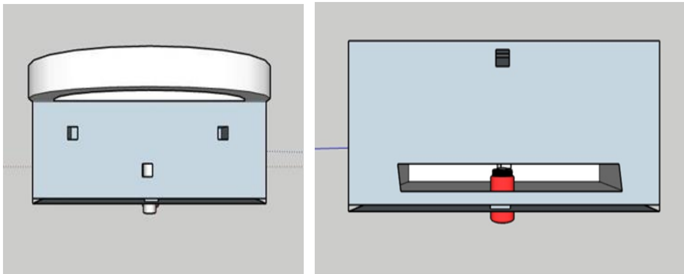
2. Methodology

2.1 Design Casing

The device has a cube shape with a spot to hang it. The front of the case features various sensors, including humidity, air pressure, and an infrared sensor. The device casing design is shown from every perspective view in Fig 1.



(a) **(b)**



(c) **(d)**

Fig 1 *Design Casing; (a) Front View; (b) Back View; (c) Top View; (d) Bottom View*

2.2 Electronic Device

A microcontroller such as the NodeMCU processes the data collected by the Internet of Things (IoT)-based air monitoring system, which makes use of a variety of environmental sensors, including light, temperature, and humidity sensors as shown in Fig 2. With the help of a Wi-Fi module, this microcontroller sends the processed data to LabVIEW for instantaneous analysis and visualization. immediately data visualization, logging, and hardware integration are all possible with LabVIEW. The system also transmits data to the cloud for advance data analytics, accessibility via the internet, and unlimited storage. With its hanging area and USB port for power, this gadget is easy to install and versatile enough to work in a variety of settings. Through the combining of real-time data processing, cloud-based analytics, and IoT technology, this complete configuration guarantees precise and dependable air quality monitoring.

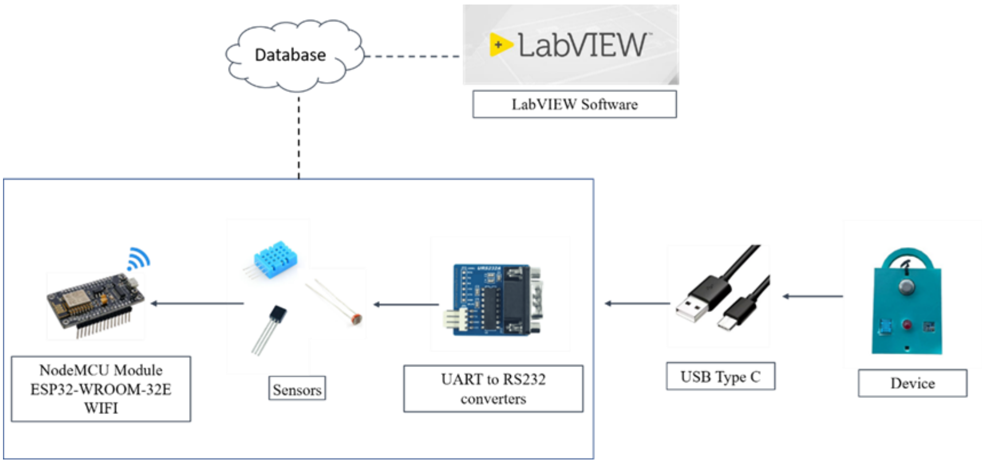


Fig 2 *Electronic Design*

2.3 IoT Device Functionality

Figs 3 and 4 show an IoT device assembly with environmental sensor installed within the top panel of the device. The device has an ESP32 Wi-Fi module for data transmission and processing, together with an IoT kit with a NodeMCU. To gather, process, and transmit data via a Wi-Fi network, the device needs a USB 5V connection for power.

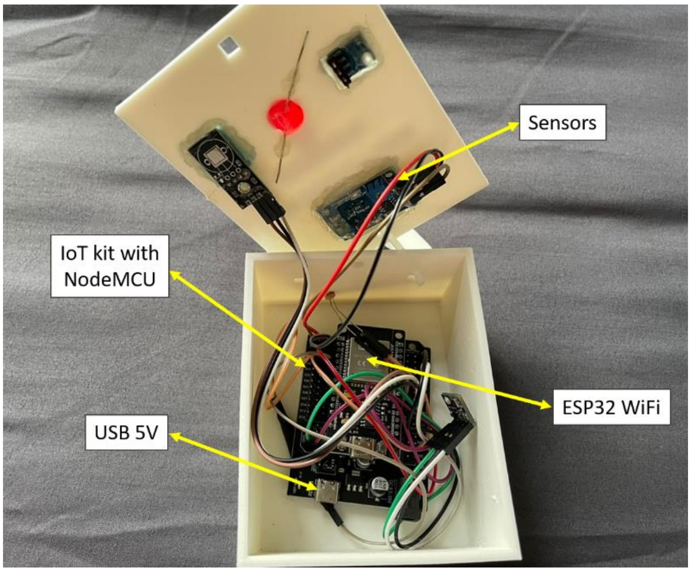


Fig 3 *The component inside the IoT Device*

Fig 4 *IoT device prototype*

Fig 5 displays a LabVIEW program's graphical user interface (GUI) for monitoring indoor air quality. Real-time readings that include several environmental and air quality factors are shown on the interface. Next, in Fig 6 shows a block diagram taken from a LabVIEW application. It provides an orderly procedure for gathering, analyzing, and storing data from various sensors. Every block symbolizes a certain function, like reading sensor data, analyzing what was detected and finally storing the processed data in files. Connecting lines represent the data flow and show the sequence of events in the data collecting and logging system.

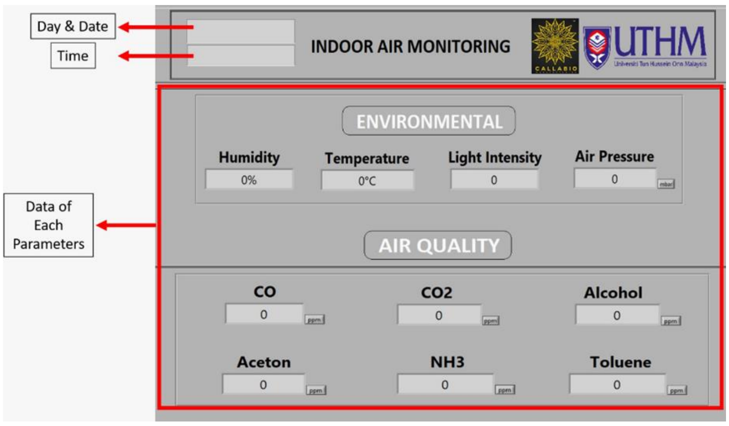


Fig 5 *GUI of LabVIEW Software*

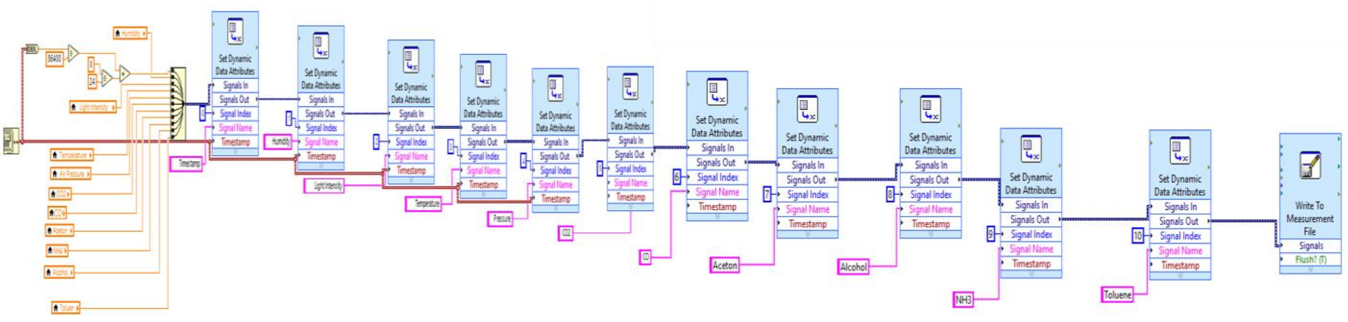


Fig 6 *Programming Block Diagram*

2.4 Type of Data (IoT Device)

In this project, the tools uploaded data to a database that the user can access via LabVIEW software. There will be ten characteristics included: humidity, temperature, light intensity, air pressure, carbon dioxide, carbon monoxide, alcohol, acetone, ammonia, and toluene. Table 1 summarizes the various forms of data.

Table 1 *Type of data*

Parameters	**Unit**
Humidity	Percent (%)
Temperature	Degree celsius (°C)
Light Intensity	-
Air Pressure	Atmosphere (atm)
Carbon Dioxide	parts-per-million (ppm)
Carbon Monoxide	parts-per-million (ppm)
Alcohol	Parts-per-million (ppm)
Acetone	Parts-per-million (ppm)
Ammonia	Parts-per-million (ppm)
Toluene	Parts-per-million (ppm)

2.5 Installation of IoT Device

Fig 7 below shows the details to install and use the IoT device to monitor the indoor air quality from the start until the analysis data.

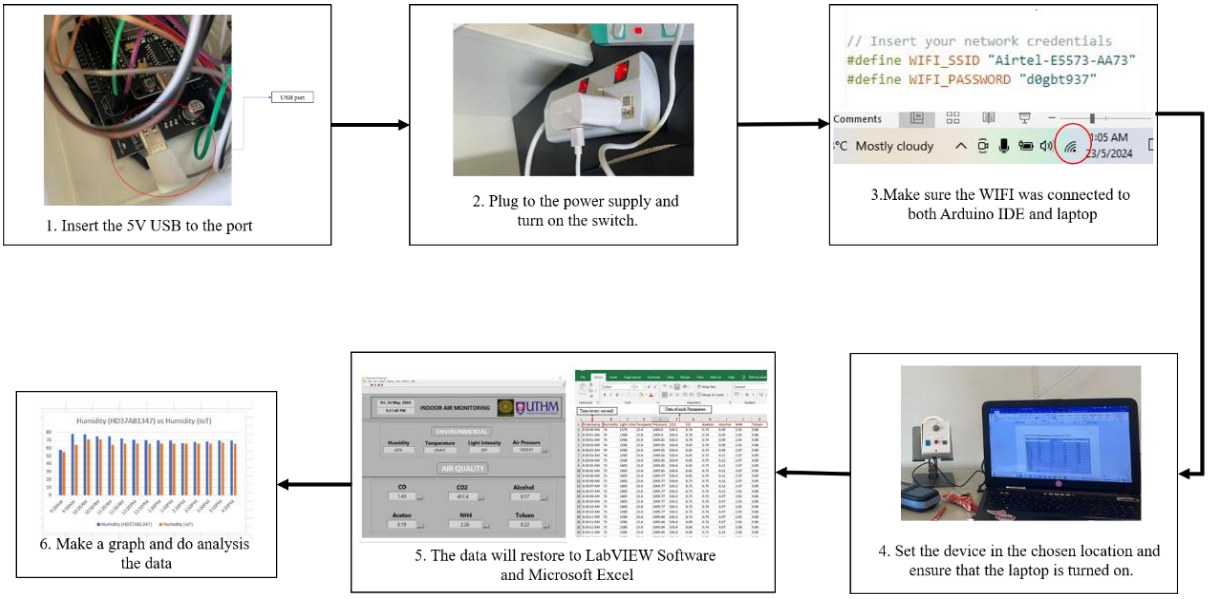


Fig 7 *Step by step to operate the device*

2.6 Delta Ohm Datalogger (HD37AB1347)

Delta Ohm Datalogger is an Indoor air quality device of the CO and CO_2 Data Logger type represented by the HD37AB1347. Its purpose was to monitor and document indoor carbon monoxide (CO) and carbon dioxide (CO_2) concentrations. This gadget was a part of a complete package that also contained programs for data processing, a carrying bag, a user manual, and rechargeable batteries. Fig 8 showed the tool of Delta Ohm Datalogger (HD37AB1347), and Table 2 showed the parameters that this device collected.

Fig 8 *Delta Ohm Datalogger*

Table 2 *Parameters from Delta Ohm Datalogger (HD37AB1347)*

Parameters	Parameter Description
CO_2	Carbon Dioxide

	Unit: parts-per-million (ppm)
RH	Humidity Unit: Percent (%)
T	Temperature Unit: degree Celsius (°C)
Patm	Air Pressure Unit: hectoPascals (hpa)

2.7 Method of Testing

Two tools were used simultaneously for this testing. The new air monitoring device operated for 24 hours, while the laboratory's instruments, designated as Delta Ohm Datalogger (HD37AB1347), operated for 7 hours. The data from the new air monitoring device were uploaded to a database and exported using LabVIEW software, whereas the data from Delta Ohm Datalogger (HD37AB1347), were written by hand. Indoor testing was carried out to make sure that all system components were working. This test was also performed to evaluate whether the IoT data logger could transfer data to the database before the system was tested in an outside area. The test was carried out inside the laboratory to assess the functionality of all components of the device involved in the performance of the IoT process without the use of natural elements. Fig 9 shows the site location of testing.

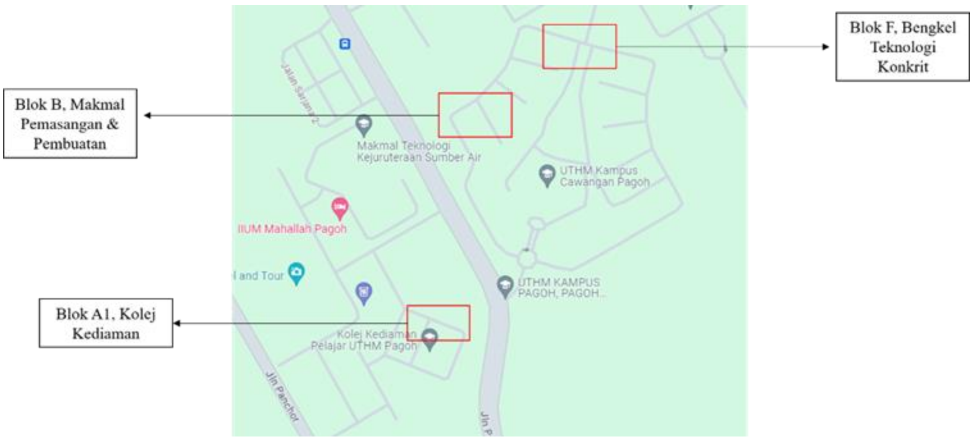


Fig 9 *Site of location*

2.8 Data Analysis

The analysis must be performed to demonstrate and show that the data from this IoT device can be used to monitor humidity, temperature, light intensity, and all the other designated parameters. The analysis provided insight into air pollutant data values as well as demonstrate the dependability of IoT data extraction. To get the results, all the raw data were imported into Microsoft Excel. The line graph is used for presenting the data, and it is straightforward to analyze. The x-axis and y-axis are the horizontal and vertical parts of the graph, respectively.

2.9 Equation

Formula below is to provide a comparison analysis to evaluate the IoT device's correctness and dependability in relation to the established IAQ device across a range of environmental factors.

$$\text{Different of percentage} = \frac{a-b}{(a+b) \div 2} \times 100\% \tag{1}$$

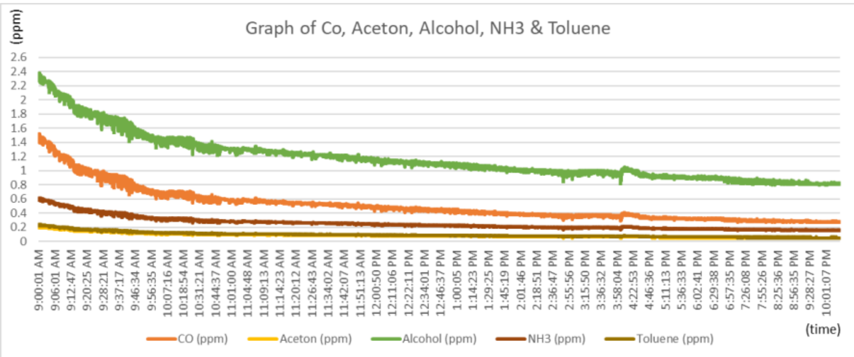
$$\text{Average} = \frac{\text{Total Different of Percentage}}{n} \tag{2}$$

3. Result and Discussion

In this project, two tools were set for testing. Two parameters were displayed on each graph, which showed the parameters. The X-axis represented time, while the Y-axis on the graph indicated the value of the parameters in their unit. Different colors corresponded to each parameter. Also shown in the appropriate color for each parameter was its value.

3.1 Test 1- Result of Concrete Technology Laboratory

A WIFI connectivity issue prevented the IoTDL device and real-time monitoring system from successfully collecting a full day's worth of data at Concrete Technology Laboratory. Regrettably, the device only collected data from 9 am to 10 pm, even though the data was supposed to be captured from 9 am to 9 am. Fig 10 showed the result of all the parameters of indoor air quality at Concrete Technology Laboratory.



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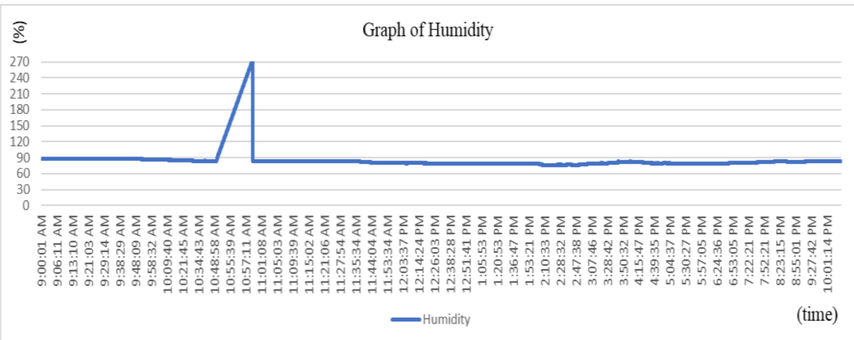

(b)

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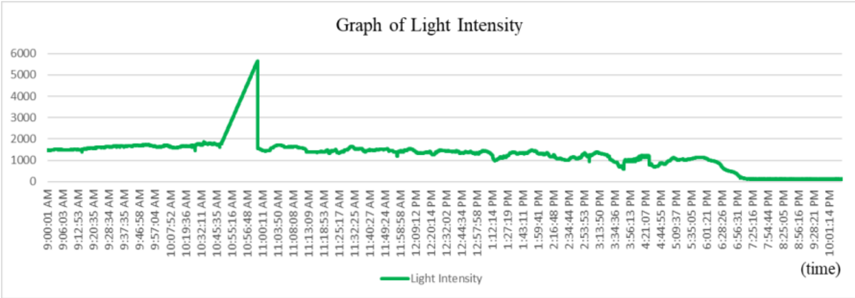

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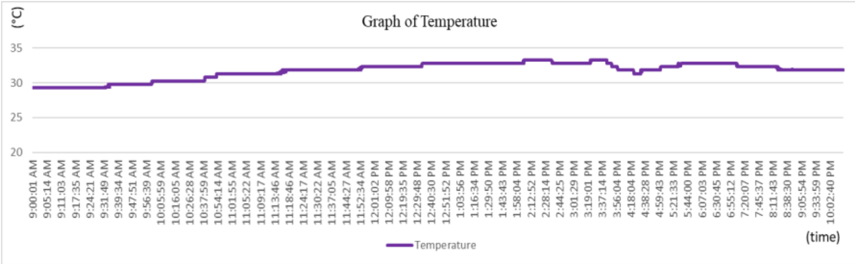

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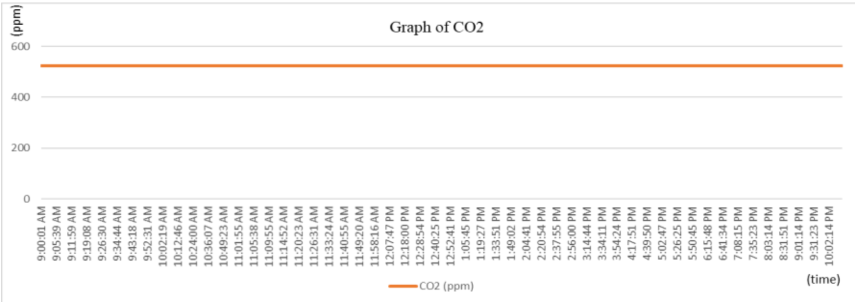

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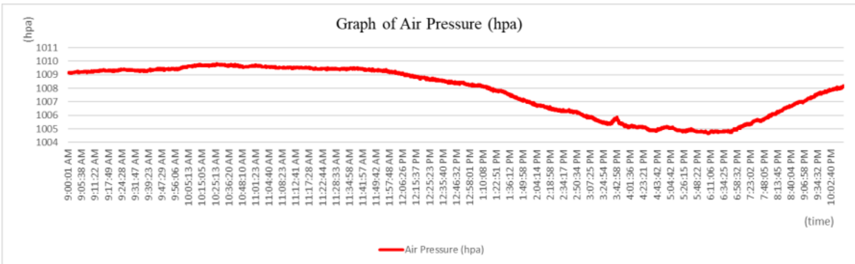


(f)

Fig 10 *Graph of CO, Aceton, Alcohol, NH_3, and Toluene; (a) Graph of Humidity; (b) Graph of Light Intensity; (c) Graph of Temperature; (d) Graph of CO_2; (e); Graph of Air Pressure (f)*

The analysis of the new device's working over the 12-hour observation period, despite the intended 24-hour collection owing to inadequate connectivity to the internet, shows some critical facts concerning the interior air quality at Concrete Technology Laboratory. Fig. 10 displays various parameters of indoor air quality, including light intensity, humidity, and ambient temperature. Despite the intended monitoring period from 9 am to 9 am, data were only collected until 10 pm. At approximately 10:57 AM, there was a sharp increase in light intensity to around 4000 units, likely due to direct sunshine resulting from a break in clouds or a change in solar position relative to a window. Humidity exhibited minimal fluctuations throughout the day, suggesting a controlled environment potentially maintained by HVAC systems or stable weather conditions. Ambient temperature showed a typical daily pattern, rising in the morning, peaking in the afternoon, and gradually decreasing towards evening, influenced by solar heat and human activity [9].

The air pressure graph shows a reasonably constant air pressure with just minor fluctuations. Notable decreases or increases may point to problems with the building's air conditioning system or variations in the surrounding environment. Maintaining constant indoor air quality and comfort requires stable air pressure [10].

According to Fig 10 (a), acetone levels may exhibit peaks that coincide with times when such items are consumed or acetone-related operations take place. For instance, acetone levels may rise during particular hours when production or extraction of dirt take place. In addition to alcohol, the employment of chemicals, additives of chemicals, chemicals for cleaning, and sterilizers during the preparation and testing of concrete caused alcohol levels to increase [12]. From Fig 10 (a), number of factors affect the variations in NH_3 and toluene concentrations over time: high levels at first, probably from residual accumulation; a notable midmorning rise around 10:54 AM. The steady decline that continued for the remainder of the day indicates that the concentrations of both substances are still being lowered by natural dispersion, chemical deterioration, or efficient removal procedures.

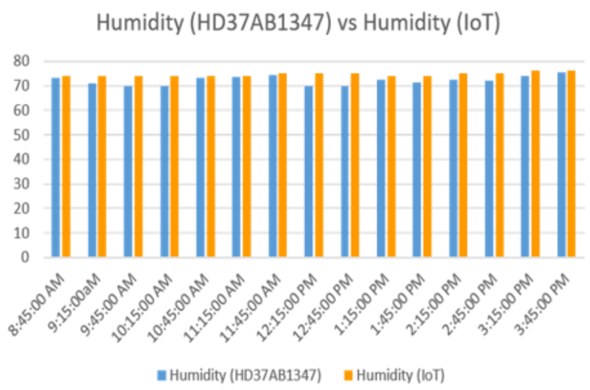
The amount of CO_2 directly relates to ventilation efficiency and occupancy. Because individuals would be using the space and exhaling CO_2 during working hours, CO_2 levels would probably grow during the 12-hour period. When occupancy is at its highest, in the middle of the morning and afternoon, CO_2 levels may reach their peaks. When people depart the area in the evening, CO_2 levels may fall. These rises and falls, which represent times of greater occupancy and the efficiency of the ventilation system in lowering CO_2 levels, may be seen on the graph in Fig 10 (e) [11].

3.1.1 Comparison Data between IoT Device and Delta Ohm Datalogger

Data from the IAQ Device (HD37AB1347) had been collected for 7 hours on the same day, at intervals of thirty minutes. Humidity, temperature, CO_2, and air pressure were the same variables that could be measured with both instruments. Fig 11 shows the full comparison data between the IoT Device and Delta Ohm Datalogger (HD37AB1347) in excel, While Figs 12 shows the graph based on the comparison. The data was taken from 9:00 am until 4:00 pm. The yellow-highlighted columns in the spreadsheet represent the percentage differences between the measurements from the Delta Ohm Datalogger (HD37AB1347) and the IoT device for humidity, temperature, CO_2, and air pressure.

Time	Humidity (HD37AB1347	Humidity (IoT)	Different % Humidity	Temperature (HD3	Temperature (IoT)	Different % Temperature	CO2 (HD37AB1347)	CO2(IoT)	Different % CO2	r Pressure (HD37AB134	Air Pressure (IoT)	Different % Air Pressu
9:00AM	78	88	12.04819277	29.3	29.3	0	473	523	10.04016064	1008	1009.12	0.111049417
9:30AM	75.2	88	15.42168675	30.3	29.3	3.355704698	470	523	10.67472306	1008	1009.36	0.134829678
10:00AM	73	88	18.63354037	30.7	30.1	1.973684211	455	522.9	13.8869005	1008	1009.4	0.138792505
10:30AM	70	88	22.78481013	31	30.2	2.614379085	434	522.9	18.58083394	1008	1009.73	0.171479831
11:00AM	70	88	22.78481013	31.7	31.3	1.26984127	411	522.8	23.94517027	1008	1009.59	0.157613787
11:30AM	65.2	88	29.76501305	32	31.8	0.626959248	384	522.8	30.61314513	1008	1009.42	0.14077386
12:00PM	62	88	34.66666667	32.5	32.3	0.617283951	380	522.7	31.61626232	1008	1009.23	0.121949406
12:30PM	63	88	33.11258278	32.8	32.3	1.53609831	372	522.7	33.68726948	1007	1008.7	0.168675894
1:00PM	63.5	88	32.34323432	33.1	32.8	0.91047041	380	522.7	31.61626232	1007	1008.7	0.168675894
1:30PM	64.1	88	31.42669297	32.9	32.8	0.304414003	376	522.7	32.647157	1006	1007.74	0.172812776
2:00PM	62.7	88	33.57664234	32.2	32.8	1.846153846	377	522.7	32.38857397	1006	1006.85	0.084457361
2:30PM	62.8	88	33.42175066	33.2	33.3	0.30075188	386	522.6	30.06823685	1005	1006.37	0.136225558
3:00PM	62.4	88	34.04255319	33.1	32.8	0.91047041	392	522.7	28.57767574	1005	1005.97	0.096470857
3:30PM	62.5	88	33.88704319	32.5	33.3	2.431610942	385	522.6	30.32172763	1005	1005.41	0.0407877
4:00PM	69.6	88	23.35025381	32	31.8	0.626959248	388	522.6	29.56292554	1004	1005.1	0.109501767
			27.41769821			1.288318767			25.88180163			0.130273086

Fig 11 *Full comparison data in excel*



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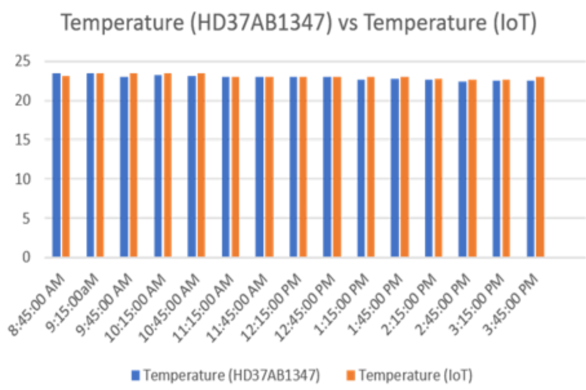

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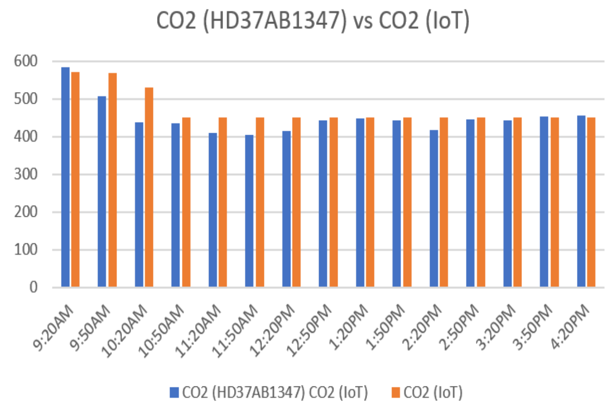

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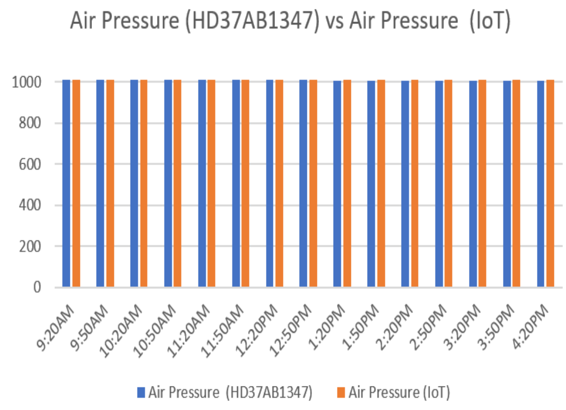


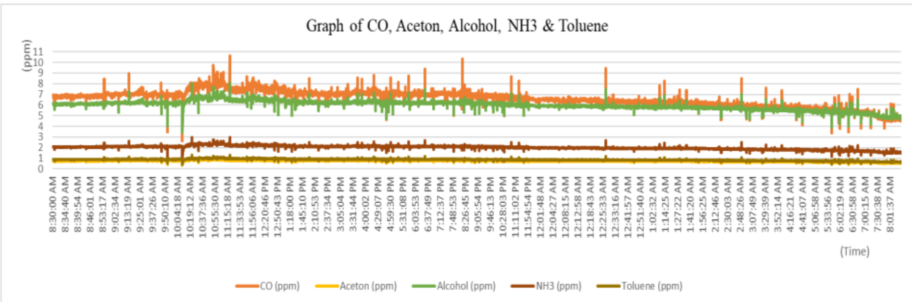
(d)

Fig 12 *Comparison graph of Humidity; (a) Comparison graph of Temperature; (b) Comparison graph of CO_2; (c) Comparison graph of Air Pressure; (d)*

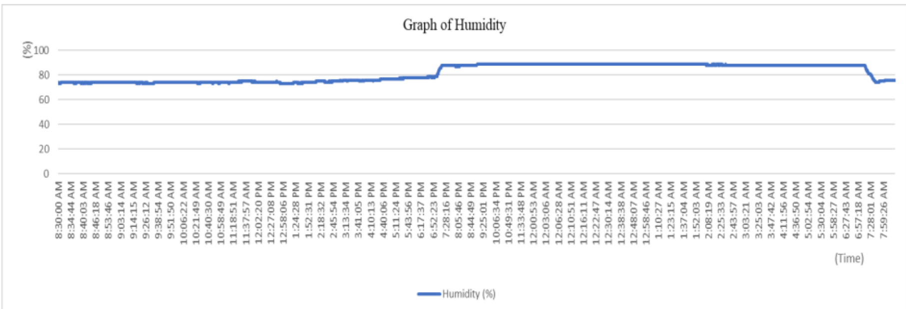
From Fig 12, the Considerable variations can be seen when that compare the results of an IoT device with the Delta Ohm Datalogger (HD37AB1347) for the features like temperature, humidity, CO_2 levels, and air pressure. There is a large discrepancy in the humidity values of about 27.42%, which may indicate problems with the calibrating or measurement accuracy. While the temperature adjustments are quite tiny, at about 1.29%, the CO_2 levels exhibit a significant difference, at about 25.88%, which raises questions regarding calibration drift and accuracy. The differences in air pressure are quite small, about 0.13%. The precision error and accuracy error of a competent measurement system should both be within 10% and 5%, respectively [13].

3.2 Test 2- Result of Manufacturing and Assembly Technology Laboratory.

The real-time monitoring system and the IoTDL were successfully interfaced with the ambient air quality through the connection of WIFI and LabVIEW software at Manufacturing and Assembly Technology Laboratory for 24 hours straight. The data was collected from 8:30 am to 8:30 am. Figs 13 show the data for all parameters in Manufacturing and Assembly Technology Laboratory.



(a)



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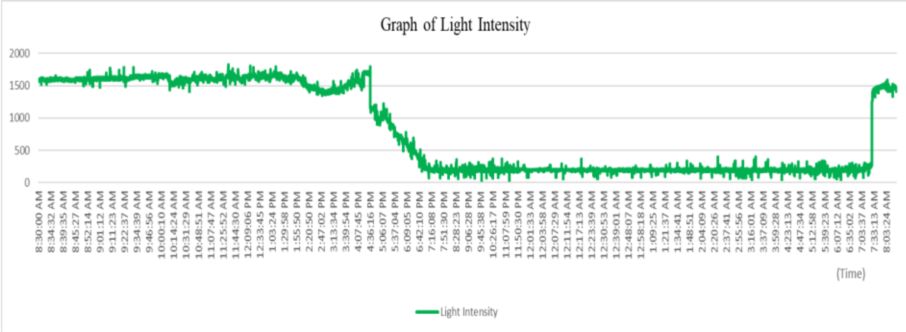

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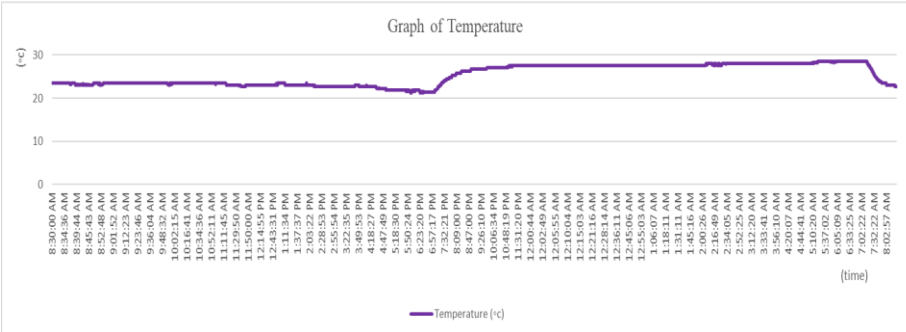

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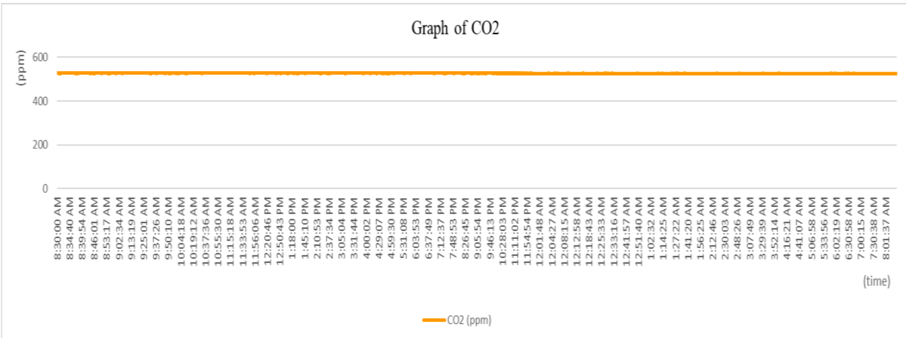

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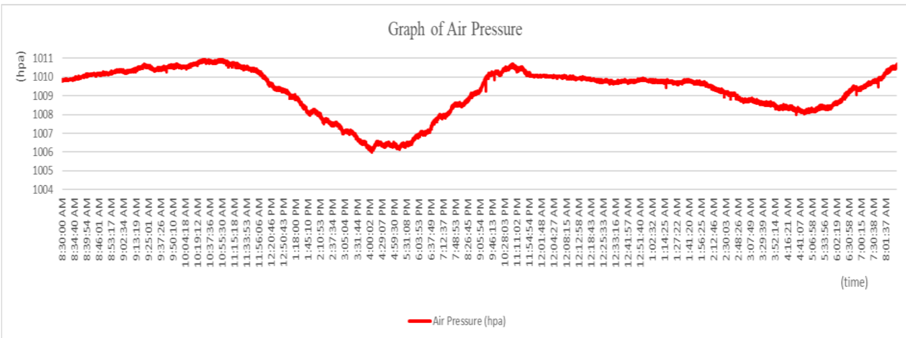


(f)

Fig 13 *Graph of CO, Aceton, Alcohol, NH_3, and Toluene; (a) Graph of Humidity; (b) Graph of Light Intensity; (c) Graph of Temperature; (d) Graph of CO_2; (e); Graph of Air Pressure; (f)*

The tool collected data at Manufacturing and Assembly Technology Laboratory successfully for 24 hours, demonstrating consistent capability in real-time air quality monitoring. The device, which had WiFi and LabVIEW software integrated, allowed for uninterrupted data collection from 8:30 am to 8:30 am, covering the entire full cycle.

Acetone levels in Fig 13 (a) begin low and rise a few times during the day. Similarly, alcohol levels start low and gradually increase. Fig 13 (a) shows that NH_3 concentration peaks early in the morning, gradually decreases, and peaks again around 10:54 AM. Toluene levels follow a similar pattern to NH_3, starting high and progressively decreasing, with a less pronounced peak at 10:54 AM, indicating a simultaneous release affecting both compounds. Fig 13 (b) shows slight variations in humidity, ranging from 70% to 80%, which exceeds the established standard [14].

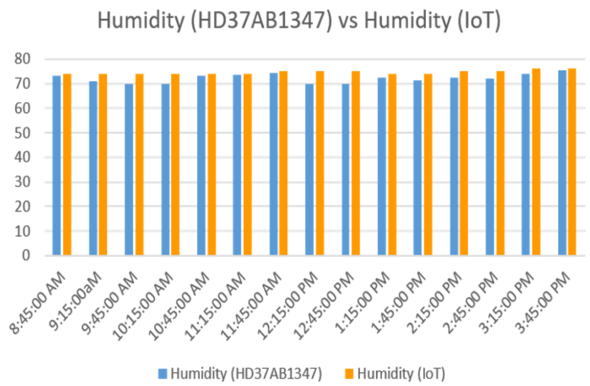
This could be caused by indoor activities, air conditioning systems, and environmental factors. The daily cycle of light intensity peaks around midday. The temperature graph in Fig 13 (d) shows a rise until midday, followed by a decline towards the evening, reflecting the normal daily temperature cycle influenced by night time cooling and daytime air conditioning. Small variations in air pressure throughout the day can be attributed to weather patterns, differences in elevation, and changes in atmospheric conditions within the monitored location. Fig 13 (e) illustrates how CO_2 levels start low and periodically rise, likely due to human activities such as breathing, combustion, and other CO_2 emissions. Peaks in CO_2 concentration correspond with periods of increased activity or occupancy in the observed area. CO levels remain comparatively low with slight variations during the day.

3.2.1 Comparison Data between IoT Device and Delta Ohm Datalogger

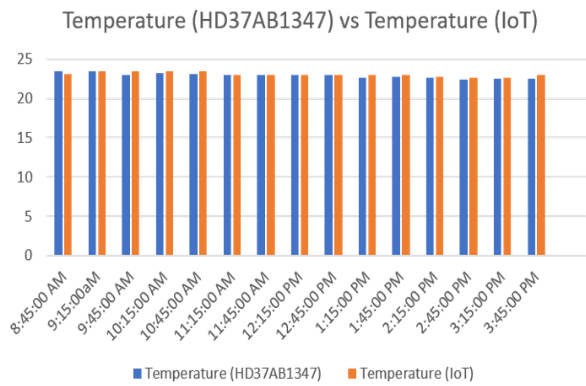
Data from the IAQ Device (HD37AB1347) was collected for 7 hours on the same day, at intervals of thirty minutes. Humidity, temperature, CO_2, and air pressure were the variables measured by both instruments. Fig 14 show the comparison data between the IoT Device and the Delta Ohm Datalogger (HD37AB1347). The data was collected from 8:45 am until 3:45 pm. The yellow-highlighted columns in the spreadsheet represent the percentage differences between the measurements from the Delta Ohm Datalogger (HD37AB1347) and the IoT device for humidity, temperature, CO_2, and air pressure. Figs 15 show the graph of the comparison.

timestamp	Humidity (HD37AB1347)	Humidity (IoT)	Different % Humidity	Temperature (HD37AB1	Temperature (IoT)	ifferent % Temperatur	CO2 (HD37AB1347)	CO2 (IoT)	Different % CO2	r Pressure (HD37AB134	Air Pressure (IoT)	Different % Air Pressure
8:45:00 AM	73	74	1.360544218	23.5	23.1	1.716738197	527	526.30001	0.132913699	1009	1010.14001	0.112920352
9:15:00aM	71	74	4.137931034	23.4	23.4	0	535	526.30001	1.639496828	1009	1009.64001	0.063410018
9:45:00 AM	70	74	5.555555556	23	23.4	1.724137931	515	526.4	2.189360476	1009	1010.5	0.148551622
10:15:00 AM	70	74	5.555555556	23.2	23.4	0.858369099	516	526.6	2.033378093	1009	1010.71002	0.169333219
10:45:00 AM	73	74	1.360544218	23.1	23.4	1.290322581	516	526.5	2.014388489	1009	1010.84003	0.182195617
11:15:00 AM	73.4	74	0.93770931	23	23	0	517	526.7	1.858771678	1009	1010.71997	0.17031767
11:45:00 AM	74.3	75	0.93770931	23	23	0	494	526.7	6.407367493	1009	1010.29999	0.1287565
12:15:00 PM	70	75	6.896551724	23	23	0	490	526.7	7.219435428	1009	1009.69	0.068361165
12:45:00 PM	70	75	6.896551724	23	23	0	484	526.9	8.487486398	1008	1009.39001	0.137802804
1:15:00 PM	72.3	74	2.323991798	22.6	23	1.754385965	472	526.5	10.91637456	1008	1008.90997	0.090234072
1:45:00 PM	71.3	74	3.716448727	22.7	23	1.312910284	485	526.49999	0.132913699	1007	1008.13	0.112151573
2:15:00 PM	72.3	75	3.66598778	22.6	22.7	0.441501104	472	526.39999	10.897434	1006	1007.71002	0.16983776
2:45:00 PM	72	75	4.081632653	22.4	22.6	0.888888889	482	526.39999	8.806027457	1006	1007.52002	0.150981364
3:15:00 PM	74	76	2.666666667	22.5	22.6	0.44345898	489	526.39999	7.366553155	1006	1007.09003	0.108294213
3:45:00 PM	75.4	76	0.792602378	22.5	23	2.197802198	507	526.6	3.792569659	1005	1006.46997	0.146158782
			3.392398843			**0.841901015**			**4.926298075**			**0.130620449**

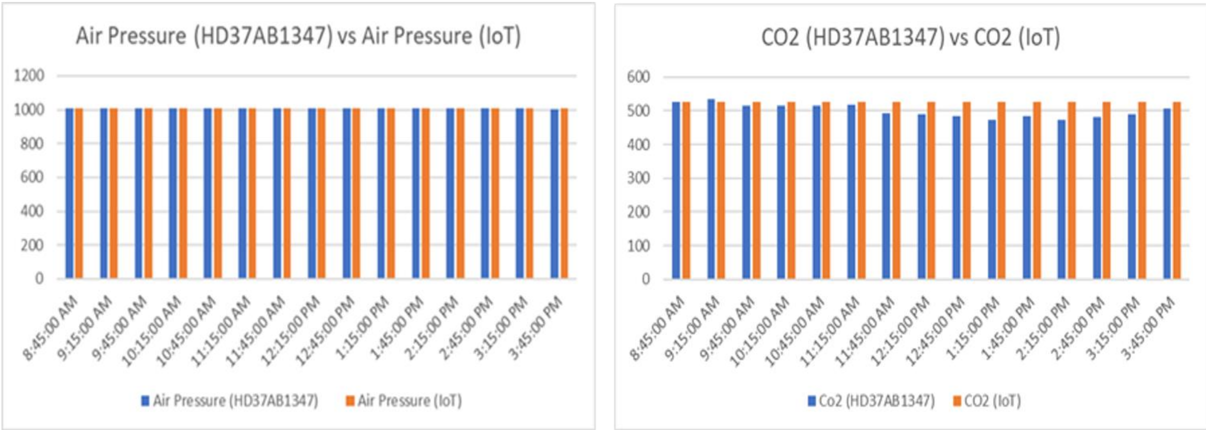
Fig 14 *Full comparison data in excel*



(a)



(b)



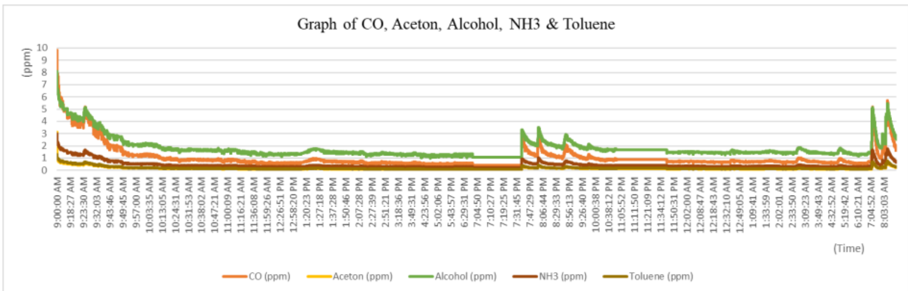
(c) **(d)**

Fig 15 *Comparison graph of Humidity; (a) Comparison graph of Temperature; (b) Comparison graph of CO_2; (c) Comparison graph of Air Pressure; (d)*

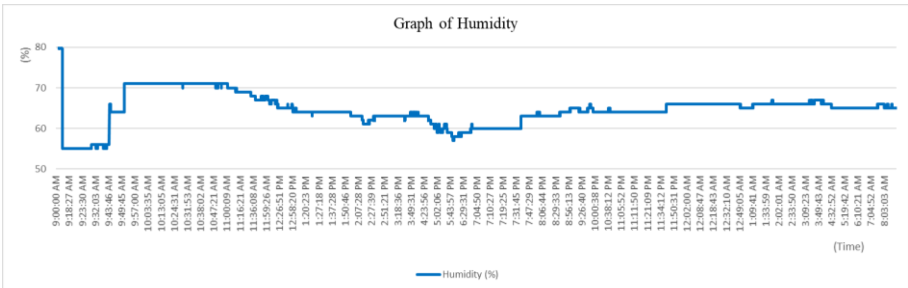
Following the results of a comparison between an IoT device and Delta Ohm Datalogger (HD37AB1347) shows differences in humidity, temperature, air pressure, and CO_2 levels, among other characteristics. Significant variations between the humidity and CO_2 measurements from the IoT device—roughly 3.392% and 4.93%, respectively indicate possible difficulties in precisely determining indoor air quality. Temperature variations indicate variance that may affect particular uses, even though they are less significant at about 0.841%. On the other hand, the air pressure measurements exhibit little difference, indicating an improved consistency on this parameter between the two devices. These differences could be the result of variances in sample techniques, environmental factors, or calibration.

3.3 Test 3- Result of Student Residential College A1

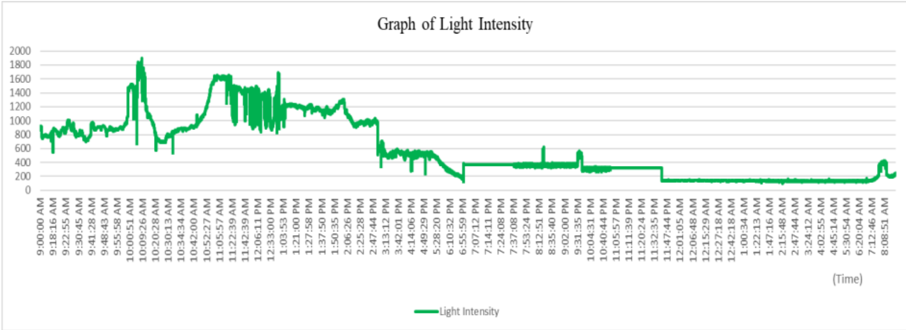
The real-time monitoring system and the IoTDL are successfully interfaced with the ambient air quality through the connection of the WIFI and LabVIEW software at Student Residential College A1 for 24 hours straight. The data was collected from 9:00 am – 9:00 am. Figs 16 show all the data of all parameters in Kolej Kediaman A1.



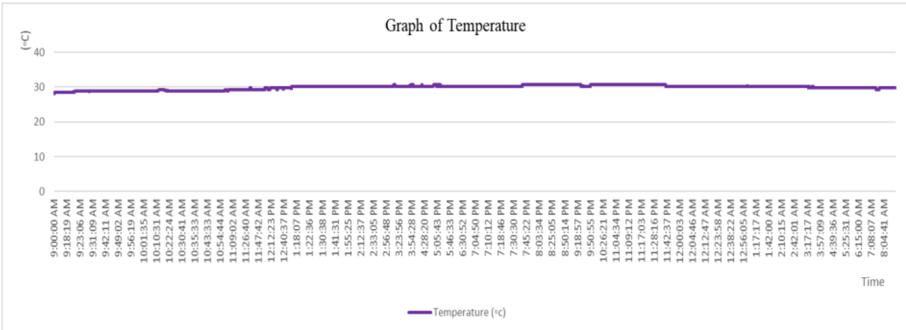
(a)



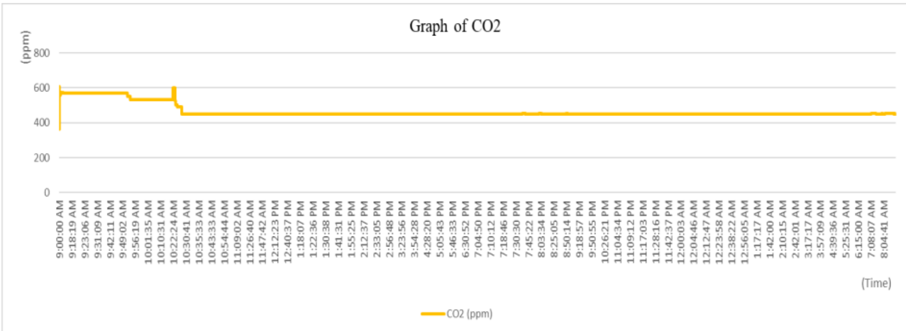
(b)



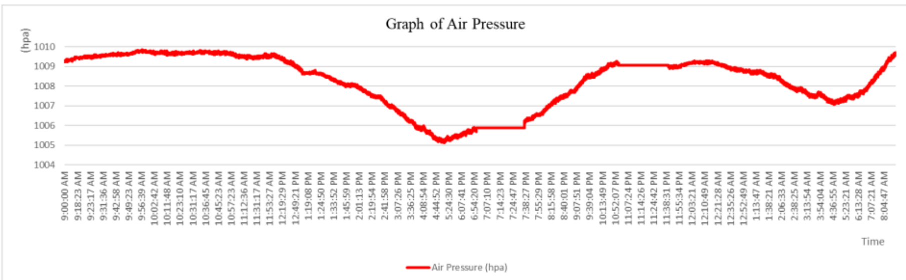
(c)



(d)



(e)



(f)

Fig 16 *Graph of CO, Aceton, Alcohol, NH_3, and Toluene; (a) Graph of Humidity; (b) Graph of Light Intensity; (c) Graph of Temperature; (d) Graph of CO_2; (e); Graph of Air Pressure; (f)*

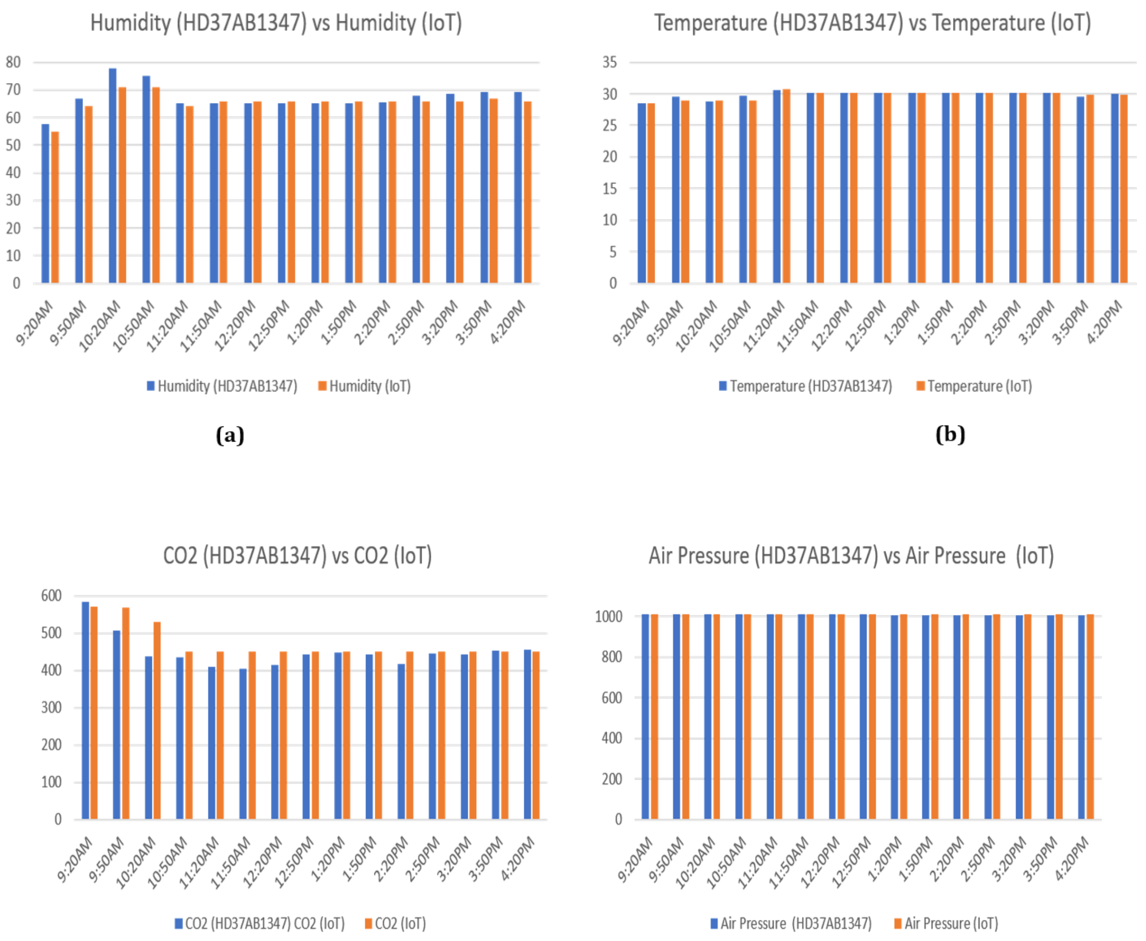
Figs 16 (a-f) provide a thorough understanding of the measured parameters. Humidity levels show small variations due to the environment, ventilation, and indoor activities. Light intensity follows a regular daily cycle, peaking at midday. Temperature rises in the morning and falls in the afternoon, reflecting the daily cycles of heating, cooling, and air conditioning. Air pressure varies slightly due to the environment and weather. CO levels remain mostly constant at low levels, occasionally rising due to human activity. CO_2 levels start at a baseline and increase over time, peaking with increased usage. Alcohol and acetone levels decrease initially and fluctuate throughout the day, indicating irregular sources. Toluene follows a similar trend to NH_3, with a less noticeable increase at 10:54 AM. NH_3 concentrations rise in the morning and steadily decrease afterward

3.3.1 Comparison Data between IoT Device and Delta Ohm Datalogger

Data from the Delta Ohm Datalogger (HD37AB1347) was collected for 7 hours at thirty-minute intervals, measuring humidity, temperature, CO_2, and air pressure. Fig 17 shows the full comparison data between the IoT Device and Delta Ohm Datalogger (HD37AB1347) in excel from 9:20 am to 4:20 pm. Yellow-highlighted columns in the spreadsheet show the percentage differences between the Delta Ohm Datalogger (HD37AB1347) and the IoT device measurements for humidity, temperature, CO_2, and air pressure. Fig 18 shows the graph of comparison data.

Time	Humidity (HD37AB1347)	Humidity (IoT)	Different % Humidity	mperature (HD37AB134	Temperature (IoT)	Different % Temperatur	CO2 (HD37AB1347)	CO2 (IoT)	Different % CO2	r Pressure (HD37AB134	Air Pressure (IoT)	Different % Air Pressure
9:20AM	57.6	55	4.618117229	28.5	28.5	0	585	571	2.422145329	1008	1009.46	0.144736451
9:50AM	67	64	4.580152672	29.5	28.9	2.054794521	507	569.2	11.55918974	1008	1009.66	0.16454705
10:20AM	77.8	71	9.139784946	28.8	29	0.692041522	437	531.1	19.44014048	1008	1009.76	0.174450876
10:50AM	75	71	5.479452055	29.7	28.9	2.730375427	435	451	3.611738149	1008	1009.67	0.165537476
11:20AM	65	64	1.550387597	30.6	30.8	0.651465798	410	451	9.523809524	1008	1009.07	0.106094484
11:50AM	65	66	1.526717557	30.1	30.2	0.331674959	404	450.8	10.94992981	1008	1009.01	0.100148239
12:20PM	65	66	1.526717557	30.1	30.2	0.331674959	415	450.8	8.26980827	1008	1009.13	0.112040374
12:50PM	65	66	1.526717557	30.2	30.2	0	444	450.8	1.519892713	1008	1008.08	0.007936193
1:20PM	65	66	1.526717557	30.2	30.2	0	448	450.8	0.62305296	1007	1008.67	0.165701727
1:50PM	65.2	66	1.219512195	30.2	30.2	0	442	450.8	1.971326165	1007	1008.49	0.147854864
2:20PM	65.4	66	0.913242009	30.1	30.2	0.331674959	417	450.8	7.789813321	1006	1008.03	0.201585875
2:50PM	67.9	66	2.83793876	30.1	30.2	0.331674959	446	451	1.114827202	1006	1007.87	0.185712087
3:20PM	68.6	66	3.863298663	30.1	30.2	0.331674959	444	450.9	1.54207174	1005	1007.6	0.258372255
3:50PM	69.4	67	3.519061584	29.5	29.8	1.011804384	452	450.8	0.26583961	1005	1007.64	0.262341999
4:20PM	69.3	66	4.87804878	30	29.8	0.668896321	455	450.8	0.927357032	1005	1007.31	0.229586893
			3.247057781			0.631183518			5.435396136			0.161776456

Fig 17 *Full comparison data in excel*



(a) (b) (c) (d)

Fig 18 *Comparison graph of Humidity; (a) Comparison graph of Temperature; (b) Comparison graph of CO_2; (c) Comparison graph of Air Pressure; (d)*

The post-calibration data comparison between the two devices, shown in Figs 18 (a-d), indicates significant similarity and precision for all measured parameters. Both devices show nearly similar measurements and patterns, demonstrating that the calibration procedure effectively reduced differences, ensuring accurate and dependable environmental monitoring. This proves that the IoT device can be relied upon for trustworthy real-time data gathering and processing, as evidenced by this consistency, verifying the success of the calibration.

4.0 Conclusion

In conclusion, the project's completion has achieved the objectives of developing a real-time air quality monitoring device with a Graphical User Interface (GUI) to measure ambient air quality in indoor locations at Universiti Tun Hussein Onn Pagoh. This IoT device reliably reads parameters such as humidity, temperature, light intensity, air pressure, carbon dioxide, carbon monoxide, alcohol, acetone, ammonium, and toluene, and its data closely approximates that of laboratory instruments. It allows for data access and uploading to the cloud via LabVIEW software, displaying the data in Microsoft Excel. This small tool can automatically collect all data, replacing heavier manual instruments. Recommendations for future improvements include further development of the IoT monitoring system, selecting a telco SIM with a strong and consistent internet connection to ensure uninterrupted connectivity, and introducing this device to UTHM Pagoh's students and staff for installation in every laboratory and room to monitor indoor air quality.

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time indoor air quality monitoring association with humidity temperature and carbon monoxide level i n the residential environment.