FUPRE Journal

of

Scientific and Industrial Research

ISSN: 2579-1184(Print) ISSN: 2578-1129 (Online)

http://fupre.edu.ng/journal

Development of an IoT-based Air Quality Monitoring System

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ARTICLE INFO

Received: 15/04/2023

Accepted: 06/07/2023

Keywords

Air Quality, Arduino IDE, Blynk, Humidity, Internet of things, Sensor

ABSTRACT

People are becoming conscious of their environment to maintain good health of body and mind. The main cause of the present-day most dangerous diseases can be attributed to poor environmental conditions such as air pollution. The consequences of air this pollution can never be over-emphasized, it is known to be the cause of diseases such as dementia, heart attacks, and strokes, to mention but a few. This work presents an IoT-based framework that will effectively monitor environmental changes using the developed hardware that comprises of microcontroller, sensors, and IoT-based software. With this framework, users can monitor humidity and be alerted of the presence of harmful gases in the environment to health. The IoT-based framework was developed using Blynk IoT to provide vital information to the user. The user will also be able to set up a notification for serious shifts in the data gotten from the sensors. Compared to other existing systems, the proposed system is low-cost, accurate, and user-friendly. It is also cloud-based and its monitoring and data visualization modules are easy. The system was tested and evaluated at three distinct stages (rainy day, sunny day, and on the application of gas pollutants) using the alpha test method. After the testing of all the functions in the different conditions, the result revealed 70.7% humidity and 206 ppm of Air Quality on a sunny day. 51.5% humidity and 198 ppm on a rainy day and 66.5% humidity and 363 ppm air quality on the application of air pollutants.

1. INTRODUCTION

With the increase in urbanization, environmental issues have been important concerns that organizations must address. Internet of Things (IoT) technology proves quite useful and efficient in reducing to the barest minimum, environment-related problems. IoT uses smart devices, and the internet to provide creative solutions to various issues related to various business, governmental, and public/private industries across the world (Sfar et al., 2017). IoT is a large subject that contains the best use of resources, sensor-based functionalities, and strategies to give businesses an uplift. The most useful IoT application is Environmental monitoring. It uses sensor devices that are advanced to pinpoint the presence of pollutants in the air and water and promote better sustainability. The surroundings can be kept cleaner and safer by the use of smart environmental monitoring solutions. Air quality is a major concern nowadays that requires monitoring of several parameters

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responsible for this problem. A feasible technical solution to monitor environmental conditions and changes is quite important. The Internet of Things (IoT) offers a very highly effective method of monitoring parameters related to air quality. If a system can be able to bring together various IoT components to track and retrieve data using IoT-based devices, then it can be used as a powerful tool for monitoring outdoor and indoor environments. Smoke, Methane, Liquid Natural Gas (LNG), Carbon-based gases, Nitrogen-based gases, and Humidity are the required indices that are required to be monitored and investigated to have a complete idea of the surrounding environment. Using the IoT concept, it becomes much more flexible and interactive for the user (Mosfiqun et al., 2020). Akazue et al. (2017), worked on extending the Internet of Things (IoT) to the Internet of Domestic Things by comparing the interlink between Radio frequency identification (RFID) of things and the Internet of Domestic Things with a view of providing smart security of personal belongings using IoT.

Sustainable growth of the whole world depends on several factors such as economy, quality education, agriculture, industries, and many others, but the environment is one of the elements that play the most vital role. Health and hygiene are key elements of the sustainability of humanity and the progress of any country, which comes from a clean, pollution-free, and hazardous-free environment. Thus, monitoring becomes important to live a healthful life.

2. MATERIALS AND METHOD

2.1 Review of Related Literatures

Previous studies carried out on the use of internet of things (IoT) technology in design and solving problems have reported IoT to be very efficient in problem solving. Many of such studies relating to smart environment has been used in solving various environmental-related issues (Sayed et al., 2019; Beebi, (2018); Bhoomika et al., 2016; Kamal, 2017; Kulkarni and Kute, 2016; Sanjeev, 2020; Sharma and John, 2017; Shinde and Siddiqui, 2018; Shete and Agrawal, 2016; Akazue and Ighoyota, 2016).

Ihama et al., (2023) proposed a framework for a smart city model enabled by the Internet of Things (IoT) to manage the menace of traffic congestion in smart cities. The smart city model offers some advantages such as energy saving, more efficient relaying of city traffic, and reducing traffic gridlock, which is known to be a contributing factor to air and noise pollution.

Akpoyibo et al., (2022) developed a floating surface water robotic oil spillage surveillance (SWROSS) system using IoT technology. The system detects gaseous substances on the surface water using the gas sensor and sends a notification to the user. nodeMCU was used in putting the system together. The output interface was designed using the Blynk IoT application. The designed system is reliable and efficient.

Dhingra et al,. (2019) designed an IoT mobile-air pollution monitoring system (IoT-Mobair) which is an Air pollution monitoring system using Gas sensors for prediction but the findings from the system analysis showed that the system monitors for only gaseous matters without regard to humidity.

Dhas and Jeyanthi (2017), applied IoT to develop an environmental monitoring system. This research focuses on use of IoT in real-time air monitoring using sensors. MQ3 Model and Raspberry Pi were also used. The designed system has accuracy issues in predicting environmental changes.

Arco et al., (2016), proposed an integrated method to monitor contaminated air. This design monitors a large area but it has noisy data, accuracy, and cost issues.

Shaikh and Hussain (2019), developed a Marine IoT for oceanic monitoring using wireless sensors but the design is costly.

Gaglio et al., (2014), Developed an IoT Environmental Monitoring Application using a mobile sensor network and WSN. The developed system is scalable. The challenge of this system is computational complexity due to the voluminous data captured.

Tadejko (2017) designed a monitoring system for the environment using the IoT standards and protocols. It has issues relating to heterogeneous sensors.

Beebi (2018), used IoT to design a monitoring system to monitor dust and humidity in the environment. The design was found to be efficient, cheaper, and portable. However, this system does not monitor the presence of gaseous pollutants in the air, which is of high importance.

These and many other types of research have been done on environmental monitoring in a bid to cushion air contamination effects.

2.2 Study Motivation

Some of the related pieces of literature reviewed were found to monitor only one parameter, which is mainly gaseous pollutants in the surroundings without considering the humidity, as high humidity levels can lead to an increase in airborne pollutants including mold, dust mites and other allergens, which causes respiratory problems. It is therefore imperative to develop a system, which can take readings of both gaseous substance and humidity of the surroundings.

2.3 Component Specification

For the development of this system, the following components are used:

a. Node MCU is an open-source IoT platform made of firmware that runs on the ESP8266 Wi-Fi SoC from Espressif Systems, and hardware that is based on the ESP-12 module. The term "NodeMCU" refers to the firmware rather than the development kits (Hari, 2014). The NodeMCU gives access to general purpose Input/Output
b. Humidity Sensor device senses as well as measures, and reports the relative humidity (RH) of air or determines the quantity of water vapor present in a given environment.
c. Gas Sensor called MQ5 detects smoke and gas in the atmosphere. This sensor has good sensitivity to harmful gases in various concentrations for long active periods and it is not expensive.

2.4 Methodology

This research adopted IoT methodology. This methodology is outlined in ten (10) steps:

a. Purpose and Requirements Specification
b. Process Specification
c. Domain Model Specification
d. Information Model Specification
e. Service Specifications
f. IoT Level Specification
g. Functional View Specification
h. Operational View Specification
i. Device and Component Integration
j. Application Development

The proposed system is an IoT-based system built to monitor atmospheric pollution and humidity in the surroundings. The system runs on PC and mobile platforms where a user- friendly interface was designed to enable the users to interact and access information in the designed hardware. The Blynk platform is used for the IoT integration while the NodeMCU board is connected to the humidity and gas sensor. The values from these sensors are viewed on the gauge and chart controls to get the readings of data. Its mobile platform alerts the user of atmospheric pollution when the system senses contaminants in the air and the humidity rises above normal.

Users can observe humidity and be aware of the presence of harmful gases the environment using the proposed system. The information is saved in a web server and is easily accessed through an internet connection. The NodeMCU (or ESP8266) is the brain of the device, and is responsible for sensor data collection, formatting the data, and sending it to the sensor gateway. The performance evaluation is done in three stages: sunny day, rainy day, and use of air pollutants.

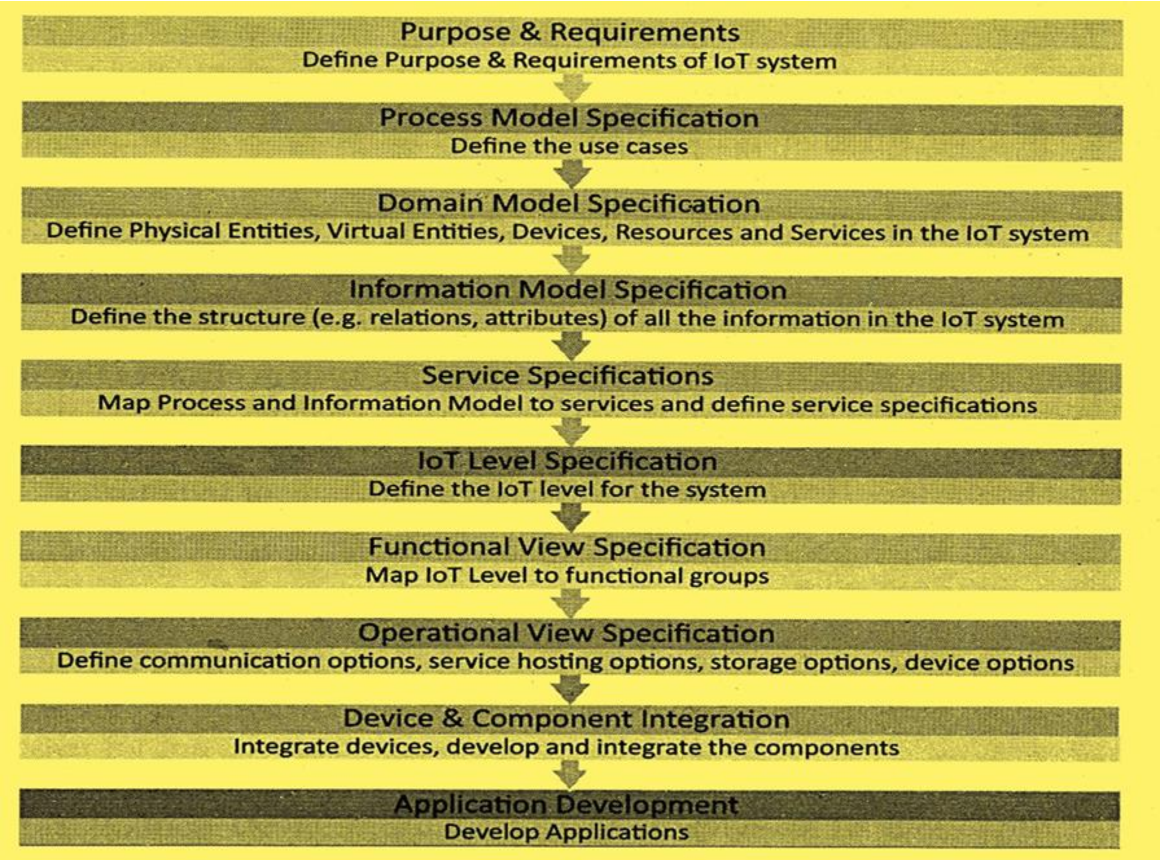

Figure 1: IoT Platforms Design Methodology (Kiran, 2020)

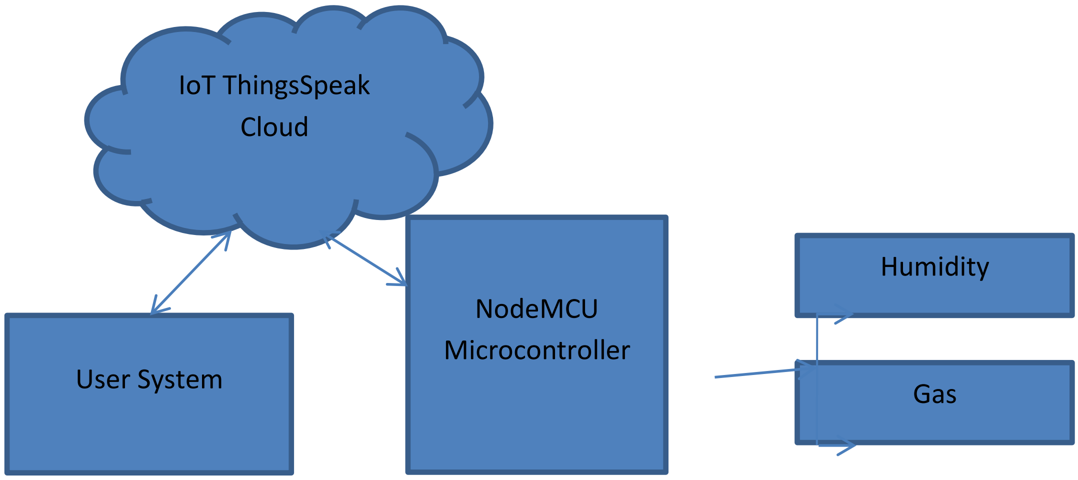

Figure 2: Block diagram of the AMOS System

Algorithm: The air quality monitoring system (AMOS) Algorithm

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Start
Step 1: The system reads the air quality through the gas sensor
Step 2: The system reads the humidity through the humidity sensor
Step 3a: System displays readings or values on user interface via Blynk (Smartphone or PC)
If air quality is above 300 ppm, then display "Air Pollution Detected"
Else, re-take the readings
End

Figure 3: Main System Control Dashboard (Output Interface)

3. RESULTS AND DISCUSSION

3.1 Review of Related Literatures

A review of some of other works done on environmental monitoring system, revealed that the designed systems monitors for one parameter which is mainly air quality by checking for harmful gaseous substances in the air. Using Dhingra et al,. (2019) as a case study, an IoT mobile-air pollution monitoring system (IoT-Mobair) was designed to monitor air pollution using Gas sensors for prediction. The output interface, which runs on a mobile platform, shows only gauge, which reads the air quality. When it encounters gaseous substance in the environment, the gauge rises according to the proportion of the pollution. Figure 4 shows the output interface of this system.

3.2 Performance Measurement for Time Complexity and Sensitivity

To check efficiency and reliability of the system, test was carried out in three stages. Stage 1 measures for precision, stage 2 measures for sensitivity and stage 3 measures for time complexity using different conditions. This is done to see how the system responds and take readings of the changes in the various stages. Table 1, 2, and 3 shows the readings gotten from the different conditions in the stages the system was deployed and tested under. The output interfaces for the conditions are also shown on the Figures 5, 6, 7, 8, and 9. The 3-conditions are: sunny day (measurement for precision), rainy day (measurement of sensitivity), and application of air pollutant (measurement of time complexity).

Figure 4: Output of the IoT Mobair (Dhingra et al,. 2019; Ibor et al. 2023)

Stage 1: Measurement for Precision (Sunny Day)

Table 1: Test Reading Table 1

	HUMIDITY (%)	AIR QUALITY (PPM)
Morning	*62*	*199*
Afternoon	70.7	206

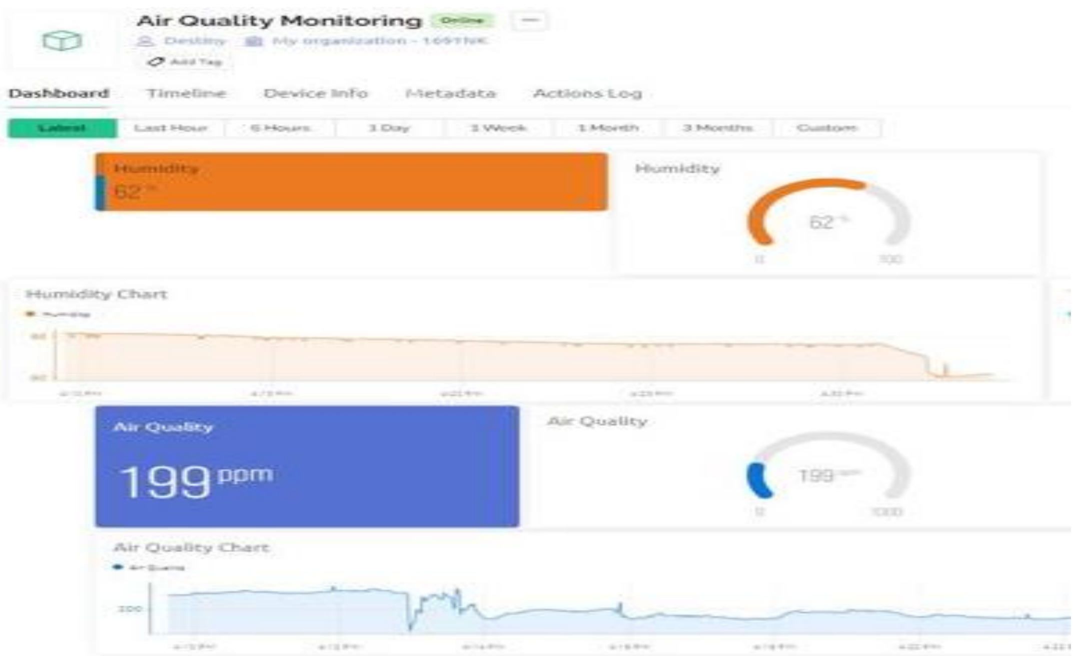

Figure 5: Output of Morning Readings (Sunny Day)

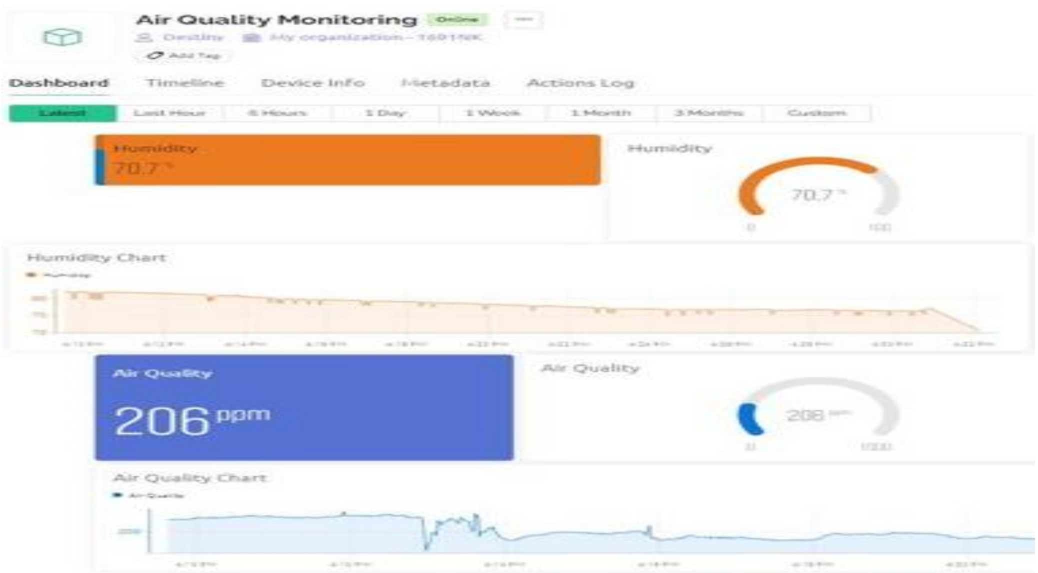

Figure 6: Output of Afternoon Readings (Sunny Day)

Stage 2: Measurement for Sensitivity (Rainy Day)

Table 2: Test Reading Table 2

	HUMIDITY (%)	AIR QUALITY (PPM)
Morning	*51.5*	*198*
Afternoon	79.4	192

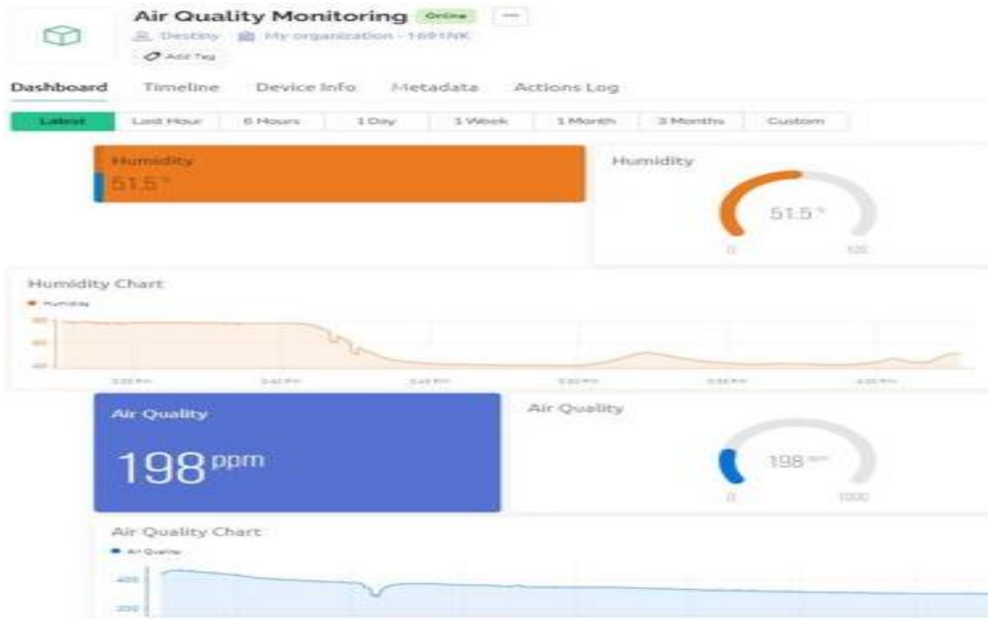

Figure 7: Output of Morning Readings (Rainy Day)

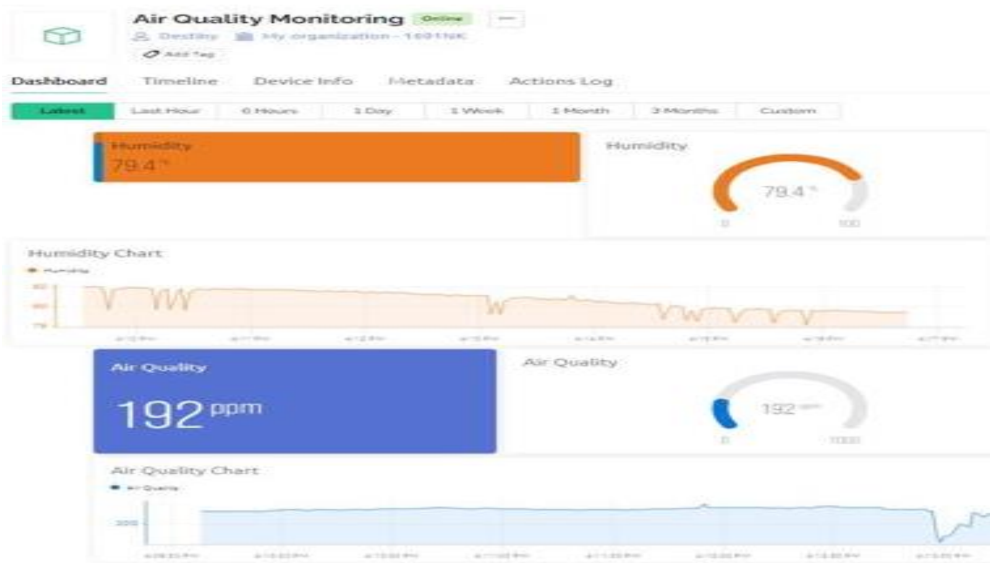

Figure 8: Output of Afternoon Readings (Rainy Day)

Stage 3: Measurement for Time Complexity (Application of air pollutants)

Table 3: Test Reading Table 3

	HUMIDITY (%)	AIR QUALITY (PPM)
Gas	*66.5*	*363*

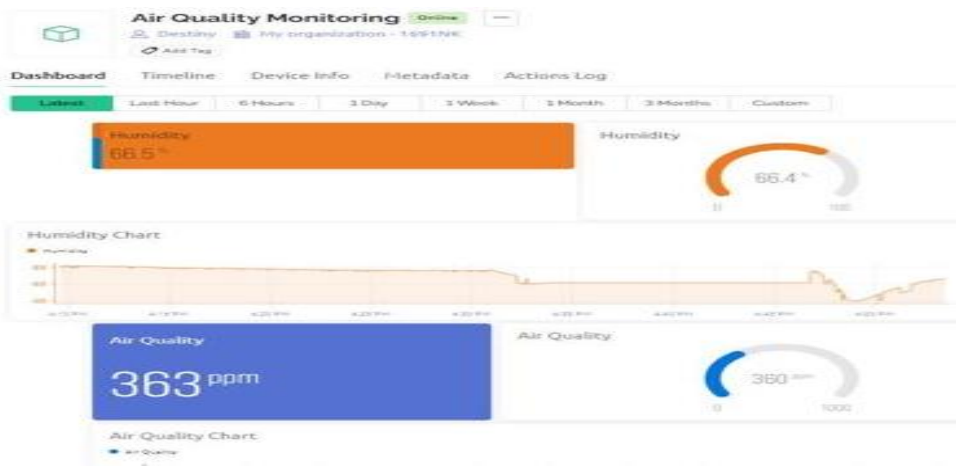

Figure 9: Output on Application of Gas

The system was tested in three stages. The result showed a high degree of accuracy and reliability. From the readings, it showed that the designed system is able to read the change in humidity and air quality at the different stages of the test as seen in the gauges and charts of the output interface.

4. CONCLUSION

This AMOS system is made from low-cost components that are readily available to be used to monitor several environmental parameters. This system can be used indoors and outdoors. The AMOS system is functionable and efficient because it was tested with different parameters. Finally, this device can connect to the gateway via WiFi without many design changes thus making it suitable for different scenarios. This System is consequently flexible and scalable. In the future, the research work is intended to introduce several machine-learning techniques that will give more insight to the user. Besides, to manage changes efficiently, the records can be kept in a secure immutable digital ledger using technologies like Blockchain.

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