Air quality monitoring system

Team member

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Introduction :

In this project, we are using DHT-11/22 (Temperature & Humidity Sensor) and MQ-135 (Gas sensor) to take the measurements of various parameters i.e., temperature, humidity and volumetric concentration(PPM) of various air pollutants like NH3, NOx, alcohol, Benzene, smoke, CO2, etc. Then this data is processed and converted into specified units(mg/m3) and then sent to the open-source data platform, Thing-speak in our case using Node MCU micro-controller. All the coding of the project is done in the Micro-Python language. This project actually helps to provide accurate readings of the temperature, humidity, and air quality index of the specific area/locality where the project will be deployed."

Air quality monitoring:

Air quality monitoring is a parameter used for determining the risk and forecast of public health due to rising levels of pollution, abnormal weather conditions, and climate change impact. The risk of public health increases as the value of AQI increases. There are a total of six, AQI categories, i.e. namely Good, Satisfactory, Moderate, Polluted, Poor, Very Poor, and Severe. The value of AQI is determined by taking a reading of a total of eight pollutants, that are, PM10, PM2.5, NO2, SO2, CO, O3, NH3, and Pb for nearly 24-hour averaging period.

Use of MQ-135 gas Sensor and PPM Calculation formula:

MQ-135 uses SnO2 as sensing material for its various pollutants. Its resistance decreases as the pollution level increases. The range of values in PPM for various pollutants are as below:

- Ammonia: 10 ppm-300 ppm
- Benzene: 10 ppm-1000 ppm
- Alcohol: 10 ppm-300 ppm

Converting PPM to Micro-grams per cubic meter :

Mg/m^3 = ppmv * M / (0.08205 * T)

Where,

- Mg/m^3 – Micro-gram of pollutant per cubic meter of air
- Ppmv – Air pollutant concentration in parts per million by volume
- M –Molecular weight of air pollutant
- T – Ambient Temperature in Kelvin
- 0.08205 – Universal Gas Constant.

"Demonstration

Step 1: Micro-Python Firmware Flash and Burn

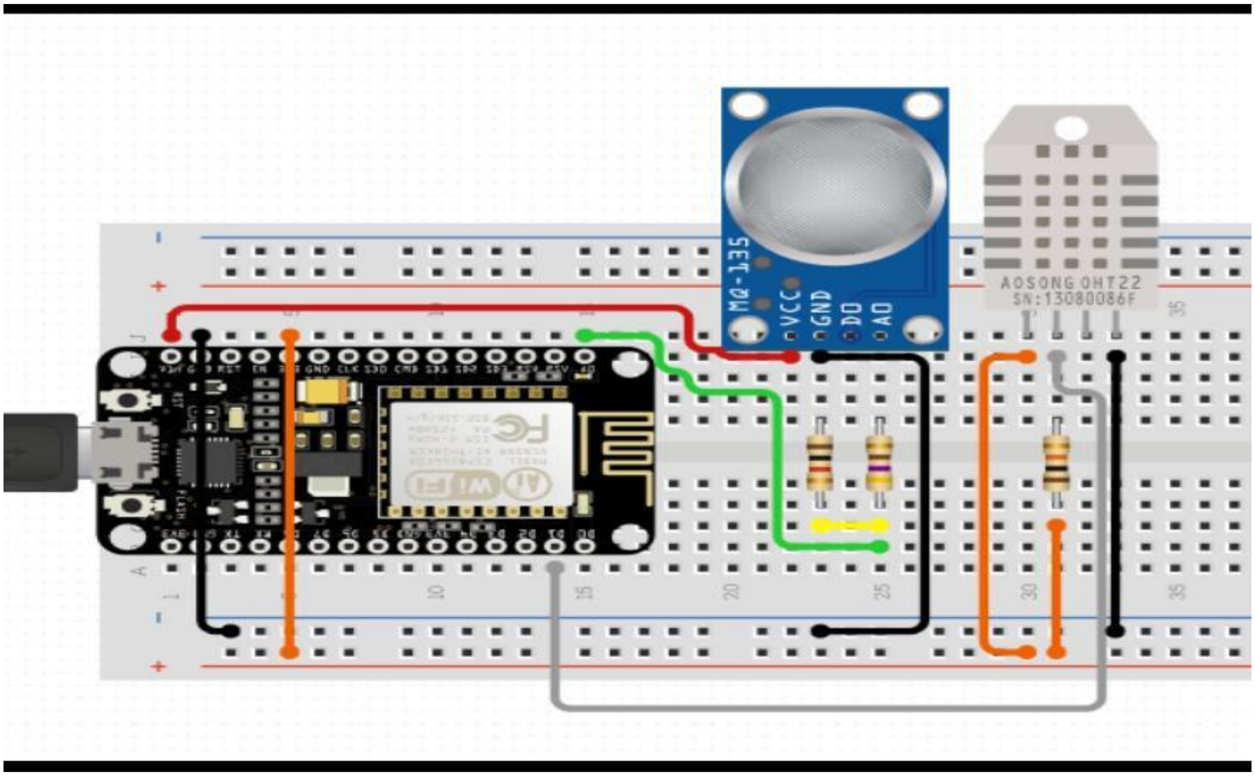
Firstly install Python 3.X on your computer, using the link https://www.python.org/downloads/

Then install Thonny IDE, using the link https://thonny.org

After installation of IDE go to https://micropython.org/download#esp8266 page and download the right firmware for your board.

Plugin the module and then open the Thony software. Go running> Select interpreter, select your ESP8266 as an interpreter, COM port, and firmware."

Step 2: Hardware Connections



2 : Connections for sensors for Nodemcu Module

Power to the module can be provided externally (+5V) or it may run when connected to your computer's USB Port.

Connect the MQ135 to the analog pin of the NodeMCU (A0).

Connect the DHT11/22 (Temperature & HumiditySensor) to the digital output pin of the module with a pull resistor of 10k to +Vcc(Not requires if you are using the module).

An Air Quality Monitoring System (AQMS) is a comprehensive system designed to measure and assess the quality of the air in a specific location or region. It plays a crucial role in environmental protection and public health. Here are the key components and functions of an AQMS:

1. **Sensors and Instruments:** AQMS typically includes various sensors and instruments to measure different air pollutants. Common measurements include particulate matter (PM2.5 and PM10), gases like nitrogen dioxide (NO2), sulfur dioxide (SO2), carbon monoxide (CO), ozone (O3), and volatile organic compounds (VOCs).

2. **Data Collection:** The sensors collect real-time data, which is then transmitted to a central database or control center. These data are used for continuous monitoring.

3. **Data Analysis:** Advanced software and algorithms are used to analyze the collected data. This analysis helps in determining the concentration of pollutants and assessing air quality.

4. **Reporting:** The AQMS generates reports and visual representations of air quality data, which can be shared with government agencies, environmental organizations, and the public. Real-time information is often made available to the public through websites and mobile apps.

5. **Alert Systems:** AQMS can trigger alerts or warnings when pollutant levels exceed safe thresholds. This information can be used to issue health advisories and take necessary actions to mitigate air quality issues.

6. **Quality Assurance and Calibration:** Regular calibration and maintenance of monitoring equipment are essential to ensure the accuracy and reliability of data.

7. **Regulatory Compliance:** Many AQMS are operated by government agencies to monitor compliance with air quality standards and regulations. They also help in assessing the impact of pollution control measures.

8. **Research and Trend Analysis:** Long-term air quality data collected by these systems are invaluable for environmental research and understanding trends in air quality over time.

9. **Source Identification:** AQMS can assist in identifying pollution sources and areas with high pollution levels, aiding in targeted interventions.

10. **Public Awareness:** AQMS contributes to raising public awareness about air quality and its impact on health, encouraging individuals and communities to take action to reduce pollution.

Overall, Air Quality Monitoring Systems are crucial tools for managing air quality, protecting public health, and addressing environmental challenges related to air pollution. They help governments, scientists, and the public make informed decisions and take actions to improve air quality and reduce the negative effects of air pollution.

Creating a mathematical tabulation for an Air Quality Monitoring System (AQMS) is complex and can involve a wide range of parameters and data. Here, I'll provide a simplified example of what such a tabulation might look like, focusing on the parameters monitored and the data collected:

Parameter	**Sensor Type**	**Measurement Unit**	**Sampling Frequency**	**Data Analysis Method**
Particulate Matter (PM2.5)	Optical or Gravimetric	µg/m³	Every 15 minutes	Real-time averaging
Particulate Matter (PM10)	Optical or Gravimetric	µg/m³	Every 15 minutes	Real-time averaging
Nitrogen Dioxide (NO2)	Chemiluminescence	Ppb	Hourly	Hourly averaging
Sulphur Dioxide (SO2)	UV Absorption	Ppb	Hourly	Hourly averaging
Carbon Monoxide (CO)	Non-Dispersive Infrared (NDIR)	Ppm	Hourly	Hourly averaging
Ozone (O3)	UV Absorption	Ppb	Hourly	Hourly averaging
Volatile Organic Compounds (VOCs)	PID or FID	Ppb/ppm	Continuous	Real-time averaging
Temperature	Thermocouple or RTD	°C	Every 5 minutes	Real-time averaging
Relative Humidity	Capacitive or Gravimetric	%RH	Every 5 minutes	Real-time averaging

- This table provides a simplified example of the parameters, sensor types, measurement units, sampling frequencies, and data analysis methods commonly used in an AQMS. In practice, AQMS can have more sensors and parameters, and the data analysis methods can be more sophisticated. The data collected would be used to assess air quality, generate reports, and trigger alerts when pollutant levels exceed safe limits.
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- It's important to note that real AQMSs are highly customized and tailored to specific environmental monitoring needs and regulatory requirements, so the tabulation may vary based on location and the specific objectives of the system.

Components:

- Air Quality Sensors (e.g., PM2.5, PM10, CO2, VOC, etc.).
- IoT Device (e.g., Raspberry Pi, Arduino, ESP8266/ESP32).
- Python Script for Data Collection.
- IoT Cloud Platform (e.g., AWS IoT, Google Cloud IoT, Azure IoT).
- Database for Storing Data (e.g., MySQL, MongoDB).
- Web Interface (optional).

Steps:

- Connect air quality sensors to the IoT device.
- Write a Python script to collect data from the sensors. You may use libraries like Adafruit_DHT for DHT sensors, or specific libraries for other sensors. Sample code to read sensor data may look like this:

Mini code:

```
Import Adafruit_DHT


Sensor = Adafruit_DHT.DHT22

Pin = 4  # GPIO pin where the sensor is connected


Humidity, temperature = Adafruit_DHT.read_retry(sensor, pin)


If humidity is not None and temperature is not None:
```

```
   Print(f"Temperature: {temperature:.2f}°C, Humidity: {humidity:.2f}%")
Else:
   Print("Failed to retrieve data from the sensor")
```

Code :

For this project, you'll need a boot.py file and a main.py file. Their specific roles are explained below-

1. **Boot.py file:-** The boot.py file has the code that only needs to run once on boot. This includes importing libraries, network credentials, instantiating pins, connecting to your network, and other configurations. We create our web server using sockets and the Python socket API.

The official documentation imports the socket library as follows:

```
Try:
    Import usocket as socket
Except:
    Import socket
```

We need to import the Pin class from the machine module to be able to interact with the GPIOs.

```
From machine import Pin
```

After importing the socket library, we need to import the network library. The network library allows us to connect the ESP32 or ESP8266 to a Wi-Fi network.

```
Import network
```

The MQTT protocol is supported in a built-in library in the Micropython binaries – this protocol is used to send data from your ESP8266, over WIFI, to a free cloud database.

We used umqtt.simple library , and knowing our SERVER ID, it is possible to create our MQTT client object :

```
From umqttsimple import MQTTClient
SERVER = “mqtt.thingspeak.com”

Client = MQTTClient(“umqtt_client”, SERVER)
```

The following lines turn off vendor OS debugging messages:

```
Import esp
esp.osdebug(None)
```

Then, we run a garbage collector:

```
import gc
gc.collect()
```

A garbage collector is a form of automatic memory management. This is a way to reclaim memory occupied by objects that are no longer used by the program. This is useful to save space in the flash memory.

The following variables hold network credentials:

```
ssid = '<your_ssid>'
password = '<your_network_password>'
```

Then, setting the ESP32 or ESP8266 as a Wi-Fi station:

```
station = network.WLAN(network.STA_IF)
```

After that, activating the station:

```
station.active(True)
```

Finally, the ESP32/ESP8266 connects to the router using the SSID and password defined earlier:

```
station.connect(ssid, password)
```

The following statement ensures that the code doesn’t proceed while the ESP is not connected to the network.

```
while station.isconnected() == False:
Pass
```

After a successful connection, print network interface parameters like the ESP8266 IP address – using the ifconfig() method on the station object.

Print('Connection successful')

Print(station.ifconfig())

Create a Pin object called led that is an output, that refers to the ESP8266 GPIO2:

Led = Pin(2, Pin.OUT)

Main.py file:- The main.py file contains the code that runs the webserver to serve files and perform tasks based on the requests received by the client.

First, we have to import the libraries for modules, sensors (MQ135, DHT) and for IoT Platform Thing-speak (MQTT Client) :

from machine import Pin

from time import sleep

import dht,math,time,network,micropython,esp

from machine import ADC

from umqttsimple import MQTTClient

import ubinascii

from MQ135 import MQ135

To initialise the sensors by creating a DHT and MQ135 instance as follows :

sensor_dht = dht.DHT11(Pin(5))

sensor_mq135 = MQ135(0)

Then create MQTT client instance and write your channel ID , write APi key from channel created on ThingSpeak. Then create MQTT "Topic"

SERVER = "mqtt.thingspeak.com"

client = MQTTClient("umqtt_client", SERVER)

CHANNEL_ID = "<your_channel_ID>"

WRITE_API_KEY = "<your_channel_write_API_key>"

Topic = “channels/” + CHANNEL_ID + “/publish/” + WRITE_API_KEY

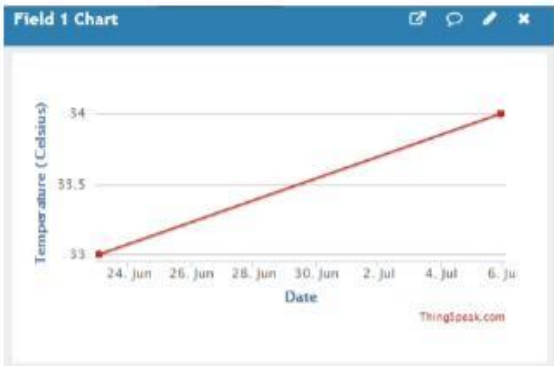
Run the loop to measure the temperature, humidity, air quality with the help of sensors as follows :

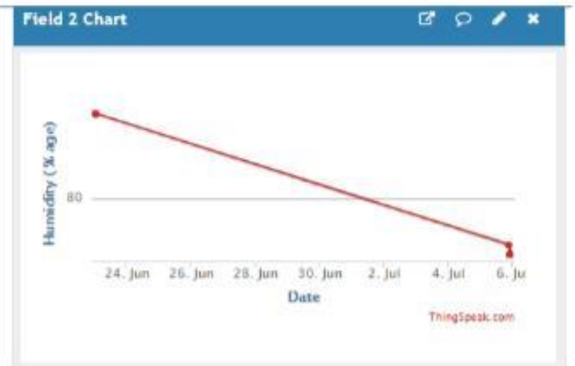
```
while true:
    sensor_dht.measure()
    temperature = sensor_dht.temperature()
    humidity = sensor_dht.humidity()

    Rzero = sensor_mq135.get_rzero()
    Corrected_rzero = sensor_mq135.get_corrected_rzero(temperature, humidity)
    Resistance = sensor_mq135.get_resistance()
    Ppm = sensor_mq135.get_ppm()
    Corrected_ppm = sensor_mq135.get_corrected_ppm(temperature, humidity)
```

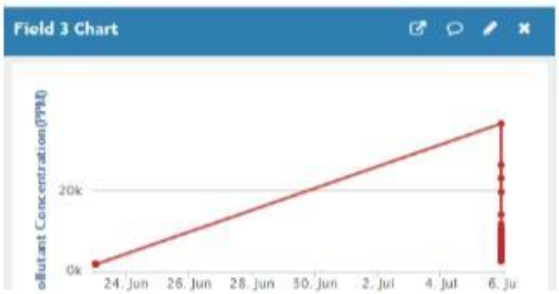
With those variables updated, we created our “MQTT Payload” and that’s it! We are ready to send data to ThinsSpeak :

```
Payload =
“field1=”+str(temperature)+”&field2=”+str(humidity)+”&field3=”+str(corrected_ppm)

    Client.connect()
    Client.publish(topic, payload)
    Print(“Payload published successfully”)
    #print(publish_check)
    Client.disconnect()
    Time.sleep(30)
```

Now, if we go to our channel page you will see that each field is having data related to the sensors :







We can easily connect our server to the circuit by the simple steps. One can follow the guide, if a novice, which is provided on the website of this particular server.

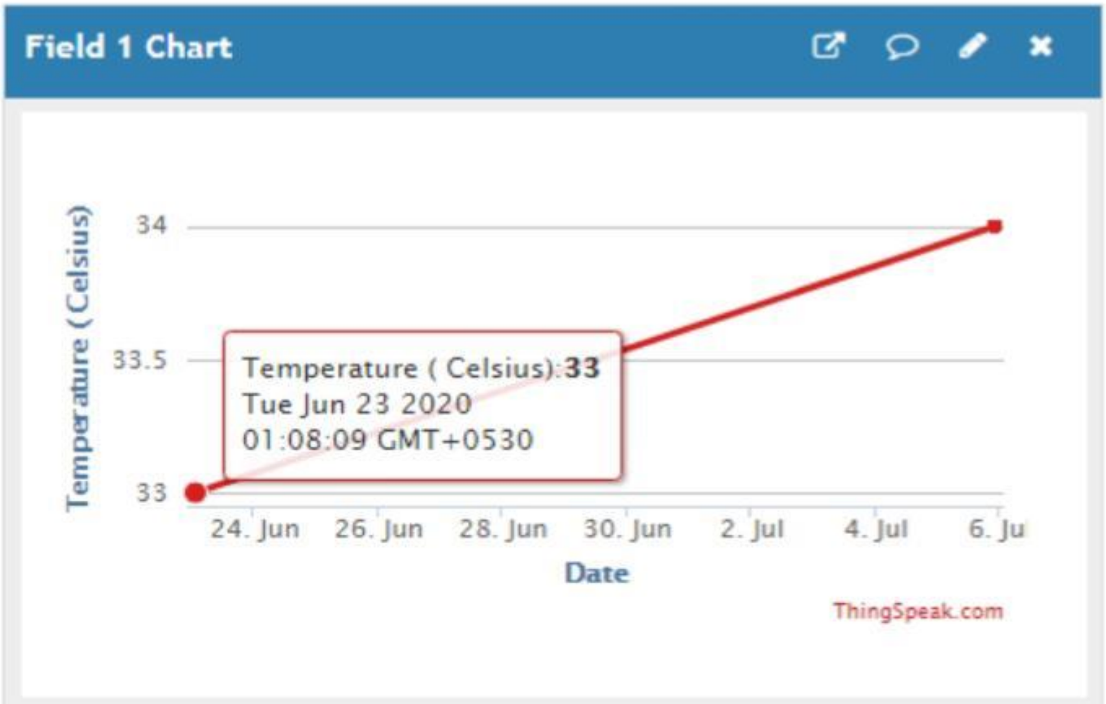
2. Adding the libraries for sensors and IoT Platform :

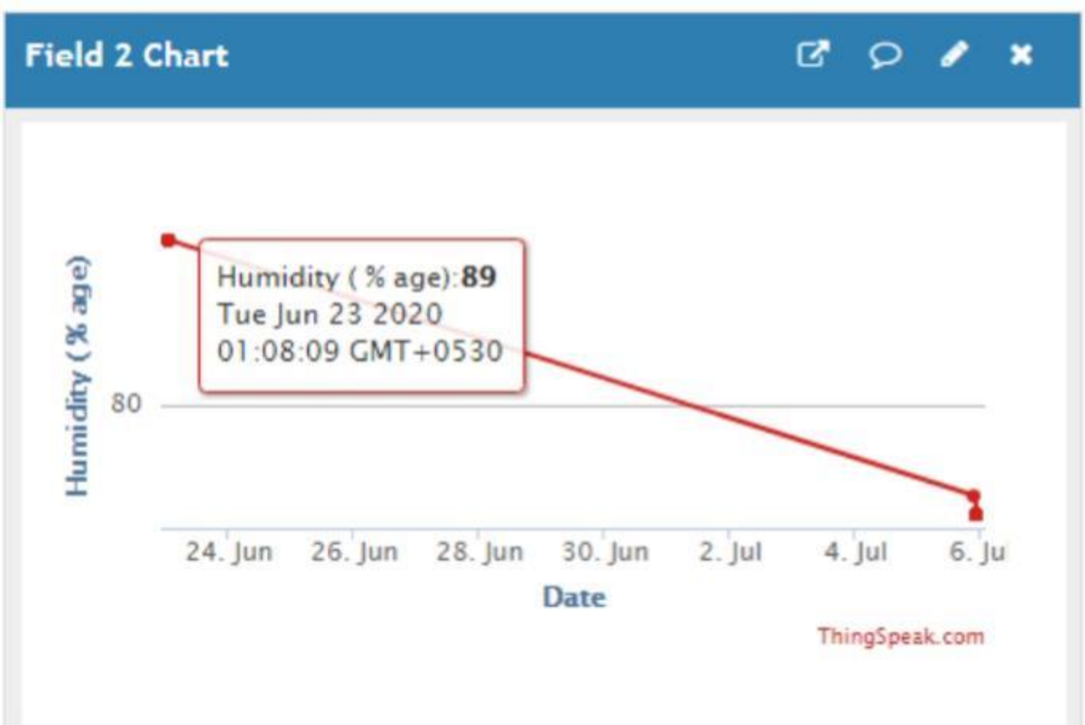
To work with the Gas sensor module and Thing-speak server, we need to upload libraries for each in the code section, else there would be hurdles on the path of the outcome. Links for MQ135 Library and umqttsimple.py Library are provided in the folder in the code section named as “Final Code”.

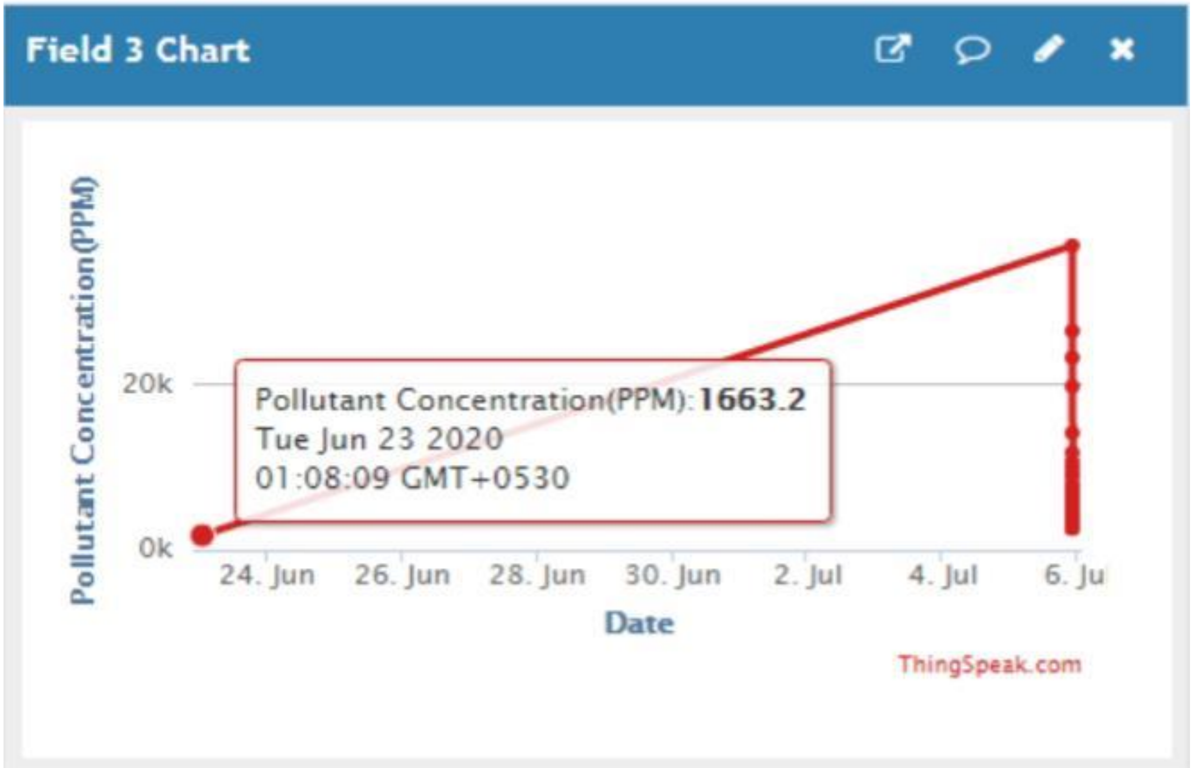
Result :

There are different readings of each and every module at distinct time intervals which are recorded in a chart displayed at the online server- Thingspeak. These readings are shown below in different graphs.

Output :


Field 1 Chart
Temperature (Celsius)
34
33.5
33
Temperature (Celsius):33
Tue Jun 23 2020
01:08:09 GMT+0530
24. Jun
26. Jun
28. Jun
30. Jun
2. Jul
4. Jul
6. Ju
Date
ThingSpeak.com


Field 2 Chart
Humidity (% age)
80
Humidity (% age):89
Tue Jun 23 2020
01:08:09 GMT+0530
24. Jun
26. Jun
28. Jun
30. Jun
2. Jul
4. Jul
6. Ju
Date
ThingSpeak.com



Conclusion :

The module is capable of doing analytics and storing the values measured from two different sensors. It can be extended to further integrate more sensors like Dust sensors. The concept of IoT enables comprehensive data assimilation that reveals critical information about the quality of air, the level of temperature and humidity, and the presence of various gases present in the environment. ThingSpeak platform is highly useful to analyze the Cloud data on the environmental condition, as an air quality monitoring system. This can help the general public to know the risk to their health due to wet and dry conditions. For example, high indoor humidity causes the air too dry, so people having diseases like whizzing will be more affected, and also for normal people, it is difficult to stay in that environment.