IOT based Air Quality Monitoring System

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Abstract

With rapid advancement in technology, the air pollution levels are growing at an alarming rate. According to a worldwide study done by Green Car Congress in 2019, about 120 deaths out of 100,000 per year are caused due to air pollution. WHO emphasises that about 97% of cities in middle and low income countries do not meet the air quality guidelines. The toxic gases pose serious environmental and increase potential health risks such as stroke, heart disease, lung cancer, asthma, and several other life altering diseases. Thus, proper monitoring of air and noise pollution is required to ensure healthy and better future. This project proposes a universal, efficient, and cost-effective air quality monitoring device that uses gas sensors to measure air quality levels in a particular area. This data is then constantly transmitted over the cloud, ensuring real-time monitoring in an area. This allows the concerned parties to keep track of air quality levels and enact necessary measures to curb pollution levels in the affected areas.

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Introduction

In developing countries like India, air pollution poses a major hazard to healthy living. In countries like India, people will spend their hard-earned money only on things which they require, afford and can be versatile in terms of their function.

In this project, we propose a cost-effective air quality monitoring system integrated with weather sensing functionalities using NodeMCU, MQ135 gas sensor, BME280 sensor and ThingSpeak Cloud Platform for visualisation.

IoT (Internet of Things) has become an integral part of our lives and it has already made an impact in various sectors, including the environment. Air pollution is a severe problem that has been affecting our planet for years. Therefore, there is a need for a reliable and efficient air pollution monitoring system to protect ourselves from its hazardous effects. An IoT-based air pollution monitoring system is an ideal solution that can provide real-time data and insights about the air quality in a particular area.

An IoT based air pollution monitoring system consists of several hardware and software components that work together to collect and process data. The hardware components include sensors, microcontrollers, and communication modules. The software components consist of a cloud platform, a mobile application, and a web-based dashboard.

The IoT-based air pollution monitoring system provides several benefits over traditional air pollution monitoring systems. It can collect real-time data from multiple locations, which then analyzed to identify the sources of pollution. It helps to take necessary measures to reduce it.

The system can also alert the users if the air quality reaches a dangerous level, allowing them to take precautions to protect themselves.

Monitor Air Quality: The primary purpose is to continuously monitor and measure various air pollutants, such as particulate matter (PM), nitrogen dioxide (NO_2), ozone (O_3), sulfur dioxide (SO_2), carbon monoxide (CO), and volatile organic compounds (VOCs) in the ambient air.

Real-time Data Collection: The system aims to collect real-time data on air quality, enabling immediate awareness of pollution levels and trends.

Early Warning System: By detecting changes in air quality, the system can serve as an early warning system for potential health hazards and environmental risks.

Environmental Protection: The system supports efforts to protect the environment by identifying pollution sources and evaluating the impact of emissions on air quality.

Public Health Improvement: By providing accurate and up-to-date air quality information, the system helps individuals and authorities take measures to protect public health, especially for vulnerable groups like children, elderly, and individuals with respiratory conditions.

Compliance Monitoring: The system aids in ensuring compliance with air quality regulations and standards set by local, regional, and national authorities.

Data Analytics and Insights: Collected data can be analyzed to gain insights into air pollution patterns, contributing factors, and long-term trends.

Decision-making Support: The system provides valuable data to support informed decision-making by governments, businesses, and individuals in areas like urban planning, industrial operations, and personal activities.

IoT Integration: The use of IoT technology allows for seamless data transmission, remote monitoring, and system scalability.

Environmental Research: Data collected from these systems can support environmental research and studies on air pollution, climate change, and public health.

IoT Monitoring System components

IoT-based air pollution monitoring systems comprise several components that work together to collect and analyze air quality data. The components include:

Sensors: Sensors are the primary components of IoT-based air pollution monitoring systems. They measure various air quality parameters such as particulate matter, carbon monoxide, sulfur dioxide, and nitrogen oxides. The sensors can be classified into two categories: physical and chemical sensors. Physical sensors measure parameters such as temperature, humidity, and pressure, while chemical sensors measure air pollutants.

Microcontroller: The microcontroller is the brain of IoT-based air pollution monitoring systems. It receives data from the sensors, processes it, and sends it to the cloud server. The microcontroller is usually a microprocessor such as Arduino, Raspberry Pi, or similar devices.

Communication Module: The communication module is responsible for transmitting data from the microcontroller to the cloud server. Communication modules can use various wireless technologies such as Wi-Fi, Bluetooth, or cellular networks.

Cloud Server: The cloud server is a centralized platform for storing, analyzing, and sharing air quality data. It collects data from the communication module and stores it in a database. The cloud server also provides web and mobile applications for users to access the data.

Power Supply: IoT-based air pollution monitoring systems require a power supply to operate. In case of permanent installations external power supply is provided and batteries are provided for portable devices.

Enclosure: The enclosure is the outer covering that protects the components from environmental factors such as dust, water, and temperature.

In Short, the sensors measure air quality parameters, the microcontroller processes the data, the communication module sends the data to the cloud server, the cloud server stores and analyzes the data, and the power supply and enclosure provide power and protection to the system. By working together, these components enable the development of accurate and reliable air pollution monitoring systems.

Usage of Monitoring System

The IoT-based air pollution monitoring system can be used in various settings, including residential, industrial, and urban areas. It can also be integrated with existing air pollution monitoring systems to enhance their capabilities. The system can provide valuable data to government agencies, researchers, and the public to make informed decisions about air pollution.

One of the significant advantages of an IoT-based air pollution monitoring system is its scalability. The system can be easily scaled up or down based on the needs of the users. It can be customized to meet the specific requirements of a particular location, making it a versatile solution for air pollution monitoring.

An IoT-based air pollution monitoring system is a revolutionary solution that can provide accurate and real-time data about the air quality in a particular area. It can help identify the sources of pollution and take necessary measures to reduce it, protecting the environment and human health.

With its scalability and versatility, the IoT-based air pollution monitoring system can be used in various settings and integrated with existing air pollution monitoring systems, making it an ideal solution for air pollution monitoring.

While air is definitely essential to sustain life, its influence on industries is far greater. The quality of air determines the performance of workers which further influences the productivity and efficiency of the entire plant.

Air also affects the operational costs of a company. Corrosive particles and gases present in the atmosphere can act as a catalyst for rusting and decomposition of the metal body of various industrial equipment, resulting in more repair and maintenance expenses. Furthermore, the presence of air or increased concentration of a particular gas in the air can affect the manufacturing processes, resulting in reduced quality of manufactured goods.

Quality of air hence plays a major role in determining the overall performance of an industry. Especially in industries like mining, oil and gas, chemical, etc.; which deals with harmful gases or are subjected to aerosols; the air quality monitoring systems are a must.

Using IoT as an Air Quality Monitor:

IoT as an interconnective device acts as a perfect medium to determine the quality of air in a particular facility. High-end devices like sensors and meters embedded in strategic places can be used to ascertain the air quality index (AQI) or identify the presence of a particular harmful gas.

Powered with features such as real-time monitoring, multi-channel alerts, and advanced analytics; IoT systems are the best tools to monitor air quality. The data is transmitted to a centralized platform without any latency that enables the monitoring of AQI of a location from anyplace.

An IoT-based air quality monitoring system has numerous applications across various domains. Some examples:

1. Environmental Monitoring: IoT-based air quality monitoring systems can be deployed in cities, industrial areas, and residential areas to continuously monitor air pollution levels. This data can help identify pollution sources, track pollutant trends, and assess the effectiveness of pollution control measures.

2. Health and Safety: These systems can be used in hospitals, schools, and workplaces to monitor indoor air quality and ensure a healthy environment. They can detect harmful gases, volatile organic compounds (VOCs), and particulate matter, providing early warnings and allowing prompt action to be taken to protect people's health.

3. Smart Homes: IoT devices can be integrated into home automation systems to monitor indoor air quality and automatically control ventilation, air purifiers, and HVAC systems. This helps maintain a healthy and comfortable living environment.

4. Industrial Applications: IoT-based air quality monitoring systems are valuable in industrial settings to monitor emissions, chemical leaks, and workplace air quality. Real-time data can be used to optimize industrial processes, ensure compliance with environmental regulations, and protect the health of workers.

5. Urban Planning: City planners can utilize air quality data collected from IoT devices to make informed decisions regarding urban development, transportation infrastructure, and zoning. This helps in designing cities that prioritize environmental sustainability and public health.

6. Traffic Management: IoT-based air quality monitoring systems can be integrated with traffic management systems to identify areas with high pollution levels. This information can be used to implement traffic control measures, reroute traffic, or develop emission reduction strategies to minimize pollution hotspots.

7. Research and Policy Development: Long-term data collected by IoT-based air quality monitoring systems can be used by researchers and policymakers to understand air pollution patterns, evaluate the effectiveness of environmental policies, and develop strategies to mitigate pollution and improve air quality.

8. Personal Health and Fitness: IoT devices that monitor air quality can be integrated into wearable health trackers, providing individuals with real-time information about the air they are exposed to. This data can help users make informed decisions about their activities and avoid areas with poor air quality.

9. Agriculture: IoT-based air quality monitoring can benefit agricultural practices by monitoring air pollution levels around farms and greenhouses. This data can help optimize crop production, protect livestock health, and ensure the quality of agricultural products.

10. Citizen Engagement: Air quality monitoring systems can engage citizens by providing real-time data through mobile applications or websites. This empowers individuals to make informed choices, such as avoiding heavily polluted areas or adjusting their activities based on air quality conditions.

Literature Review

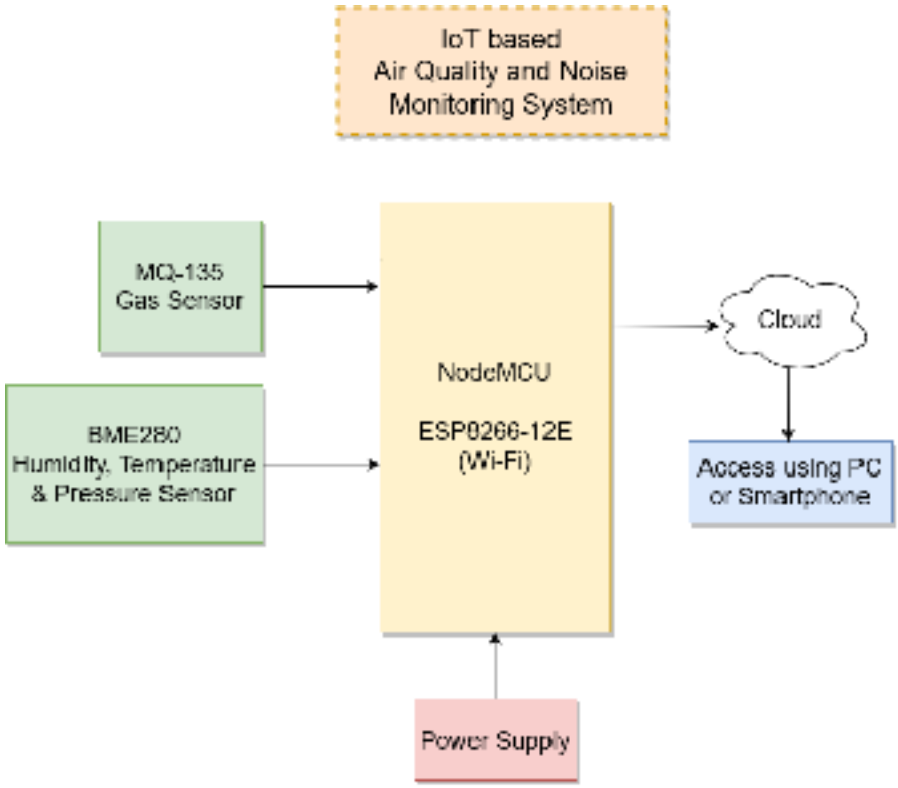
Title	Author	Journal/ Conference	Year	Findings
A New Black Crabon Sensor for Dense Air Quality Monitoring Networks	J. J. Caubel, T.E. Cados, T.W. Krichstetter	IEEE	2018	A new BC sensor—the Aerosol Black Carbon Detector (ABCD)- designed for dense deployment in air quality monitoring networks was presented. This sensor provides Black Carbon concentration in the atmosphere. The system uses photodiodes and RH/T sensors interfaced with a Microcontroller Unit.
An IoT Based Air Pollution Monitoring System for Smart Cities	Harsh Gupta, Dhananjay Bhardwaj, Himanshu Agrawal, Vinay Anand Tikkiwal, Arun Kumar	ICSETS	2019	Proposed an IoT Based Air Pollution Monitoring System for Smart Cities, which uses multiple sensors to continuously monitor atmospheric parameters like Temperature, Humidity, CO, Smoke, LPG, PM 2.5, and PM 10 levels. They proposed a Raspberry Pi system that sends its data to a ThingSpeak Channel over the cloud, and the same data is visualised over a mobile application. The mobile application was equipped with firebase API providing features like Authentication, Messaging, Analytics, etc.
A mobile application for assessment of air pollution exposure	G. Lo Re, D. Peri, S. D. Vassallo	IEEE	2013	A system over Arduino was proposed that collects air quality related data using sensors like MQ7, MQ2 and MQ135 and communicated this data to a user through a mobile application. The data collected is uploaded over the cloud i.e., Ubidots using Internet connection through ESP8266 module. The app also uses historical data collected from the sensors to train and execute a prediction model.

IoT Based Air Pollution Monitoring System using Arduino	Monika Singh, Misha Kumari, Pradeep Kumar Chauhan	International Research Journal of Engineering and Technology, IRJET	2019	Proposed an IoT Based Air Pollution System interfacing hardware through Arduino microcontroller. The system is equipped with MQ135 and MQ6 gas sensors, which senses different types of gases in the air. Access to the internet is provided through the addition of a Wi-Fi module. An LCD panel and buzzer is used to communicate data to the user.
IoT based air pollution monitoring and predictor system on Beagle Bone Black	Nitin Sadashiv Desai, John Sahaya Rani Alex	International Conference on Nextgen Electronic Technologies, ICNET	2017	Proposed a system over the beagle bone interface that measures the levels of CO2, CO, and noise in the environment. Data was aggregated over Azure Cloud using python SQL. A reserved database in the form of .CSV file is created over the beagle bone, the same is them uploaded over the cloud and then deleted at end of the day. This data is then used to train a Machine Learning service.
Air Quality Monitoring System Based on ISO/IEC/IEEE 21451 Standards	K. S. E. Phala, A. Kumar, and Gerhard P. Hancke	IEEE	2016	Proposed an air quality monitoring system that is composed of a monitoring station, communication links, a sink node, and a data server. They created a GSM module-based sink node with data server as a PC. The data was collected and stored on a micro-SD card in text format and the data server. They used MySQL database. Infrared and electrochemical sensors were used to measure CO, CO2, SO2 and NO2 levels in the air. A test incubator was constructed to evaluate the performance of the senor unit. The base station consists of a sink node and a master computer equipped with a GUI application. The data flows from the sensor node to the sink using GSM and then the same is transferred over to the master computer for visualisation and storage.

IoT based air pollution monitoring system using Arduino	Poonam Pal, Ritik Gupta, Sanjana Tiwari, Ashutosh Sharma	IRJET	2017	Proposed a system to monitor air quality using Arduino. They utilised the MQ135 sensor to sense different types of harmful gases. The sensor outputs were configured to provide a PPM reading. The system was interfaced with a Wi-Fi module to provide internet access to enable communication with the webpage and LCD panel was used to provide visual output.
Iot Based Air and Sound Pollution Monitoring System	Rajat Sankhe, Pravin Shirodkar, Avinash Nangare, Abhishek Yadav, Gauri Salunkhe	IJERT	2017	Proposed a system using carbon sensors for sensing Carbon particulates and other pollutants in the air and provides output as analog readings which are later converted into Digital readings by the ADC. The values are communicated visually through an LCD display. If the pollutants exceed a certain threshold buzzer was sounded and a notification is sent on the webpage over a smart phone using a GPRS module.
Internet of Things Mobile – Air Pollution Monitoring System (IoT-Mobair)	Swati Dhingara, Rajasekhara Babu Madda, Amir H. Gandomi, Rizwan Patan, Mahmoud Daneshmand	IEEE	2019	Describes an implementation of an IoT based air pollution detection using a Wireless Sensor Network (WSNs) and a Mobile Application (IoT-Mobair). The mobile application also incorporates Google Maps Navigation. The proposed system uses Arduino Uno, ESP8266 Wi-Fi module, gas sensors, Ubidots cloud service and Android Application. The application provides location specific Air Quality indices, Health related information,
IoT Enabled Air Pollution Monitoring and Awareness Creation System	Yamunathangam, K. Pritheka, P. Varuna	IRJET	2018	Average pollution index was computed using matlab algorithm and time-controlled results were communicated through an android app. The app also provided location-based air quality index and health related information to ensure user awareness.

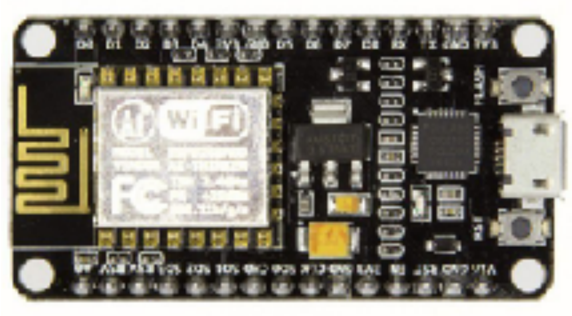
Proposed Architecture

The following diagram represents the various hardware components and software dependencies of the proposed system. The major hardware components include NodeMCU, MQ135 gas sensor and BME180 Humidity, Temperature and Pressure sensor. Secondary components include a power supply like solar powered or rechargeable battery. Software dependencies include Arduino IDE for deployment of programming code onto the microcontroller and ThingSpeak for data visualisation over the web.



Hardware Requirements

1. **<u>NodeMCU (ESP8266):</u>** It is a development board (Microcontroller) which includes firmware that runs on the ESP8266 Wi-Fi SoC from Espressif Systems, and hardware which is based on the ESP-12E module. It is used for circuiting and allows data transfer using the Wi-Fi protocol.



2. **<u>BEM280 Humidity, Temperature & Pressure, Sensor</u>**: It is an integrated environmental sensor which is very small sized with low power consumption. This Atmospheric Sensor Breakout is the easy way to measure barometric pressure, humidity, and temperature readings all without taking up too much space. It works on I2C Communication.

3. **<u>MQ135 Gas Sensor</u>**: The MQ135 gas sensor senses the gases like ammonia nitrogen, oxygen, alcohols, aromatic compounds, sulfide and smoke. MQ135 gas sensor can be implemented to detect the smoke, benzene, steam, and other harmful gases. It has the potential to detect different harmful gases. It is at a low cost and particularly suitable for Air quality monitoring applications. It has two outputs: analog output and TTL output. The TTL output is low signal light that can be accessed through the IO ports on the Microcontroller. The analog output is a concentration i.e., increasing voltage is directly proportional to increasing concentration. This sensor has a long life and reliable stability as well.

BME280 can also be replaced with DHT11 or DHT22 temperature and humidity sensors.

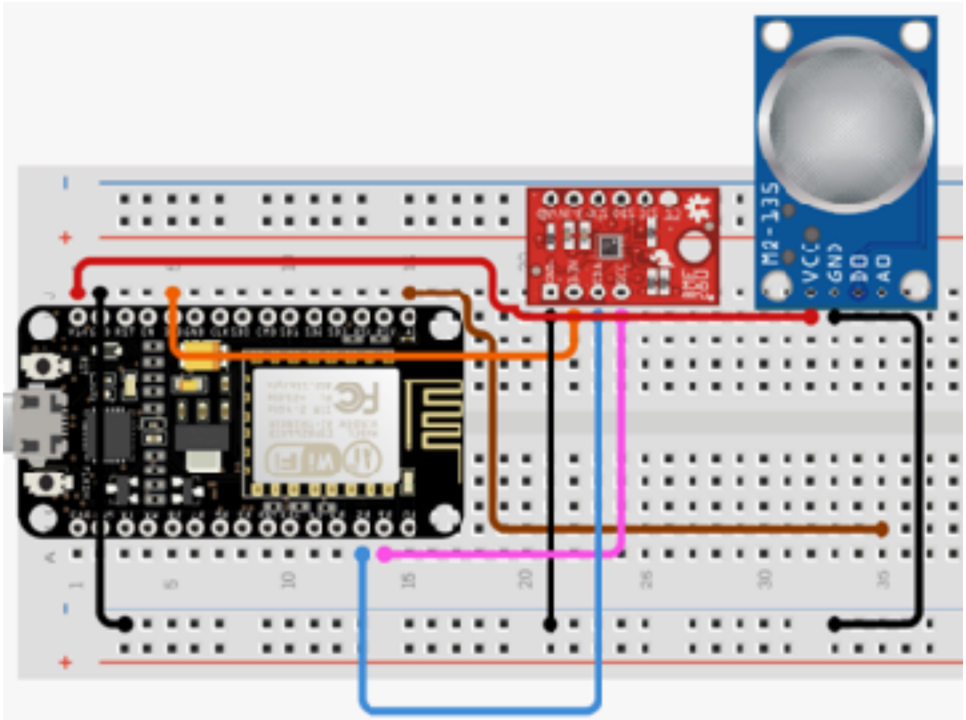
Software Requirements

1. **<u>The Arduino Integrated Development Environment (IDE)</u>:** It is the main text editing program used for Arduino programming. It is where you'll be typing up your code before uploading it to the board you want to program. Arduino code is referred to as sketches.

2. **<u>ThingSpeak</u>**: It is an IoT analytics platform service that allows you to aggregate, visualize, and analyse live data streams in the cloud. We can send data to ThingSpeak from your devices, create instant visualization of live data, and send alerts.

Proposed Circuit

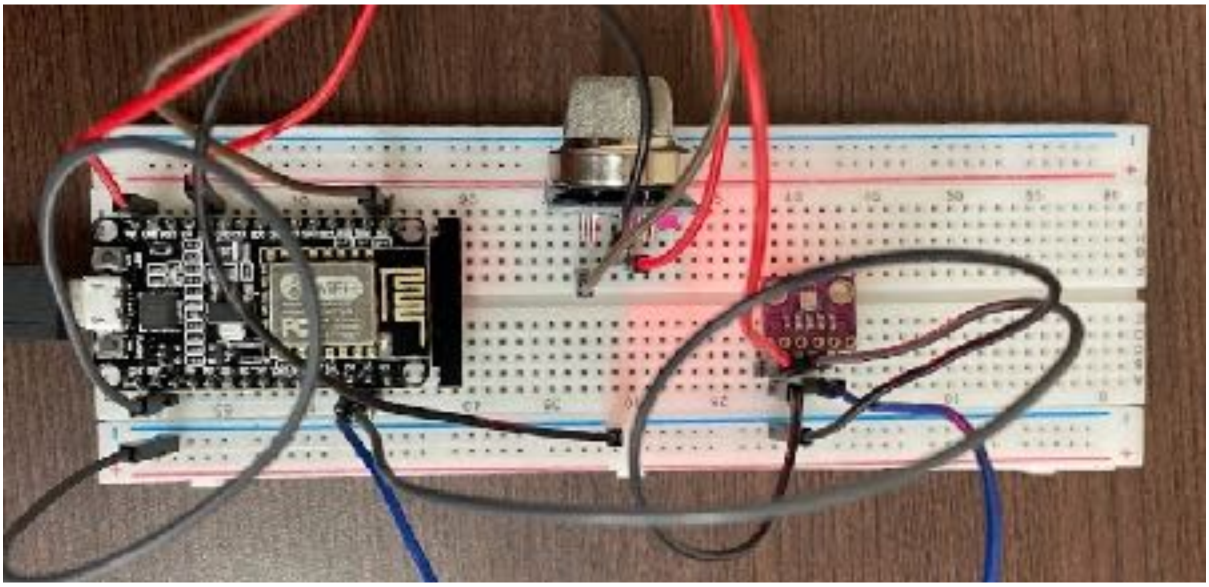
MQ135 is an analog sensor so connect its A0 pin to A0 pin of NodeMCU. Connect the VCC pin to Vin 5V & GND to GND on breadboard. And then we have BME280 Sensor which works on I2C Communication so connect it SCL & SDA pin to I2C pin of NodeMCU i.e., D1, D2.



The proposed circuit can be configured/modified based on the functionalities needed. For example, addition of MQ6 gas sensor for LPG detection.

Implementation

Circuiting



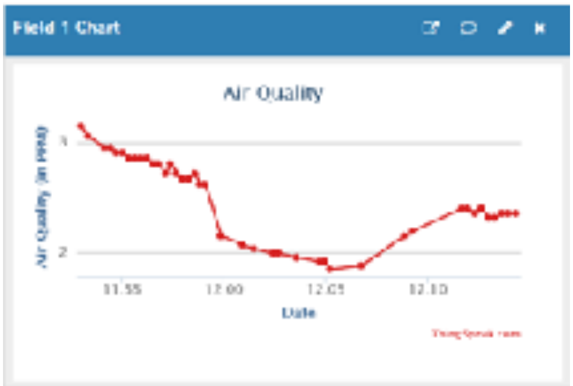
Code

```
#include <ESP8266WiFi.h>
#include <Wire.h>
#include <Adafruit_Sensor.h>
#include <Adafruit_BME280.h>
#include "MQ135.h"
#include <Arduino.h>
#include "ThingSpeak.h"

float h, t;
Adafruit_BME280 bme;

const char* apiKey = "B188N8MI5X2B0OS3";
const char* ssid = "Ayush";
const char* password = "ayushsaha";
const char* server = "api.thingspeak.com";

WiFiClient client;
void setup(){
  Serial.begin(9600);
  delay(10);
  Serial.println();
  Serial.print("Connecting to ");
  Serial.println(ssid);
  WiFi.begin(ssid, password);

  while (WiFi.status()!= WL_CONNECTED) {
    delay(500);
    Serial.print(".");
  }
  Serial.println("");
```

```
  Serial.println("WiFi connected");

  Serial.println(WiFi.localIP());
  if (!bme.begin()){
    Serial.println("Could not find a valid BME280 sensor, check
wiring!");
    while (1);
  }
  ThingSpeak.begin(client);
}

void loop(){
  static unsigned long OledTimer=millis();
    if (millis() - OledTimer >=10000){
      OledTimer=millis();
      MQ135 gasSensor = MQ135(A0);
      float air_quality = gasSensor.getPPM();
      Serial.print("Air Quality: ");
      Serial.print(air_quality);
      Serial.println("  PPM");
      Serial.println();
      ThingSpeak.setField(1, air_quality);
      h = bme.readHumidity();
      t = bme.readTemperature();
      t = t*1.8+32.0;
      ThingSpeak.setField(2, t);
      ThingSpeak.setField(3, h);
      ThingSpeak.writeFields(1706264, apiKey);
      Serial.print("Temperature = ");
      Serial.println(t);
      Serial.print("Humidity = ");
      Serial.println(h);


Serial.println("...............................................");
    }
  }
```

Result and Conclusion

The proposed air quality monitoring system provides data about the air quality, temperature, and humidity, which can be easily visualised through plots over the ThingSpeak channel. This allows the user to keep track of their exposure to polluted air and make necessary lifestyle changes to safeguard their health. The project also focuses on making air quality monitoring systems accessible to all, which is done by reducing costs by switching high end sensors with cost effective and reliable sensors.



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