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The Air Alchemist - Environmental Monitoring of Poisonous Gases

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***Abstract*— This paper presents about Air pollution is a growing problem that puts people's and communities' health at serious risk. Conventional air quality monitoring systems frequently lack real-time data accessibility, have restricted coverage, and are expensive. This project suggests creating an Internet of Things-based air quality monitoring system that offers real-time information on air pollution levels in order to overcome these constraints. The system continuously measures the concentration of dangerous gases and particulate matter using BME680 sensors that are integrated with ESP-8266 and linked to a cloud-based platform. A user-friendly interface allows for remote access to the wirelessly transmitted data. Furthermore, the system is integrated with made to immediately sound an alarm when pollution levels surpass predetermined limits, allowing for prompt action to enhance the environmental safety and health of households. This economical and effective solution provides a scalable strategy to improve air quality monitoring, supporting environmental sustainability and public health.**

***Index Terms*— Health, Pollution, Air, Quality, Sound Alarm, Economics, Environment.**

I. INTRODUCTION

The World Health Organization (WHO) reports that air pollution is one of the leading causes of premature deaths worldwide, with millions of people suffering from the effects of prolonged exposure to harmful air pollutants. To address this issue, an efficient and cost-effective approach to monitoring and mitigating air pollution in real-time is required [1][2]. Rapid urbanization, industrial expansion, and increasing vehicular emissions have led to a sharp rise in air pollution levels, necessitating continuous and effective monitoring of air quality and environmental organizations, involve the use of high-cost, stationary monitoring stations that provide limited coverage [3][4].

These systems, while accurate, are not accessible to the general public and often lack real-time data accessibility. Consequently, there is a growing demand for affordable, scalable, and real-time monitoring solutions that can be deployed in both urban and rural settings to provide localized air quality insights [5][6].

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The advancement of the Internet of Things (IoT) has opened new possibilities in environmental monitoring, offering innovative solutions for tracking and analysing air pollution levels. IoT-based air quality monitoring systems integrate low-cost gas sensors with microcontrollers, wireless communication technologies, and cloud-based data storage to provide real-time monitoring of air pollutants [7][8].

These systems offer several advantages, including affordability, accessibility, and scalability, making them suitable for Particulate matter (PM), carbon monoxide (CO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), ozone (O_3), and volatile organic compounds (VOCs) are among the dangerous substances that make up air pollution [9][10]. These pollutants come from a variety of sources, including the burning of fossil fuels, vehicle exhaust, industrial emissions, and natural occurrences like dust storms and wildfires. High concentrations of these pollutants can have detrimental effects on health, especially for vulnerable groups like children, the elderly, and people with underlying medical conditions [11][12].

Beyond its effects on human health, air pollution has an impact on the environment, causing problems like acid rain, climate change, and ecosystem degradation. Excessive levels of air pollutants can erode infrastructure and buildings, harm crops, and impair vision. The necessity of monitoring and reducing air pollution is essential to guaranteeing a more sustainable and healthy future [13][14]. To precisely measure air pollution levels, traditional air quality monitoring stations use complex and costly equipment. Usually maintained by environmental organizations, these stations are positioned thoughtfully in particular areas. Although these systems offer accurate data, they have a number of drawbacks [15][16].

Traditional air quality monitoring stations are expensive to install and maintain, which prevents their widespread use in residential areas. Furthermore, because these stations are stationary, they only provide data for a limited area, missing regional variations in pollution. Response times are delayed because the data gathered by these stations is frequently processed and analysed before being made public [17][18]. These surveillance systems also require dedicated infrastructure, power sources, and trained personnel to operate and maintain them. Given these challenges, there is a need for a more accessible and cost-effective solution that allows individuals and communities to monitor air quality in real-time and take immediate action when necessary. This project presents an IoT-based air quality monitoring system that integrates two different models for comprehensive pollution tracking and real-time data accessibility [19][20].

The first model consists of MQ-series gas sensors interfaced with an Arduino Uno, which displays air quality data on an LCD screen. The second model features a BME680 sensor connected to an ESP8266 module, which transmits data to a cloud-based platform for remote monitoring via a website. The Arduino Uno-based system uses MQ sensors to detect specific pollutants like volatile organic compounds (VOCs), nitrogen dioxide (NO_2), and carbon monoxide (CO) [21][22]. Real-time local monitoring is made possible by the Arduino Uno processing the gathered data and displaying it on an LCD screen. Temperature, humidity, and gas concentration are among the air quality parameters that are measured by the BME680 and ESP8266-based model. This data is then sent to a cloud-based platform and made available online [23][24].

This system's hardware consists of MQ sensors to detect dangerous gases, an Arduino Uno microcontroller to process sensor data, an LCD display to visualize data in real time on-site, a BME680 sensor to measure environmental parameters and air quality, and an ESP8266 module to transmit data wirelessly [25][26]. The Arduino IDE, which is used to program the Arduino Uno and ESP8266, is one of the software components. The combination of MQ sensors and BME680 provides a wider range of pollutant detection; the real-time data is accessible both locally via an LCD screen and remotely through a website, ensuring user convenience; the system is scalable for deployment in multiple locations due to the use of low-cost sensors and microcontrollers [27][28]; it can send automated alerts when pollution levels exceed safety thresholds, allowing for timely interventions; and it has potential applications in a number of domains, including smart cities, where policymakers and urban planners can track healthcare facilities, where the best possible air quality can be maintained to shield patients from airborne illnesses; and safety, where businesses can keep an eye on emissions to guarantee regulatory compliance [29][30].

Air pollution is a serious worldwide issue that needs to be monitored locally and in real time to lessen its detrimental effects on the environment and human health. Despite their accuracy, traditional air quality monitoring techniques are frequently costly, stationary, and do not provide real-time data accessibility [31]. This project presents an Internet of Things (IoT)-based air quality monitoring system that combines a BME680 sensor with an ESP8266 for web-based remote access and MQ sensors with an Arduino Uno for an LCD display on-site [32]. By offering scalable, reasonably priced, and real-time air pollution monitoring, the system empowers people and communities to take preventative action. This system uses IoT technology to create a healthier and more sustainable environment, with potential applications in residential, industrial, and urban settings [33].

II. RELATED WORKS / LITERATURE REVIEW

A. IoT-based Environmental Monitoring

In 2018, Kumar et.al. developed an IoT-based air pollution monitoring system using Arduino and various gas sensors. Their project focused on real-time data collection, wireless data transmission, and cloud-based storage to analyse pollution trends. The system provided users with a mobile application interface to access real-time air quality data.

B. Air Quality Monitoring using Wireless Sensor Networks (WSN)

A study by Shukla et.al. (2019) introduced a wireless sensor network for air pollution detection in urban areas. Their model utilized multiple sensor nodes deployed in different locations to measure CO, NO_2, and PM levels. The collected data was transmitted to a central server, where analytics were performed to determine pollution trends over time.

C. Integration of IoT and Cloud Computing for Smart Air Monitoring

In 2020, Lee et.al. proposed a cloud-based air monitoring system integrating IoT sensors with cloud computing technologies. Their system enabled large-scale deployment, with real-time alerts and predictive analytics to detect pollution spikes. The use of AI-based models helped improve the accuracy of pollution forecasting.

D. Low-Cost Sensor Deployment for Real-Time Air Quality Monitoring

A 2021 study by Patel et.al. examined the effectiveness of low-cost air quality sensors in monitoring urban pollution. Their research compared MQ-series gas sensors with expensive laboratory-grade instruments and found that, while low-cost sensors had limitations, proper calibration and data processing techniques could significantly improve their accuracy.

IV. HARDWARE DEVELOPMENT

- ESP-8266: The ESP8266 Wi-Fi module is responsible for wireless data transmission. It connects the BME680 sensor to a web server, allowing remote air quality monitoring via a website.
- BME-680: A multi-functional environmental sensor that measures temperature, humidity, pressure, and gas concentrations. Used for detecting air quality parameters and transmitting data through the ESP8266 module.
- MQ series Sensors: Includes gas sensors such as MQ-2, MQ-7, and MQ-135 for detecting pollutants like CO, NO_2, and VOCs. These sensors provide real-time air quality data to the Arduino Uno for local monitoring.
- LCD Display: Used for real-time on-site visualization of air quality data. Connected to the Arduino Uno to display sensor readings directly to users.
- Arduino Uno: Serves as the microcontroller for processing data from MQ-series sensors, controls the LCD screen to display air quality information in real-time.
- Power Supply: A power supply unit is required to provide electrical power to the ESP-8266, Arduino Uno and LCD.
- The prototype of the hardware project developed is shown in the Fig. 2.

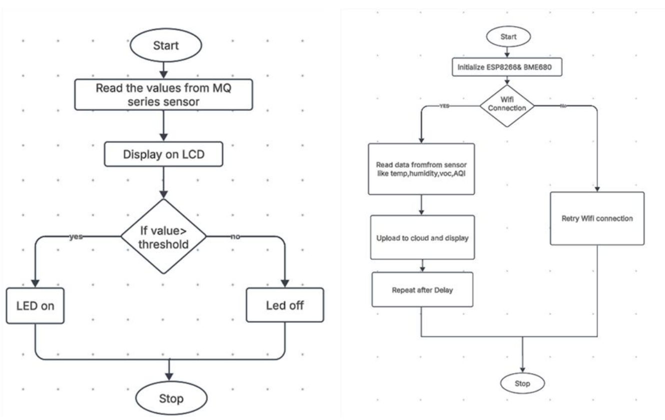

Figure 1. Flow-chart used for the project

V. Software Development

- Arduino IDE **-** The primary software used for writing and uploading code to the Arduino Uno and ESP8266. Facilitates the integration of MQ-series sensors and LCD display with the Arduino Uno for local air quality monitoring.
- ThingSpeak cloud: A cloud platform used for real-time data visualization and analysis. The ESP8266 module sends air quality data from the BME680 sensor to ThingSpeak for remote monitoring. Enables historical data tracking and alert-based notifications when pollution levels exceed safety limits.
- Vite -React : Used for developing a responsive web-based dashboard for remote air quality monitoring. React ensures an interactive and user-friendly interface for displaying real-time sensor data. Vite serves as a fast and optimized build tool for efficient deployment of the web application.
- Custom Scripts and APIs: Scripts for integrating additional functionalities, such as alert mechanisms for high pollution levels. API integration to fetch environmental data from external sources for enhanced monitoring. Custom UI enhancements to improve user experience on both LCD and web interfaces.
- The flow-chart development is shown in the Fig. 1.

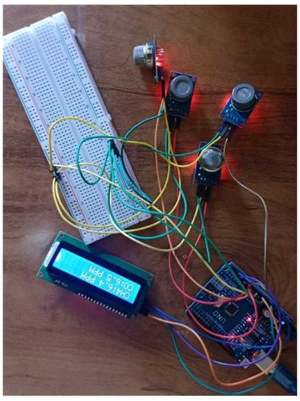

Figure 2. Photographic view of the project developed

VI. Conclusions

This mini-project presents the design and implementation of a real-time IoT-based air quality monitoring system leveraging Arduino Uno and ESP8266 technology. The system serves as a multifunctional environmental monitoring solution, offering real-time data on air pollution levels and ensuring immediate alerts for hazardous conditions. Utilizing Arduino Uno as the core computational unit, the system seamlessly integrates multiple gas sensors (MQ-series and BME680) to detect harmful pollutants such as CO, NO_2, and VOCs. The LCD module provides real-time, on-site air quality updates, while the ESP8266 module transmits data from the BME680 sensor to a cloud-based dashboard, enabling remote monitoring via a website. Moreover, the system utilizes ThingSpeak Cloud for real-time data visualization, analytics, and long-term storage, allowing users to analyze air quality trends over time. The web-based dashboard, developed using Vite and React, provides an intuitive user interface for monitoring environmental conditions, displaying historical data, and triggering alerts when pollution levels exceed safe thresholds. Furthermore, real-time notification features ensure that users receive instant alerts if air quality deteriorates, promoting timely intervention and improving indoor and outdoor environmental safety.

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