

IOT-BASED INDOOR ENVIRONMENTAL AIR QUALITY MONITORING SYSTEM (CO₂,VOC,DUST) USING ARUDINO

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Abstract—Indoor air quality has a significant impact on human health, comfort, and productivity, especially in enclosed environments such as homes, offices, hospitals, and industrial spaces. The presence of pollutants like carbon dioxide (CO₂), volatile organic compounds (VOCs), and particulate matter (dust) can lead to respiratory diseases, allergies, and long-term health complications. To address this issue, this paper presents the design and implementation of an IoT-based indoor environmental air quality monitoring system using an Arduino-based platform. The proposed system integrates multiple sensors, including MQ-series gas sensors for detecting CO₂ and VOC gases, along with a dust sensor for measuring particulate matter concentration. These sensors continuously monitor environmental conditions and transmit real-time data to the Arduino microcontroller for processing. The processed data is displayed locally using an LCD module for immediate user awareness. Furthermore, the system is equipped with IoT capabilities, enabling wireless transmission of collected data to a cloud platform for remote monitoring, storage, and analysis. This allows users to access air quality information from anywhere and observe trends over time. The system can also be configured to generate alerts when pollutant levels exceed predefined safety thresholds, ensuring timely preventive actions.

Keywords— Internet of Things (IoT), Air Quality Monitoring, Arduino, ESP32, CO₂ Detection, Volatile Organic Compounds (VOC), Dust Sensor, Environmental Monitoring, Smart Systems, Embedded Systems, Real-Time Monitoring, Cloud Computing, ThingSpeak.

I. INTRODUCTION

Indoor air quality (IAQ) has become a critical concern in modern society, as people spend a significant portion of their time inside enclosed environments such as homes, offices, hospitals, and educational institutions. Poor indoor air quality can have serious effects on human health, leading to respiratory diseases, allergies, headaches, fatigue, and long-term chronic conditions. Common indoor pollutants include carbon dioxide (CO₂), volatile organic compounds (VOCs), and particulate matter (dust), which originate from sources

such as human activities, building materials, household products, and inadequate ventilation.

Traditional air quality monitoring systems are typically designed for outdoor environments and are often expensive, bulky, and inaccessible for everyday indoor use. Moreover, many existing systems provide only local readings without offering remote monitoring, data storage, or intelligent analysis. With the rapid advancement of the Internet of Things (IoT), it has become possible to develop compact, cost-effective, and efficient systems capable of continuously monitoring environmental parameters and transmitting data in real time.

This paper presents an IoT-based indoor environmental air quality monitoring system using an Arduino-based platform. The system integrates multiple sensors to measure key air quality parameters, including CO₂ levels, VOC concentration, and dust particles. These sensors continuously collect data, which is processed by the microcontroller and displayed locally using an LCD module for real-time awareness.

In addition to local monitoring, the system utilizes wireless communication to transmit data to a cloud platform, enabling remote access, visualization, and storage of environmental data. This feature allows users to monitor air quality from anywhere and analyze trends over time. Furthermore, the system can be enhanced with intelligent features such as threshold-based alerts to notify users when pollutant levels exceed safe limits, promoting timely corrective actions.

The proposed system is designed to be low-cost, scalable, and user-friendly, making it suitable for a wide range of applications including smart homes, offices, healthcare facilities, and industrial environments. By combining embedded systems with IoT technology, this work aims to provide an effective solution for improving indoor air quality and enhancing overall environmental awareness.

II. REVIEW&LITERATURE SURVEY

In recent years, significant research has been carried out in the field of air quality monitoring using Internet of Things (IoT) technologies. The increasing

awareness of environmental pollution and its impact on human health has led to the development of various smart monitoring systems that are cost-effective, real-time, and accessible.

Several researchers have proposed IoT-based systems for monitoring environmental parameters using different microcontrollers and sensor technologies. A study by **Samuel Kristiyana and Aldi Rinaldi (2020)** developed an indoor air quality monitoring system using the NodeMCU ESP8266 microcontroller. The system utilized sensors such as LM35, DHT11, and MQ135 to measure temperature, humidity, and air quality. The collected data was transmitted to a cloud platform for real-time visualization, enabling users to monitor environmental conditions remotely.

Similarly, **Srinivasan Purushothaman et al. (2025)** proposed a real-time environmental monitoring system using the ESP32 microcontroller integrated with multiple gas sensors like MQ2, MQ7, and MQ135. The system provided continuous monitoring of air pollutants and transmitted data to cloud platforms for analysis. Their work emphasized low-cost implementation and real-time accessibility, making it suitable for smart environmental applications.

In another study, **Quynh Anh Tran et al. (2022)** introduced an advanced approach by integrating IoT with machine learning techniques such as K-Nearest Neighbors (KNN), ARIMA, and Long Short-Term Memory (LSTM) algorithms. This system not only monitored environmental data but also predicted future air quality trends with high accuracy, demonstrating the potential of combining IoT with intelligent data analytics.

Research by **L. M. Easterline (2024)** focused on multi-sensor integration for detecting various pollutants. The system improved accuracy by combining multiple sensing elements and transmitting real-time data to cloud platforms for visualization and decision-making. This approach highlighted the importance of sensor fusion in achieving reliable environmental monitoring.

Furthermore, **M. N. A. Ramadan (2024)** proposed an IoT-based system enhanced with artificial intelligence for predictive environmental monitoring. The system analyzed sensor data using AI models to identify abnormal conditions and provide early

warnings, particularly in industrial environments where pollution levels can fluctuate rapidly.

Another contribution by **Ashish Kumar Luhach et al. (2019)** demonstrated the use of MQ-series sensors for detecting harmful gases such as carbon monoxide and other pollutants. Their system incorporated machine learning techniques to improve data interpretation and emphasized the role of smart monitoring in increasing public awareness about environmental health.

From the above studies, it is evident that IoT-based air quality monitoring systems have evolved from simple data acquisition systems to intelligent platforms capable of prediction and decision-making. However, many existing systems still face challenges such as high cost, limited scalability, lack of real-time alerts, or absence of integrated machine learning capabilities.

III. RESEARCH METHODOLOGY

The development of the proposed IoT-based indoor environmental air quality monitoring system follows a structured and systematic methodology that integrates hardware design, software implementation, and data analysis. The first stage involves identifying the key air quality parameters that significantly impact indoor environments, namely carbon dioxide (CO₂), volatile organic compounds (VOCs), and particulate matter (dust). Based on these parameters, suitable sensors such as MQ-series gas sensors and an optical dust sensor are selected considering factors like sensitivity, response time, cost, and compatibility with the microcontroller.

In the next stage, the hardware architecture of the system is designed and implemented. The selected sensors are interfaced with an Arduino-based microcontroller (or ESP32 module), which acts as the central processing unit. The sensors continuously capture environmental data in the form of analog or digital signals. These signals are then converted into meaningful values using appropriate calibration techniques and mathematical conversions within the microcontroller. A regulated power supply is designed to ensure stable operation of all components, and a 16×2 LCD module is integrated to display real-time air quality parameters locally for immediate user feedback.

The software development phase involves programming the microcontroller using Embedded C/C++ in the Arduino IDE. The code is structured to perform continuous data acquisition, sensor calibration, data processing, and display operations. Libraries required for sensor interfacing, LCD control, and Wi-Fi communication are incorporated. The microcontroller is programmed to connect to a wireless network, enabling IoT functionality. Using HTTP protocols and API keys, the processed data is transmitted to a cloud platform such as ThingSpeak, where it is stored and visualized in graphical form for remote monitoring.

To enhance system intelligence, predefined threshold values for CO₂, VOCs, and dust levels are established based on standard air quality guidelines. The system continuously compares real-time sensor readings with these thresholds. Whenever the pollutant levels exceed safe limits, alert mechanisms such as buzzer notifications or cloud-based alerts are triggered to inform users, enabling timely preventive actions like improving ventilation.

Additionally, the collected data is analyzed over time to study air quality patterns and trends. This enables the possibility of integrating machine learning techniques for predictive analysis, such as forecasting future air quality levels or detecting abnormal conditions. Finally, the system undergoes testing and validation in different indoor environments to evaluate its performance in terms of accuracy, reliability, response time, and scalability.

This comprehensive methodology ensures that the proposed system is not only capable of real-time monitoring but also provides remote accessibility, intelligent analysis, and user-friendly operation, making it an effective solution for maintaining healthy indoor air quality.

IV. EXISTING SYSTEM

Conventional air quality monitoring systems are primarily designed for outdoor environments and are generally deployed by government agencies or environmental organizations. These systems use high-precision instruments to measure pollutants such as carbon dioxide (CO₂), particulate matter, and other harmful gases. While they provide accurate and reliable data, they are often expensive, bulky, and require regular maintenance, making them

unsuitable for widespread indoor usage in homes, offices, or small-scale environments.

In indoor settings, the available systems are mostly standalone devices that provide only basic monitoring functionality. These devices typically display air quality readings locally without offering features such as remote access, data storage, or real-time alerts. As a result, users are unable to monitor air quality continuously or access historical data for analysis. Additionally, many of these systems lack connectivity and do not utilize Internet of Things (IoT) technology, limiting their ability to integrate with modern smart environments.

Another major limitation of existing systems is the absence of intelligent data analysis. Most traditional monitoring solutions only present raw sensor data without identifying patterns, predicting future conditions, or detecting abnormal situations. They also often rely on a limited number of sensors, which reduces accuracy when monitoring multiple pollutants simultaneously.

Overall, existing air quality monitoring systems are either too complex and costly for general use or too simple to provide meaningful insights. These limitations highlight the need for a cost-effective, compact, and intelligent IoT-based solution capable of real-time

V. PROPOSED METHODOLOGY

The proposed system is an IoT-based indoor environmental air quality monitoring system designed to continuously measure, analyze, and report key air quality parameters such as carbon dioxide (CO₂), volatile organic compounds (VOCs), and particulate matter (dust). The system is built around an Arduino-based microcontroller (or ESP32), which serves as the central unit for data acquisition, processing, and communication.

Multiple sensors, including MQ-series gas sensors for CO₂ and VOC detection and an optical dust sensor for particulate matter measurement, are integrated into the system. These sensors continuously collect environmental data and send it to the microcontroller. The collected signals are processed and converted into meaningful air quality values using appropriate calibration techniques. The processed data is then displayed on a 16×2 LCD module, providing real-time feedback to users within the indoor environment.

To enable remote monitoring, the system incorporates IoT functionality through a Wi-Fi module. The microcontroller transmits sensor data to a cloud platform such as ThingSpeak using internet connectivity. This allows users to monitor air quality levels from anywhere and visualize data through graphs and dashboards. The cloud platform also stores historical data, enabling long-term analysis of air quality trends.

An important feature of the proposed system is the implementation of threshold-based alert mechanisms. Predefined safe limits for CO₂, VOCs, and dust levels are set within the system. Whenever these levels are exceeded, the system generates alerts through a buzzer or cloud-based notifications, prompting users to take necessary actions such as improving ventilation or reducing pollution sources.

The system is designed to be low-cost, compact, and energy-efficient, making it suitable for deployment in smart homes, offices, hospitals, and industrial environments. It also provides scalability for future enhancements, such as integration with machine learning algorithms for predictive analysis and automated control systems. Overall, the proposed system offers an efficient and intelligent solution for real-time indoor air quality monitoring and management.

VI. BLOCK DIAGRAM

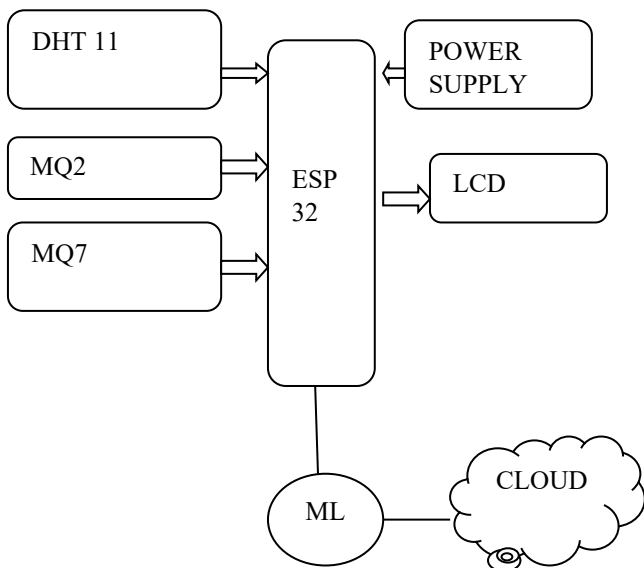


Fig. 6.2. Block Diagram

VII. RESULTS AND OUTCOMES

The developed IoT-based indoor environmental air quality monitoring system was successfully implemented and tested under various indoor conditions to evaluate its performance and reliability. The system effectively measured key air quality parameters such as carbon dioxide (CO₂), volatile organic compounds (VOCs), and particulate matter (dust) using the integrated sensors. The sensor readings were continuously acquired, processed by the microcontroller, and displayed in real time on the LCD module, providing immediate feedback to the user.

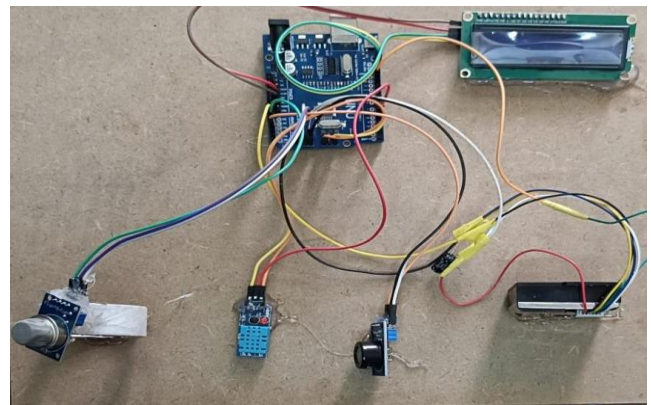


Fig:7.1: Output1

The IoT functionality of the system was validated by successfully transmitting the collected data to the cloud platform. The data was visualized in the form of graphs and charts, allowing users to monitor air quality remotely and observe variations over time. The system demonstrated stable wireless communication and consistent data updates, ensuring real-time accessibility from any location.



Figure 6.2.a Dust&Temp



Figure 6.2.b Air Quality



Figure 6.2.c Humidity



Figure 6.2.d Co2

Fig:7.2: Output 2

The threshold-based alert mechanism functioned as expected, generating notifications when pollutant levels exceeded predefined safe limits. This feature proved useful in identifying poor air quality conditions and enabling timely corrective actions such as improving ventilation or reducing pollutant sources. The system also showed good responsiveness, with minimal delay between data acquisition and alert generation.

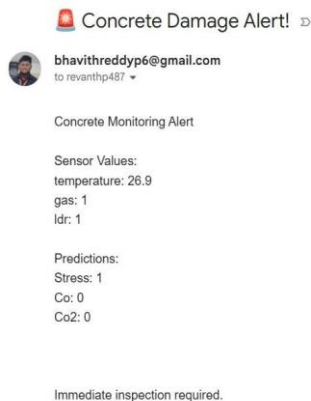


Fig:7.3: Output 3

Experimental results indicated that the system provides reasonably accurate readings when compared with standard environmental conditions, although minor variations may

occur due to sensor limitations and environmental factors. The integration of multiple sensors improved the overall reliability and effectiveness of the system in detecting different types of pollutants.

Overall, the proposed system achieved its objective of providing a low-cost, compact, and efficient solution for indoor air quality monitoring. It offers real-time monitoring, remote accessibility, and alert-based notifications, making it suitable for applications in smart homes, offices, hospitals, and industrial environments. The outcomes demonstrate the potential for further enhancements, such as incorporating machine learning algorithms for predictive analysis and improving sensor calibration for higher accuracy.

VIII.CONCLUSION

This paper presented the design and implementation of an IoT-based indoor environmental air quality monitoring system using an Arduino-based platform. The system was developed to address the growing concern of indoor air pollution by continuously monitoring key parameters such as carbon dioxide (CO₂), volatile organic compounds (VOCs), and particulate matter (dust). By integrating multiple sensors with a microcontroller and IoT technology, the system provides real-time data acquisition, processing, and visualization both locally and remotely.

The implementation demonstrated that the system is capable of accurately monitoring indoor air quality and transmitting data to a cloud platform for remote access and analysis. The inclusion of a local LCD display ensures immediate awareness, while cloud connectivity enables users to track air quality trends over time. The threshold-based alert mechanism enhances the system's functionality by notifying users when pollutant levels exceed safe limits, thereby supporting timely preventive actions.

One of the key advantages of the proposed system is its cost-effectiveness, compact design, and scalability, making it suitable for deployment in various environments such as homes, offices, hospitals, and industries. The use of IoT technology transforms the system from a simple monitoring device into a smart and connected solution capable of improving environmental awareness and decision-making.

However, the system has certain limitations, such as dependency on sensor calibration accuracy and internet connectivity for cloud-based monitoring. These limitations can be addressed in future work by incorporating more precise sensors, advanced calibration techniques, and offline data logging capabilities. Additionally, the system can be further enhanced by integrating machine learning algorithms for

predictive analysis and automated control systems for improving indoor air quality.

In conclusion, the proposed IoT-based air quality monitoring system provides an effective, reliable, and intelligent solution for maintaining healthy indoor environments. It not only enables real-time monitoring but also promotes proactive measures to reduce air pollution, thereby contributing to improved human health and well-being.

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