# TITLE OF THE PROJECT REPORT

# INDOOR AIR-QUALITY MONITORING SYSTEM

# A PROJECT REPORT

*Submitted by*


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*in partial fulfillment for the award of the degree*

*of*

## BACHELOR OF COMPUTER APPLICATION


**Department of COMPUTATIONAL SCIENCES**

**BRAINWARE UNIVERSITY**
**398, Ramkrishnapur Road, Barasat, North 24 Parganas, Kolkata - 700 125**

January, 2025

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MAY 2025

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## COMPUTATIONAL SCIENCES

## <u>BONAFIDE CERTIFICATE</u>

Certified that this project report "**INDOOR AIR-QUALITY MONITORING SYSTEM"**

is the bonafide work of "**Dhurba Mandal, Ritesh Dhara, Trisha Das, Shreeparna De, Ritam Ghosh**" who carried out the project work under my supervision.

| | |
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## ACKNOWLEDGEMENT

**Project Title:** INDOOR AIR-QUALITY MONITORING SYSTEM

**Project Group ID: BCA22A008**

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## ABSTRACT

This project presents the design and implementation of a real-time **Indoor Air Quality Monitoring System** aimed at improving environmental health and safety within enclosed spaces. With increasing awareness of the adverse effects of indoor pollution on human health—such as respiratory issues, allergies, and reduced cognitive function—this system provides a practical, cost-effective solution to monitor key environmental parameters. The system leverages low-cost sensors like the DHT22 for temperature and humidity, and the MQ135 for gas detection (including $CO_2$ and volatile organic compounds), offering users critical insights into their indoor air quality.

Built around the Arduino UNO R3 microcontroller and programmed using the Arduino IDE, the system collects, processes, and displays data in real-time through an LCD using the I2C communication protocol. Its compact architecture is designed for simplicity and scalability, allowing for future enhancements such as wireless connectivity, mobile alerts, or data visualization dashboards. The integration of multiple sensors into a unified system required careful calibration, efficient code structuring, and robust hardware setup to ensure reliability and accuracy across diverse environmental conditions.

The system finds valuable application across residential, commercial, and institutional settings. From optimizing HVAC systems in offices to safeguarding air quality in classrooms and healthcare facilities, the monitoring platform supports healthier environments and promotes informed decision-making. Additionally, the project raises awareness of indoor environmental health, encouraging proactive behaviours that contribute to overall well-being—especially among vulnerable groups such as children and the elderly.

In conclusion, the Indoor Air Quality Monitoring System demonstrates how accessible embedded technologies can be harnessed to address real-world health and environmental challenges. Through collaborative problem-solving, hardware-software integration, and user-centered design, the project delivers a functional prototype with the potential for significant societal impact. It reflects the team's technical proficiency and commitment to building sustainable, health-conscious living spaces for the future.

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# Indoor air quality monitoring system

# Introduction

In recent years, the significance of indoor air quality monitoring has gained considerable attention. With growing awareness about the impact of environmental factors on health, it is crucial to ensure that indoor environments, where people spend most of their time, are safe and healthy.

Indoor air pollution can originate from various sources such as building materials, household cleaning products, and gases emitted from cooking appliances. These pollutants can adversely affect human health, leading to respiratory issues, allergic reactions, and deterioration in general well-being. To combat these challenges, the development of an Indoor Air Quality Monitoring System is imperative.

This project focuses on creating a reliable and efficient system to monitor indoor air quality using multiple sensors. By deploying sensors such as DHT22 for humidity measurement and MQ135 for detecting harmful gases like $CO_2$, this system offers real-time data on air conditions. The information gathered helps in taking timely actions to improve air quality and maintain a healthy indoor environment.

A critical component of this system is the Arduino UNO R3 microcontroller, which acts as the brain of the operation, integrating sensor data and displaying it on an LCD for easy reading. The use of C programming and the Arduino IDE facilitates seamless execution and management of the system's tasks. This report delves into the details of the hardware components, the system's operation, its applications, and the benefits of maintaining good indoor air quality for both child and adult health.

Through systematic documentation and assessment of challenges faced during development, this report seeks to provide a comprehensive understanding of the Indoor Air Quality Monitoring System and its significance.

# Project Objectives

The primary objective of this Indoor Air Quality Monitoring System is to provide a practical solution for assessing and improving the air quality within indoor environments. This project aims to achieve the following specific objectives:

1. **Real-time Air Quality Monitoring**: Develop a system capable of continuously monitoring key air quality parameters such as humidity, temperature, and the presence of harmful gases, including CO2. By integrating multiple sensors, the system seeks to provide comprehensive data to the user.

2. **User-friendly Interface**: Implement a user-friendly display using an LCD screen with I2C protocol. The goal is to ensure that the information is easily accessible and interpretable for users, enabling them to make informed decisions about their indoor environment.

3. **Data-driven Environmental Improvements**: Utilize the gathered data to identify trends and patterns in indoor air quality, which can aid in developing strategies to mitigate pollution and improve overall air health.

4. **Health Protection and Awareness**: Educate users on the impact of air quality on health, particularly focusing on how improved air conditions can benefit both children and adults. The system is designed to raise awareness and promote actions that lead to healthier living spaces.

5. **Cost-effective and Scalable Solution**: Provide a cost-effective monitoring system using readily available components such as Arduino and standard sensors. Furthermore, the system should be scalable, allowing for future enhancements and the incorporation of additional features as needed.

By achieving these objectives, this project endeavors to contribute to better living standards and enhanced well-being by ensuring safer indoor air quality. The research and development involved in this project are in line with current technological advancements and address real-world challenges associated with indoor air pollution.

# System Architecture

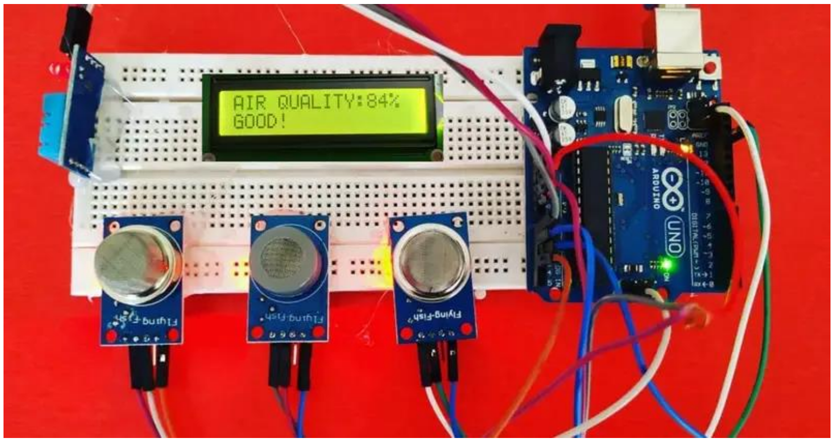



Fig. 1

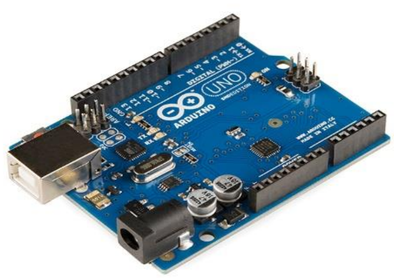
The Indoor Air Quality Monitoring System is designed to efficiently assess and report on various air quality parameters, leveraging a combination of hardware components and software logic. At the core of this architecture is the Arduino UNO R3 microcontroller, which serves as the central processing unit, integrating inputs from various sensors and displaying results on an LCD screen.

Key components and their roles in the system architecture are as follows:

## 1. ARDUINO UNO R3

- **Definition**: The Arduino UNO R3 is a microcontroller board based on the ATmega328P, part of the Arduino platform, which provides an open-source environment for hardware and software development.
- **Roles**: Acts as the central processing unit for a variety of embedded systems and IoT projects. It controls sensors, actuators, and other electronic components.
- **Uses**: Commonly used for prototyping, robotics, data logging, automation systems, and educational purposes due to its simplicity and compatibility with numerous sensors and modules.

Fig. 2



## 2. DHT22 Humidity Sensor

- **Definition**: A digital sensor that measures both temperature and relative humidity using a thermistor and a capacitive humidity sensor.
- **Roles**: Measures environmental conditions, providing temperature and humidity data in real time.
- **Uses**: Widely used in weather monitoring systems, HVAC (heating, ventilation, and air conditioning) controls, and indoor air quality monitoring.

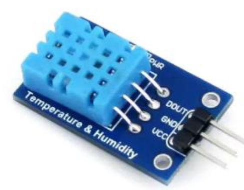



Fig. 3

## 3. MQ135 Gas Sensor

- **Definition**: An air-quality sensor capable of detecting gases such as ammonia, sulfur, benzene, carbon dioxide, and smoke. It uses a tin dioxide (SnO2) sensing layer whose resistance changes in response to the presence of specific gases.
- **Roles**: Monitors air quality by detecting the concentration of harmful gases in the environment.
- **Uses**: Frequently employed in industrial safety systems, pollution control, air purification systems, and IoT-based environmental monitoring projects.

Fig. 4

## 4. LCD with I2C Protocol

- **Definition**: A liquid crystal display (LCD) with an I2C (Inter-Integrated Circuit) communication interface, which reduces the number of pins required for operation by using serial communication.
- **Roles**: Displays alphanumeric characters and simple graphics, serving as a visual output device in embedded systems.
- **Uses**: Used in systems where a compact and efficient interface for displaying data is needed, such as IoT projects, appliances, educational kits, and robotics.

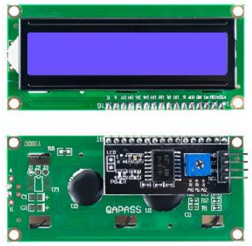


Fig. 4

# 6. Connectivity and Integration:

- The system uses a breadboard for assembling temporary electrical circuits and jumper wires to connect different components seamlessly, allowing flexibility in the setup. This configuration not only simplifies the prototype but also permits easy modifications for future iterations or improvements.

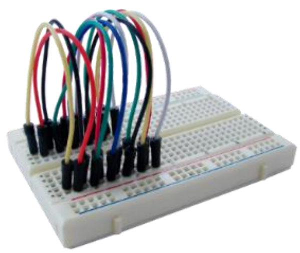


Fig. 5

# 7. Power Supply:

- For powering the system, a battery pack is used to ensure that the components operate efficiently and independently of wired power sources, thereby offering portability and ease of use.

Fig. 6

The integration of these components forms a cohesive system architecture that captures real-time air quality data, processes it efficiently, and presents it in a user-friendly format. The schematic representation of the system setup, including connections between the sensors, microcontroller, and display, is crucial for understanding the layout and operation.

# Programming with Arduino IDE

**Definition**:
The Arduino Integrated Development Environment (IDE) is an open-source software used to write, compile, and upload code to Arduino boards. It provides a simple interface and supports C/C++ programming languages with additional libraries specific to Arduino hardware.

## Key Features:

1. **Code Editor**:
- Simple editor for writing, editing, and saving Arduino programs (known as sketches).
- Includes syntax highlighting and auto-formatting.
2. **Library Manager**:
- Allows easy integration of pre-written libraries for sensors, modules, and components.
- Reduces development time by enabling plug-and-play functionality.
3. **Serial Monitor**:
- Displays real-time data from the Arduino board, allowing debugging and monitoring of sensor readings and program outputs.
4. **Board Support**:
- Compatible with various Arduino boards (e.g., UNO, Mega, Nano).
- Users can select the specific board and port in the IDE for uploading code.

## Programming Process:

1. **Setup**:

- Install the Arduino IDE and select the appropriate board and COM port from the **Tools** menu.

2. **Code Structure**:
 Arduino programs consist of two main functions:

- void setup(): Runs once at the beginning to initialize settings.
- void loop(): Contains code that runs repeatedly after the setup.

3. Example Code:void setup() {     Serial.begin(9600);

   // Initialize serial communication }void loop() {     Serial.println("Hello, World!");

   // Print to Serial Monitor     delay(1000);

   // Wait for 1 second }

4. **Compilation and Uploading**:

- The "Verify" button compiles the code to check for errors.
- The "Upload" button transfers the compiled code to the Arduino board.

## Applications:

- Developing IoT systems.
- Controlling sensors and actuators.
- Robotics and automation projects.
- Prototyping embedded systems.

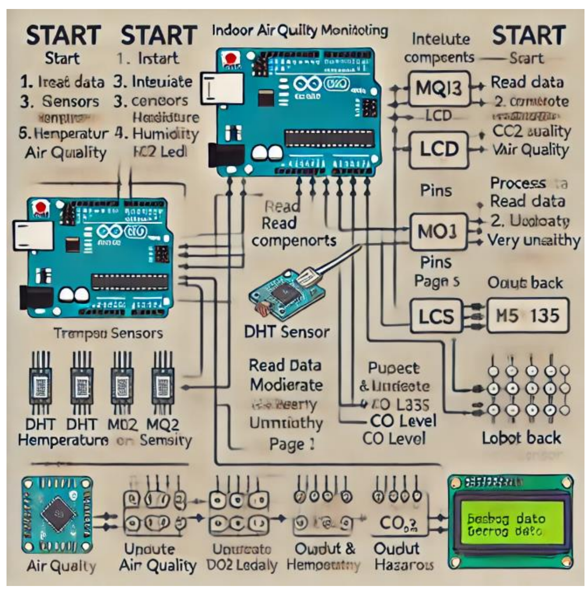



Fig. 7

The Arduino IDE is widely used by beginners and professionals alike for its user-friendly interface and extensive community support.

# Data Collection and Display

**1. Data Collection**
Data collection in an indoor air quality (IAQ) monitoring system involves gathering information about environmental parameters using various sensors.

- **Process**
  - Sensors generate analog or digital signals proportional to the concentration of the parameter being measured.
  - These signals are processed by a microcontroller (e.g., Arduino) to convert them into usable data.

**2. Data Processing**

- **Calibration**: Sensor readings are calibrated to ensure accuracy, often using predefined equations or external references.
- **Data Fusion**: Combining readings from multiple sensors for comprehensive air quality assessment.

**3. Data Display**

- **Methods of Display**:
  - **Onboard LCD/LED Screens**:
    Displays real-time data using I2C-enabled LCDs or seven-segment displays. Parameters like gas concentrations, temperature, and humidity are shown in an easy-to-read format.
  - **Web-Based Dashboards**:
    Data is transmitted via Wi-Fi or Bluetooth to IoT platforms (e.g., Blynk), allowing remote monitoring on smartphones or computers.
  - **Mobile Applications**:
    Displays detailed insights and trends for users in an interactive format.

# Applications and Benefits

**Applications:**

1. **Residential Use**:
- Monitoring air quality in homes to ensure a healthy environment.
- Reducing exposure to pollutants such as carbon dioxide ($CO_2$), volatile organic compounds (VOCs), and particulate matter (PM).
2. **Commercial Buildings**:
- Used in offices, malls, and schools to maintain comfort and health standards.
- Optimizes HVAC (heating, ventilation, and air conditioning) systems for energy efficiency and better air circulation.
3. **Industrial Environments**:
- Tracks pollutant levels in manufacturing units to meet safety regulations.
- Identifies harmful gas leaks or increased levels of particulate matter to protect worker health.
4. **Healthcare Facilities**:
- Ensures sterile and pollutant-free air in hospitals and clinics.
- Reduces airborne disease transmission by monitoring humidity and air exchange rates.
5. **Smart Cities and Urban Areas**:
- Contributes to city-wide air quality networks to inform public health policies.
- Provides data for environmental studies and pollution control measures.
6. **Educational Institutions**:
- Improves indoor environments in classrooms, leading to better cognitive performance and reduced health risks for students and staff.
7. **Transport Systems**:
- Used in airports, subway systems, and vehicle cabins to manage air quality for passengers.

**Benefits:**

1. **Health Improvement**:

- Reduces risks of respiratory diseases, allergies, and chronic conditions caused by prolonged exposure to poor air quality.

2. **Productivity Boost**:

- Cleaner air enhances cognitive performance and reduces fatigue, leading to increased productivity at workplaces and schools.

3. **Real-Time Awareness**:

- Provides instant feedback on indoor pollutant levels, allowing timely action to mitigate hazards.

4. **Energy Efficiency**:

- Enables efficient HVAC operation, reducing energy consumption and utility costs by adapting to real-time air quality needs.

5. **Regulatory Compliance**:

- Helps businesses and industries adhere to environmental and occupational safety standards.

6. **Environmental Impact**:

- Contributes to sustainability by minimizing the carbon footprint of air management systems.

7. **Customized Alerts and Automation**:

- Integrates with smart devices to provide alerts and automate air purifiers or ventilation systems when pollutant levels rise.

8. **Data for Decision-Making**:

- Long-term data trends help identify pollution sources and guide preventive measures or infrastructure improvements.

Indoor air quality monitoring systems are essential for creating healthier living and working environments, driving operational efficiency, and contributing to broader sustainability goals.

# Health Benefits

## Health Benefits of Using Indoor Air Quality Monitoring Systems

Indoor air quality monitoring systems (IAQMS) provide significant health benefits by identifying and mitigating environmental pollutants. Poor air quality is linked to various health issues, and monitoring systems play a vital role in promoting better well-being.

## Key Health Benefits:

1. **Reduction of Respiratory Issues**:

- **Impact**: Pollutants like particulate matter (PM2.5, PM10), VOCs, and carbon monoxide can cause or worsen respiratory conditions such as asthma, bronchitis, and chronic obstructive pulmonary disease (COPD).
- **Benefit**: IAQMS helps in maintaining clean air, reducing irritants that trigger respiratory symptoms.

2. **Prevention of Allergies and Asthma Attacks**:

- **Impact**: Dust, pollen, mold, and pet dander are common indoor allergens.
- **Benefit**: Real-time monitoring enables early detection, allowing occupants to take action to remove allergens, reducing the frequency and severity of allergic reactions.

3. **Minimized Risk of Cardiovascular Diseases**:

- **Impact**: Long-term exposure to high levels of indoor pollutants, especially fine particulate matter and carbon monoxide, is linked to heart diseases.
- **Benefit**: Continuous air quality monitoring ensures pollutant levels remain within safe limits, reducing cardiovascular risks.

4. **Improved Cognitive Function**:

- **Impact**: High levels of $CO_2$ and poor ventilation can lead to fatigue, reduced concentration, and impaired decision-making.
- **Benefit**: Monitoring ensures proper ventilation and air exchange, improving mental clarity and productivity.

5. **Reduced Headaches and Fatigue**:

- **Impact**: VOCs from cleaning products, paints, and furniture can cause headaches, fatigue, and nausea.
- **Benefit**: IAQMS detects these harmful chemicals, prompting actions to reduce exposure and improve indoor comfort.

6. **Lower Risk of Long-Term Health Conditions**:

- **Impact**: Chronic exposure to pollutants like formaldehyde and radon can increase the risk of cancer and other serious illnesses.
- **Benefit**: Monitoring systems help detect harmful gases early, reducing long-term health hazards.

7. **Protection Against Infectious Diseases**:

- **Impact**: Poor ventilation and high humidity create conditions favorable for the growth and transmission of bacteria, viruses, and mold.
- **Benefit**: By monitoring and optimizing humidity and ventilation, IAQMS reduces the spread of airborne diseases.

8. **Better Sleep Quality**:

- **Impact**: Polluted air can lead to discomfort, nasal congestion, and interrupted sleep patterns.
- **Benefit**: Clean air promoted by monitoring systems ensures better oxygen intake, improving sleep quality.

9. **Support for Vulnerable Groups**:

- **Impact**: Children, the elderly, and individuals with pre-existing conditions are more sensitive to air pollutants.
- **Benefit**: IAQMS provides a safer environment for these groups by continuously maintaining air quality standards.

10. **Mental Health Improvement**:

- **Impact**: Clean air contributes to a more pleasant and stress-free environment, reducing anxiety linked to health concerns.
- **Benefit**: Monitoring air quality alleviates concerns and promotes a sense of well-being.

# Challenges and Solutions

## Challenges Faced While Developing the Indoor Air Quality Monitoring System and Solutions We Implemented

Developing an indoor air quality monitoring system as a project presented several challenges due to limited resources, technical hurdles, and time constraints. Here's a breakdown of the challenges we faced and the creative solutions we implemented:

### 1. Limited Budget

**Challenge**:

- As students, we had limited funding for procuring high-quality sensors, microcontrollers, and additional components.
- High-accuracy sensors like particulate matter detectors were expensive.

**Solution**:

- We researched affordable alternatives, such as MQ135 for gas detection and DHT22 for humidity and temperature.
- To improve accuracy, we calibrated these low-cost sensors against professional-grade equipment borrowed from our lab.
- Recycled components from older projects to save costs.

### 2. Sensor Calibration and Accuracy

**Challenge**:

- Many sensors, especially affordable ones, provided raw data that was inaccurate or required calibration for real-world conditions.
- Variations in temperature, humidity, and voltage affected the readings.

**Solution**:

- Conducted multiple calibration sessions using reference devices to create correction formulas.
- Implemented software algorithms in our microcontroller to normalize sensor data and filter noise.
- Used moving average methods to stabilize fluctuating readings.

## 3. Integrating Multiple Sensors

**Challenge**:

- Managing multiple sensors (gas, temperature, humidity, and particulate matter) with different data protocols and formats was complex.
- Interference between sensors caused data discrepancies.

**Solution**:

- Used an Arduino UNO with sufficient digital and analog pins to connect sensors efficiently.
- Adopted the I2C protocol for LCD displays and prioritized sensor polling to prevent data clashes.
- Verified sensor readings individually before integrating them into a unified system.

## 4. Ensuring Real-Time Monitoring

**Challenge**:

- Achieving real-time data updates with limited processing power and slow sensor response times.
- Maintaining a stable power supply during extended testing sessions.

**Solution**:

- Optimized the code to minimize delays between sensor readings.
- Used efficient communication protocols to reduce latency.
- Powered the system with portable power banks to ensure continuous operation during testing.

## 5. Hardware Assembly and Maintenance

**Challenge**:

- Components were fragile and required careful handling during assembly.
- Breadboard connections were prone to disconnection during testing.

**Solution**:

- Transitioned from a breadboard to a soldered PCB for better durability.
- Labeled connections clearly to avoid errors during reassembly.

# Conclusion

As college students, developing the Indoor Air Quality Monitoring System was an enriching and challenging experience that deepened our understanding of environmental health, electronics, and teamwork. The project allowed us to apply theoretical knowledge from our coursework to a practical, real-world problem, bridging the gap between classroom learning and practical application.

Throughout the process, we faced numerous challenges, including sensor calibration, data integration, budget constraints, and technical limitations. However, by leveraging creative problem-solving, resource optimization, and effective collaboration, we successfully developed a functional prototype capable of monitoring indoor air quality in real-time.

This project not only enhanced our technical skills in areas such as IoT, programming, and hardware assembly but also taught us the importance of resilience, planning, and adaptability in tackling complex tasks. Moreover, it highlighted the critical role technology plays in improving public health and environmental sustainability.

The system we built can provide valuable insights into indoor air quality, empowering individuals to make informed decisions about their environment and contributing to healthier living and working spaces. This experience has motivated us to continue exploring innovative solutions to pressing global challenges and underscored the significance of interdisciplinary efforts in achieving impactful outcomes.

## Resource List

These are the hardware, software, and online platforms used in this project:

### 1. Hardware:

- ESP32 Microcontroller
- DHT22 Temperature and Humidity Sensor
- MQ135 Gas Sensor (for CO2 monitoring)
- 16×2 LCD with I2C Module
- Breadboard and Jumper Wires

### 2. Software:

- Arduino IDE (Integrated Development Environment) for programming the microcontroller.
- Libraries:
  - Wire.h for I2C communication.
  - LiquidCrystal_I2C.h for LCD handling.
  - DHT.h for interfacing the DHT22 sensor.

### 3. Online Documentation and Tutorials:

- Arduino Reference: https://www.arduino.cc/reference
- Adafruit DHT Sensor Library Documentation: https://learn.adafruit.com/dht
- Blynk IoT Platform Documentation: https://docs.blynk.io
- SparkFun MQ135 Gas Sensor Guide: https://learn.sparkfun.com/tutorials

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