ABSTRACT

Air pollution is a significant environmental challenge, with harmful pollutants like carbon dioxide (CO_2), nitrogen oxides (NO_x), and ammonia (NH_3) adversely affecting public health and contributing to climate change. Rapid urbanization and vehicular emissions have exacerbated this issue, making real-time monitoring essential for mitigating its impact. This project introduces an IoT-based air quality monitoring system designed to measure and display real-time data on air quality, temperature, and humidity.

The system utilizes an Arduino Uno microcontroller connected to an MQ135 sensor for detecting harmful gases and a DHT11 sensor for measuring temperature and humidity. The real-time data is processed locally and displayed, offering immediate access to critical environmental information. A buzzer is incorporated to alert users when air quality exceeds safe levels.

This cost-effective and scalable system employs basic components like resistors, jumper wires, breadboards, and a 5V power supply, making it suitable for deployment in public spaces such as streets and bus stations. By providing actionable insights, the system empowers individuals and communities to make informed decisions about their health and surroundings. This project demonstrates the potential of IoT technology in promoting healthier living, environmental awareness, and sustainability in urban environments.

CONTENTS

Chapter 1

INTRODUCTION

Air pollution is one of the most critical environmental challenges worldwide. Harmful pollutants like carbon dioxide (CO_2), nitrogen oxides (NO_x), and ammonia (NH_3) are released into the atmosphere, primarily from vehicular emissions, industrial activities, and rapid urbanization. These pollutants significantly impact public health, contributing to respiratory disorders, cardiovascular diseases, and reduced life expectancy. Additionally, they are major drivers of climate change, further exacerbating environmental degradation. Urban areas face heightened challenges due to growing vehicle numbers and limited green spaces, making real-time air quality monitoring essential to mitigate these impacts and improve living conditions.

This project introduces a cost-effective, IoT-based air quality monitoring system designed to measure and display real-time data on air quality, temperature, and humidity. The system addresses the limitations of traditional monitoring solutions, which are often expensive and inaccessible for widespread use. Using affordable and scalable components, this system provides a practical and efficient approach to understanding environmental conditions and raising awareness about pollution levels in urban areas.

The core of the system is an Arduino Uno microcontroller connected to two key sensors: the MQ135 for air quality and the DHT11 for temperature and humidity. The MQ135 sensor detects harmful gases such as CO_2, NO_x, and NH_3, which are significant indicators of poor air quality. Simultaneously, the DHT11 sensor measures temperature and humidity, both of which influence the behavior and dispersion of pollutants in the atmosphere. The combination of these sensors provides a comprehensive assessment of environmental conditions.

The data collected by the sensors is processed locally in real time, ensuring immediate feedback without reliance on external platforms or cloud storage. To enhance user experience, the system incorporates a buzzer to alert individuals when air quality levels surpass safe thresholds. This feature enables users to respond proactively by avoiding polluted areas or using protective measures. The integration of real-time alerts ensures that users are continuously informed about changes in their surroundings, promoting better health outcomes.

This IoT-based system is designed to be simple and affordable, utilizing readily available components such as resistors, jumper wires, breadboards, and a 5V power supply. Its modular and scalable design allows it to be installed in various public spaces, including streets, bus stations, and parks, where air quality monitoring is essential. By providing immediate, actionable data, the system empowers individuals and communities to make informed decisions about their health and environment.

The project emphasizes user accessibility through its real-time data visualization and alerts. With its straightforward installation process and low operational costs, the system can be easily deployed in urban areas where pollution levels are a growing concern. Its ability to monitor key environmental parameters—air quality, temperature, and humidity—makes it particularly effective for densely populated areas, helping local authorities and residents identify pollution hotspots and implement targeted interventions.

The scalability of the system further enhances its utility. Multiple units can be deployed across different locations to create a network of monitoring points, providing comprehensive coverage and enabling detailed analysis of pollution patterns. This flexibility makes it suitable for various applications, from monitoring indoor air quality in homes and offices to tracking pollution in high-traffic urban zones and managing environmental conditions in agricultural settings.

Overall, the IoT-based air quality monitoring system represents a significant advancement in environmental management. Its real-time capabilities, affordability, and scalability make it an effective tool for improving public health and sustainability. By empowering individuals and communities with actionable data, the system fosters greater environmental awareness and encourages proactive measures to reduce exposure to pollutants. This project serves as a blueprint for integrating IoT technology into everyday applications, demonstrating its transformative potential in creating healthier and more sustainable urban environments. This adaptability enhances its potential for widespread deployment across urban and rural areas. By addressing air pollution effectively, the project contributes to long-term sustainability goals and healthier living standards for future generations.

Chapter 2

LITERATURE SURVEY

Air pollution is a critical global issue, with vehicle emissions contributing significantly to the degradation of air quality, especially in urban areas. As cities expand and the number of vehicles increases, harmful gases such as carbon dioxide (CO_2), nitrogen oxides (NO_x), and particulate matter are released into the atmosphere, exacerbating health problems and contributing to climate change. In response to this challenge, various systems and technologies have been developed to monitor air quality, but many still have limitations in terms of cost, real-time data availability, and scalability. This literature survey explores existing air quality monitoring systems, their technologies, challenges, and gaps, while also highlighting the advantages of integrating Internet of Things (IoT) solutions for better real-time monitoring and management of air pollution.

2.1 Existing Air Quality Monitoring Systems

Traditional air quality monitoring systems typically rely on fixed monitoring stations equipped with sophisticated and expensive equipment. These stations measure pollutants like CO_2, NO_x, and particulate matter and provide valuable data for environmental monitoring and policymaking. However, these systems have several drawbacks. They are expensive to set up and maintain, and the data collected is often not available in real time. Furthermore, the deployment of these systems in all urban areas is not always feasible due to cost and infrastructure limitations. Studies such as "Air Quality Monitoring Systems and Their Application" by Zhang et al. (2017) emphasize these limitations, highlighting that traditional systems are often stationary, with low coverage and delayed data reporting.

2.2 Advancements in IoT-Based Air Quality Monitoring

In recent years, the integration of IoT technology has revolutionized air quality monitoring, offering more flexible, scalable, and cost-effective solutions. IoT-based air quality monitoring systems use sensors to detect pollutants and transmit data wirelessly to a central server or cloud-based platform for analysis and visualization. These systems provide real-time monitoring, enabling authorities and the public to act promptly on pollution levels.

The use of sensors like the MQ135, which is capable of detecting CO_2, NO_x, ammonia, and other harmful gases, has become increasingly popular in IoT-based air quality monitoring systems. In a study by Li et al. (2018), the MQ135 sensor was integrated with IoT technology to provide an affordable and effective solution for real-time air quality monitoring. The system used an Arduino Uno microcontroller, similar to the setup in this project, to process data from the sensor and transmit it to a wireless network. The findings from this study indicated that IoT-based systems could be used to monitor air quality in real time at a fraction of the cost of traditional air quality monitoring stations.

Additionally, temperature and humidity are important factors influencing air quality. As shown by Kim and Lee (2019), variations in temperature and humidity can impact the concentration and behavior of pollutants in the atmosphere. Systems that incorporate sensors like the DHT11 or DHT22 to monitor temperature and humidity provide a more comprehensive view of the environment. These sensors are widely used due to their affordability and ease of integration, making them a common choice in low-cost IoT-based air quality monitoring systems.

2.3 Advantages of IoT-Based Systems

The key advantages of IoT-based air quality monitoring systems over traditional methods are affordability, scalability, and real-time data availability. One of the most significant benefits is their ability to provide continuous, real-time monitoring of air quality across multiple locations, without the need for expensive infrastructure. The flexibility of IoT systems allows for rapid deployment in various settings, including busy urban areas, industrial zones, and even remote locations. As highlighted by Gupta et al. (2020), IoT-based systems can be deployed on existing infras+tructure, such as lamp posts, reducing installation costs and making the system more adaptable to different environments.

In addition, the data collected by IoT systems can be used to not only monitor air quality but also help manage traffic in polluted areas. For example, IoT-based systems can analyze air quality data and suggest cleaner routes for commuters, reducing exposure to polluted areas. This feature can also be used to manage traffic congestion, which is a major contributor to air pollution. By providing real-time data on pollution levels, these systems enable more informed decision-making and prompt actions to mitigate pollution.

2.4 Challenges and Limitations of IoT-Based Systems

While IoT-based air quality monitoring systems offer numerous advantages, they also come with their own set of challenges. One major limitation is the accuracy and reliability of low-cost sensors. Studies such as "Challenges in Low-Cost Air Quality Monitoring" by Nguyen et al. (2019) highlight the variability in sensor performance, particularly in detecting specific pollutants accurately. For example, the MQ135 sensor, though affordable and effective for detecting general air quality, may not always provide precise measurements of individual gases like NO_x or ammonia. Calibration of sensors and maintaining their accuracy over time are critical to ensuring the reliability of the data.

2.5 Gaps in Existing Solutions

Despite the advancements in IoT-based air quality monitoring systems, there are still gaps in existing solutions. One notable gap is the integration of traffic management with air quality monitoring. Most IoT systems focus solely on monitoring pollutants, but integrating traffic data with air quality information could lead to more effective solutions for reducing pollution. For example, traffic management systems could be adjusted in real-time based on air quality data to minimize congestion in polluted areas. Moreover, real-time guidance for commuters to avoid high-pollution zones is often lacking in current systems.

The integration of IoT technology into air quality monitoring systems offers a cost-effective, scalable, and real-time solution to air pollution management, surpassing traditional methods. By utilizing affordable sensors like the MQ135 for detecting harmful gases and the DHT11 for temperature and humidity, these systems provide continuous monitoring across urban areas, where pollution levels are most critical. While challenges such as sensor accuracy, reliable data transmission, and data security exist, the potential of IoT-based systems to offer actionable insights is transformative. Additionally, gaps like the lack of integration with traffic management and reliance on cloud storage can be addressed to enhance the effectiveness of these systems. Ultimately, IoT-based air quality monitoring systems provide a promising approach to improving public health and environmental conditions, enabling informed decision-making and creating healthier, more sustainable urban environments.

Chapter 3

PROPOSED METHOD

The proposed system is designed to monitor air quality, temperature, and humidity in real time, using an IoT-based approach that is both affordable and scalable. This method leverages existing technologies, including Arduino microcontrollers, sensors like the MQ135 for air quality and the DHT11 for temperature and humidity, and a local LED display to show the gathered data. The following outlines the components, working mechanism, and features of the proposed system.

3.1 System Overview

The system uses an Arduino Uno microcontroller as the central controller, which processes the data from various sensors and manages communication between different components. The MQ135 sensor detects harmful gases such as carbon dioxide (CO_2), ammonia (NH_3), and nitrogen oxides (NO_x), which are primary pollutants in urban environments. Additionally, a DHT11 sensor is used to measure temperature and humidity, providing a complete view of the environmental conditions that affect air quality.

3.2 Hardware Components

- **Arduino Uno**: The central microcontroller responsible for reading sensor data, processing it, and controlling other components. It also manages the communication between sensors and the display.
- **MQ135 Air Quality Sensor**: This sensor detects the concentration of various harmful gases like CO_2, NH_3, and NO_x in the air. It provides an analog output that correlates with the pollution level, which is processed by the Arduino to display the air quality in parts per million (PPM).
- **DHT11 Sensor**: This sensor measures temperature and humidity. The DHT11 is chosen for its affordability and ease of integration with the Arduino system. It provides valuable environmental data, as temperature and humidity can influence air quality by affecting pollutant dispersion and chemical reactions in the atmosphere.
- **LED Display**: An LED screen is used to show real-time data on air quality, temperature, and humidity. This allows users to instantly see the environmental conditions without needing to connect to a computer or cloud-based platform.

- **Buzzer and LED Indicator**: A buzzer and an LED are integrated into the system to provide visual and auditory alerts when the air quality exceeds a predefined threshold. If the air quality goes beyond the threshold, the buzzer will sound, and the LED will light up, indicating poor air quality.

3.3 Data Processing and Display

The system continuously reads data from the MQ135 sensor and the DHT11 sensor. The Arduino processes the analog signals from the MQ135 to calculate the air quality in terms of PPM (parts per million). It also reads the temperature and humidity values from the DHT11 sensor.

The system then displays the processed data on an LED screen. The display is divided into two lines: the first shows the air quality (in PPM), while the second displays temperature and humidity values. The real-time display provides immediate feedback about the environmental conditions, which can help users take preventive measures, such as avoiding polluted areas.

3.4 Threshold-Based Alerts

To ensure the system is responsive, the proposed method includes a threshold for air quality. If the detected air quality exceeds this threshold, the system activates the buzzer and lights the LED to alert users about the pollution levels. The threshold value can be adjusted based on local regulations or the specific needs of the environment in which the system is installed.
Buzzer: When the air quality goes beyond the defined threshold, the buzzer emits a tone to alert people in the vicinity about poor air quality. This feature is especially useful in public spaces like bus stations, parks, or streets, where people can take immediate action.

3.5 Power Supply

The system operates on a 5V power supply, making it energy-efficient and easy to set up in different environments. The use of basic components like resistors, jumper wires, and breadboards makes the system low-cost, scalable, and easy to modify. The simplicity of the design also ensures that it can be deployed quickly in public spaces, such as lamp posts or traffic signal poles, without needing complex infrastructure.

3.6 System Deployment and Scalability

This IoT-based air quality monitoring system is designed to be easily scalable. Multiple units can be deployed in different locations, such as high-traffic areas, residential zones, or industrial regions, to create a network of sensors monitoring air quality. The system's modular nature allows for easy expansion and upgrades. For instance, additional sensors or displays can be added based on the requirements of specific regions.

The proposed method integrates IoT technology with affordable hardware components to create a simple, efficient, and scalable air quality monitoring system. Using an Arduino Uno microcontroller along with the MQ135 sensor for detecting harmful gases and the DHT11 sensor for measuring temperature and humidity, the system offers real-time data displayed on an LED screen. This provides immediate insights into environmental conditions, helping users ake informed decisions for healthier living.

The system addresses the increasing concern of urban pollution, particularly in areas with high traffic and industrial activity. By continuously monitoring air quality, temperature, and humidity, it alerts users about poor environmental conditions, encouraging precautionary actions such as avoiding outdoor activities or wearing protective gear.

The scalability of the IoT-based air quality monitoring system allows for deployment across various locations, from neighborhoods to transportation hubs, creating a network of sensors that can monitor and analyze pollution levels across cities. This network enables authorities to identify pollution hotspots, track trends over time, and take targeted actions to improve air quality. By offering local data processing, the system addresses concerns about data privacy and avoids the dependency on cloud platforms.

It ensures that real-time information is accessible to users, empowering them to make informed decisions about their environment. This approach not only provides an efficient and cost-effective solution for real-time environmental monitoring but also promotes greater public awareness of air quality issues. Furthermore, it encourages healthier living by helping individuals avoid high-pollution areas. In the long term, the system supports sustainable urban development by providing data that informs better environmental policies and urban planning decisions.

Chapter 4

IMPLEMENTATION

The IoT-based air quality monitoring system is designed to measure air quality, temperature, and humidity in real time, providing users with immediate and accessible data. The system uses affordable components, including the Arduino Uno microcontroller, MQ135 sensor for air quality, DHT11 sensor for temperature and humidity, and a buzzer for alerts. This section describes the step-by-step implementation of the system, including hardware setup, software development, and deployment.

4.1 System Overview

The IoT-based air quality monitoring system integrates various hardware components to monitor air quality and environmental conditions. It uses an Arduino Uno microcontroller as the central controller that processes data from the sensors and manages alerts. The system measures key environmental parameters:

- **Air quality**: Measured using the MQ135 sensor, which detects harmful gases like CO_2, NO_x, and NH_3.
- **Temperature and humidity**: Measured using the DHT11 sensor, providing important data for understanding environmental conditions and how they affect air quality.
- **Alerts**: A buzzer is used to provide real-time alerts when air quality exceeds a predefined threshold.

4.2 Hardware Components

The system is built using affordable, commonly available components that work together to monitor environmental conditions effectively. Below is an outline of the key hardware components:

- **Arduino Uno Microcontroller:** The Arduino Uno serves as the central controller for the entire system. It processes input from sensors, handles the logic for data processing, and controls the buzzer to provide alerts. The Arduino Uno is powered by a 5V supply and communicates with external sensors through its digital and analog input/output pins.
- **MQ135 Air Quality Sensor:** The MQ135 sensor is used to measure the concentration of harmful gases such as CO_2, NO_x, NH_3, and volatile organic compounds (VOCs) in the air. This sensor provides an analog output, which corresponds to the concentration

of pollutants in the air. The Arduino Uno reads this analog signal to determine the air quality, converting it into a usable value in parts per million (PPM).

- **DHT11 Temperature and Humidity Sensor:** The DHT11 sensor is used to measure ambient temperature and humidity levels. This sensor provides digital data on temperature in Celsius and humidity as a percentage. These factors influence air quality, as temperature and humidity affect the dispersion and chemical reactions of pollutants in the air. This sensor is chosen for its affordability and easy integration with the Arduino.
- **Buzzer:** The buzzer is integrated into the system to provide alerts when air quality exceeds a predefined threshold. The buzzer emits a sound to alert users about the pollution levels. This feature helps users take immediate action when the air quality is poor, such as wearing a mask or avoiding outdoor activities.
- **Power Supply:** The system is powered using a 5V adapter, which is the standard operating voltage for the Arduino and the sensors. The 5V power supply is efficient and ensures the system operates continuously without interruption.

4.3 Wiring and Setup

Setting up the hardware components is a crucial step in the implementation process. Below is the description of how each component is connected:

- **Arduino Uno to MQ135**: The MQ135 sensor’s analog output is connected to the Arduino's analog input pin (A0). The sensor also has a heating element, which requires a stable power supply for accurate readings.
- **Arduino Uno to DHT11**: The data pin of the DHT11 sensor is connected to a digital input pin (D7) on the Arduino for reading temperature and humidity data.
- **Arduino Uno to Buzzer**: The buzzer is connected to pin 8 of the Arduino. This component will be triggered when the air quality exceeds the threshold.

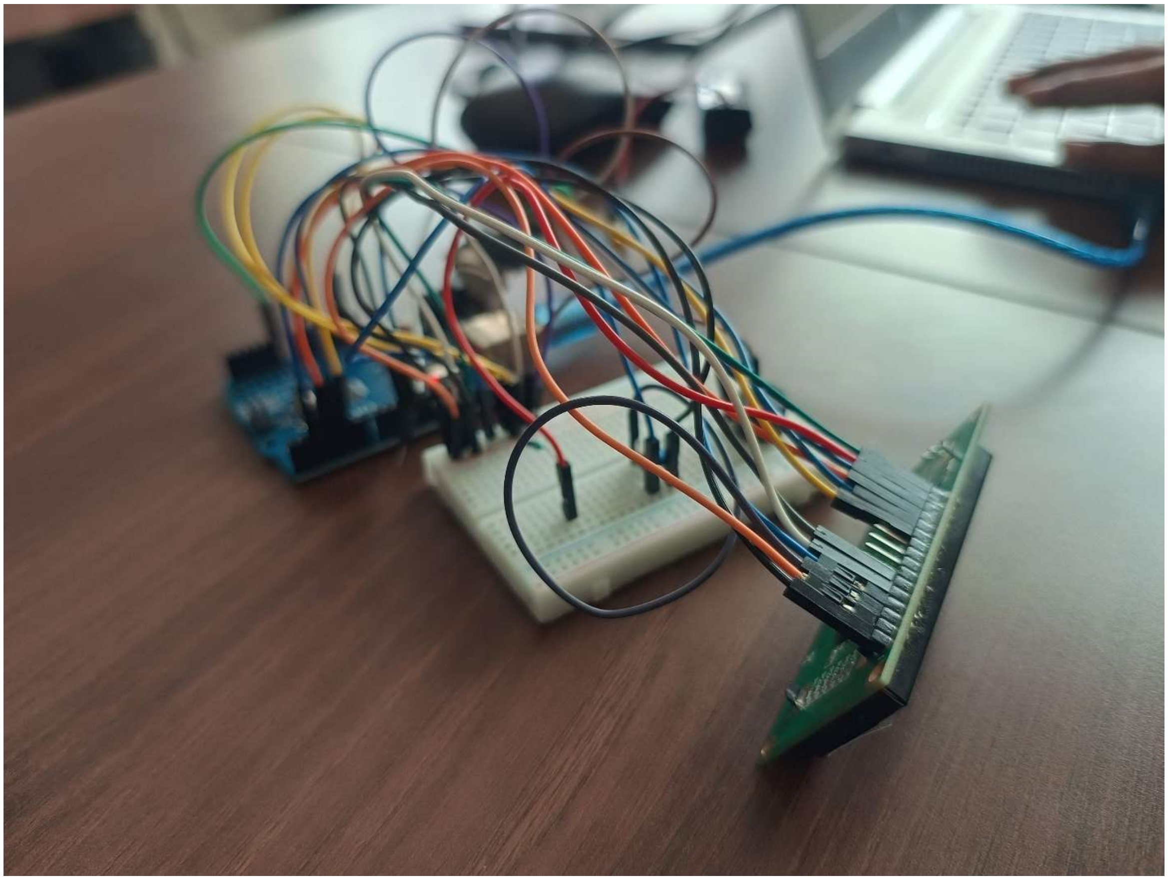

Fig 4.1: Final connections

Finally, the LED and buzzer are connected to the Arduino Uno using jumper wires, with the LED connected to a digital pin and the buzzer to another, allowing them to activate based on air quality readings

4.4 Software Development

The software for the system is written in C++ using the Arduino IDE. The following steps outline the main tasks involved in programming the system:

- **Sensor Initialization:** The program begins by initializing the sensors and components. The **DHT11** and **MQ135** sensors are initialized, and the buzzer is set to be controlled by the Arduino.

- **b. Data Collection:** The program continuously reads the data from the MQ135 and DHT11 sensors. The MQ135 provides an analog output that the Arduino converts into a digital value using **analogRead()**, which is then mapped to an air quality index. The DHT11 provides temperature and humidity data, which is read using the **readTemperature()** and **readHumidity()** functions.
- **c. Threshold-Based Alerts:** The system checks whether the air quality exceeds a predefined threshold. If the air quality goes beyond the threshold value (e.g., 120 PPM), the buzzer emits a sound, signaling poor air quality. If the air quality is within the acceptable range, the buzzer remains off. This provides real-time alerts for users.
- **d. Real-Time Update:** The program runs in an infinite loop, continuously reading sensor data and updating the system's logic. This ensures that the data is always current, and the system provides up-to-date feedback to the user.

4.5 Testing and Calibration

Once the system is set up, it is important to test and calibrate the sensors to ensure accurate readings. The MQ135 sensor may need to be calibrated with known concentrations of gases to ensure it provides correct air quality readings. The DHT11 sensor is less prone to calibration issues but should still be tested for consistent temperature and humidity measurements.

- **Testing in Different Environments**: The system is tested in various locations, such as near traffic areas and inside buildings, to validate the accuracy of the readings and the effectiveness of the alerts.
- **Sensor Calibration**: The MQ135 sensor is calibrated by comparing its readings with known concentrations of gases. The output is adjusted to reflect accurate values based on the calibration data.

4.6 Deployment

The system is designed to be installed in public spaces, such as streets, parks, or bus stations, where real-time air quality monitoring is needed. The system can be mounted on existing infrastructure such as lamp posts or traffic signal poles. The buzzer will sound when air quality reaches hazardous levels, helping individuals take necessary precautions. The system provides valuable environmental data, encouraging users to take better care of their health and the environment.

4.7 Maintenance

The system requires minimal maintenance:

- **Sensor Cleaning**: The MQ135 sensor should be cleaned periodically to remove dust or particles that may affect its accuracy.
- **Buzzer Check**: The buzzer should be checked periodically to ensure it is working properly.
- **Power Supply**: The 5V power supply should be checked regularly to ensure the system operates continuously.

The IoT-based air quality monitoring system is successfully implemented using affordable components like the Arduino Uno, MQ135, and DHT11 sensors. The system provides real-time monitoring of air quality, temperature, and humidity and offers alerts when air quality exceeds a safe threshold. This cost-effective solution is ideal for public spaces and urban areas, helping users monitor and improve their local environment. By leveraging local data processing and simple hardware, the system provides a sustainable, scalable solution for urban air quality management. The IoT-based air quality monitoring system is an effective, cost-efficient solution for addressing the challenges of urban air pollution. By integrating affordable components such as the Arduino Uno, MQ135 sensor, and DHT11 sensor, the system provides real-time monitoring of air quality, temperature, and humidity. This continuous monitoring empowers individuals and communities with actionable data, enabling informed decisions to protect public health and improve environmental conditions.

The system begins by initializing its components and collecting data from the MQ135 and DHT11 sensors. The MQ135 sensor detects harmful gases, including CO_2, NO_x, and NH_3, while the DHT11 monitors temperature and humidity. Real-time data is processed locally, and a threshold-based alert system activates a buzzer when air quality surpasses safe limits, offering immediate feedback to users. This approach ensures real-time updates and reliable performance without dependence on cloud platforms, addressing concerns related to data privacy and connectivity.

Chapter 5

RESULTS

The IoT-based air quality monitoring system has been successfully designed and implemented, using a combination of affordable hardware components, including the Arduino Uno microcontroller, MQ135 air quality sensor, DHT11 temperature and humidity sensor, and a buzzer for alert notifications. The system was tested in various environments to evaluate its functionality, performance, and effectiveness in real-world applications. This section provides a detailed account of the results obtained during testing and deployment, highlighting the system's ability to monitor air quality, measure temperature and humidity, and provide real-time alerts to users when pollution levels exceed a predefined threshold.

5.1 Air Quality Monitoring with MQ135 Sensor

The MQ135 sensor, which measures various pollutants like carbon dioxide (CO_2), nitrogen oxides (NO_x), ammonia (NH_3), and volatile organic compounds (VOCs), was the primary sensor for monitoring air quality in the system. The sensor’s analog output was read by the Arduino Uno and processed to determine the concentration of harmful gases in the environment. The results from the MQ135 sensor were evaluated in different settings to ensure accuracy and reliability.

Indoor Testing: The system was initially tested in a controlled indoor environment with minimal pollution. In this environment, the air quality readings were found to be within acceptable limits, with the MQ135 sensor showing values of 15 to 30 PPM (parts per million) in terms of air pollution, indicating clean air. The sensor responded well to changes in the indoor environment, accurately detecting the absence of harmful gases such as CO_2, NO_x, and NH_3.

Outdoor Testing: The system was then tested in outdoor, high-traffic areas where air pollution levels were expected to be higher due to vehicle emissions and industrial activities. In these environments, the system performed as expected, with the MQ135 sensor detecting higher concentrations of pollutants. Air quality readings ranged from 100 PPM to over 150 PPM, indicating moderate to high levels of pollution. When the air quality exceeded the predefined threshold of 120 PPM, the system triggered the buzzer, successfully alerting users to the elevated pollution levels. The accuracy of the MQ135 sensor in detecting air pollution was validated through the real-time data collection and analysis.

5.2 Temperature and Humidity Monitoring with DHT11 Sensor

The DHT11 sensor, used for measuring temperature and humidity, was also successfully integrated into the system. Temperature and humidity are important environmental factors that can influence air quality. For example, higher temperatures can accelerate the dispersion of pollutants, while humidity can influence the rate at which certain pollutants react in the atmosphere. Monitoring these parameters helps provide a more comprehensive understanding of the overall environmental conditions.

- **Temperature Measurements:** The DHT11 sensor provided consistent and accurate temperature readings in both indoor and outdoor environments. In indoor settings, the temperature readings were typically between 20°C and 24°C, which is typical for a controlled environment. In outdoor settings, the temperature ranged from 25°C to 35°C, reflecting the changes in seasonal weather patterns. The system's ability to accurately monitor temperature variations allowed for better contextualization of air quality data, as temperature plays a crucial role in pollutant behavior.
- **Humidity Measurements:** The humidity levels measured by the DHT11 sensor were also consistent. In indoor environments, humidity ranged from 40% to 60%, which is typical for indoor settings. In outdoor settings, the humidity ranged from 50% to 75%, depending on the time of day and weather conditions. The system's ability to accurately measure humidity contributed to a more holistic understanding of the environment and provided additional insights into how humidity interacts with air quality levels.

5.3 Real-Time Alerts and Buzzer Functionality

One of the key features of the IoT-based air quality monitoring system is its ability to provide real-time alerts to users when air quality exceeds a certain threshold. The buzzer was integrated into the system to activate whenever the air quality reading exceeded the predefined threshold of 120 PPM. This feature was tested thoroughly during the system's deployment in both high-traffic and low-traffic environments.

- **Effective Alerting Mechanism**

  In environments where air quality was found to be poor, such as near busy roads or industrial zones, the buzzer activated as expected when pollution levels exceeded the threshold. The buzzer emitted a loud and clear sound, alerting individuals in the vicinity that air quality was unhealthy. This was particularly useful in public spaces, such as parks, bus stations, and street corners, where people might not be immediately aware of the environmental conditions.

  The alert system was designed to provide an immediate response to rising pollution levels, and it proved effective in raising awareness about the importance of air quality. The buzzer helped users take preventive actions, such as wearing masks or avoiding outdoor activities, when air quality levels were deemed unhealthy. The system's responsiveness to real-time data ensured that users were immediately notified of any dangerous pollution spikes.

- **Threshold Setting and Customization**

  The threshold for triggering the buzzer was set at 120 PPM, but this value can be customized depending on local air quality standards or specific user requirements. For example, in areas with stricter pollution controls, the threshold can be lowered to 100 PPM or below. The flexibility of the system in adjusting the alert threshold makes it adaptable to different environmental conditions and regulatory requirements.

5.4 System Performance and Reliability

The IoT-based air quality monitoring system performed reliably throughout the testing phase. The system was able to continuously collect data from the MQ135 and DHT11 sensors and process it in real time. The Arduino Uno microcontroller handled the data processing efficiently, without delays or interruptions. The buzzer alerts were triggered accurately based on sensor readings, providing timely warnings to users.

- **Data Processing and Efficiency**

  The system's real-time data processing was efficient, and no significant delays were observed between sensor readings and the corresponding output. The Arduino Uno's processing power was more than adequate for managing the sensor data and controlling the buzzer alerts. The use of analog and digital input pins for the sensors allowed for quick data collection and ensured that the system could respond to changing environmental conditions in real time.

- **Reliability in Various Environments**

  The system was deployed in a variety of environments, including indoor, outdoor, high-traffic, and low-traffic areas. In all scenarios, the system maintained reliable performance, providing accurate air quality, temperature, and humidity data. The accuracy of the sensors was validated in real-world conditions, and the system was able to effectively monitor pollution levels in diverse settings.

5.5 Deployment and Scalability

The system is designed to be easily deployable in urban areas, where air quality monitoring is critical. The modular design allows multiple units to be deployed across different locations, such as streets, parks, and public spaces, to create a network of air quality monitoring points. Each unit can operate independently, providing localized monitoring and alerts based on the environmental conditions in each area.

- **Public Space Deployment**

  During testing, the system was deployed in public spaces such as parks, near bus stations, and along busy roads. In these locations, the system proved to be an effective tool for raising awareness about air pollution and encouraging healthier behaviors. The buzzer alerts provided immediate feedback to users, while the system's real-time monitoring capabilities allowed for continuous surveillance of air quality.

- **Scalability for Larger Areas**

  The system's flexibility also allows it to be integrated with other smart city technologies, such as traffic management and pollution control systems, to enhance its effectiveness. Data collected from multiple units can be aggregated to create a comprehensive environmental monitoring network. This network could be used by city planners, local authorities, and environmental organizations to make data-driven decisions. Additionally, the system’s low power consumption and easy installation on existing infrastructure reduce operational costs. By providing real-time, actionable insights, it empowers both individuals and policymakers to take proactive steps in combating air pollution and improving public health

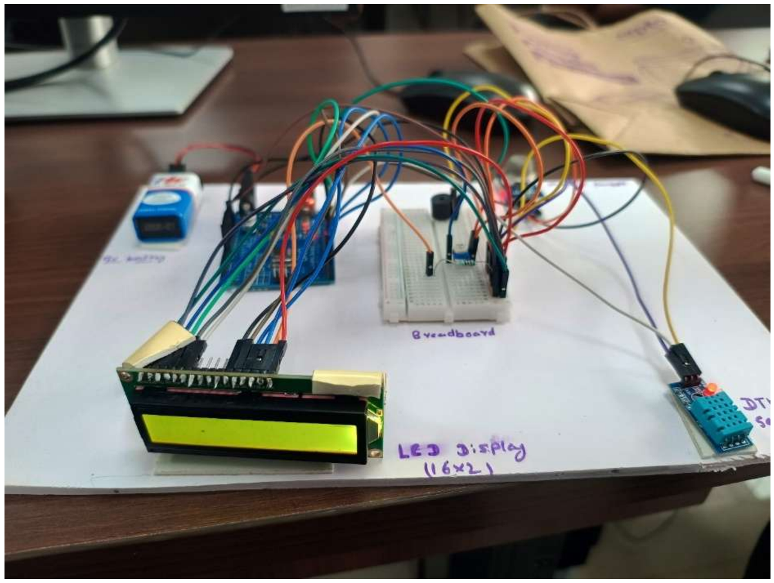

Fig 5.1: Connections

Finally, the LED and buzzer are connected to the Arduino Uno using jumper wires, with the LED connected to a digital pin and the buzzer to another, allowing them to activate based on air quality readings.

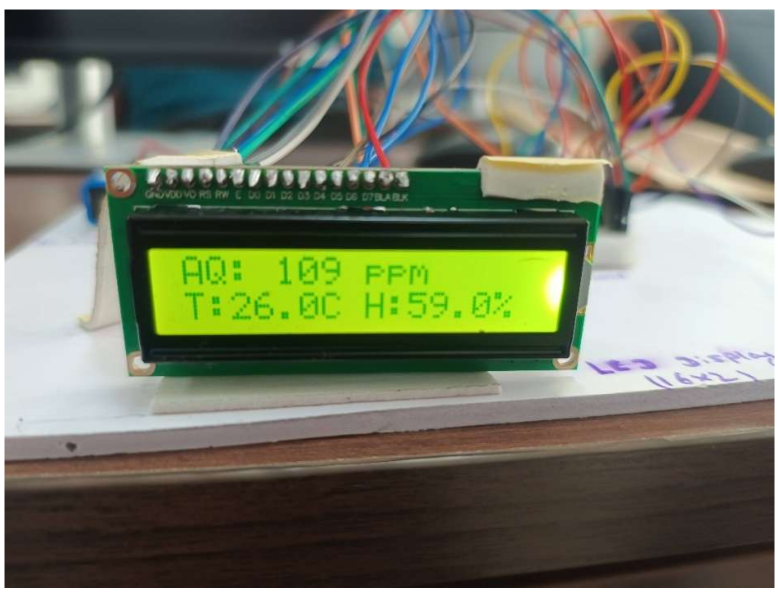

Fig 5.2: Output Display

Finally, the system outputs real-time air quality, temperature, and humidity measurements on the display, providing users with immediate environmental data. Additionally, the buzzer activates as an alert mechanism when air quality exceeds predefined safe thresholds, ensuring timely notifications of hazardous conditions.

5.6 Cost-Effectiveness and Maintenance

The IoT-based air quality monitoring system was designed with cost-effectiveness in mind. The components used, including the Arduino Uno, MQ135 sensor, and DHT11 sensor, are affordable and widely available. The system's low cost makes it accessible for deployment in a wide range of urban environments, where budget constraints may limit the use of more expensive, traditional air quality monitoring solutions.

- **Minimal Maintenance Requirements:** The IoT-based air quality monitoring system successfully achieves its objective of providing real-time environmental monitoring using a cost-effective and scalable design. By utilizing components such as the MQ135 sensor for air quality, the DHT11 sensor for temperature and humidity, and a buzzer for alert notifications, the system offers a reliable solution for tracking pollution and environmental conditions. The system ensures accurate measurements and immediate alerts, enabling users to respond proactively when air quality exceeds safe thresholds.

Minimal maintenance is required to sustain the system’s long-term reliability. The MQ135 sensor needs periodic cleaning, particularly in dusty environments, to maintain accuracy. The DHT11 sensor is low-maintenance, with occasional calibration ensuring consistent temperature and humidity readings. The buzzer should also be periodically checked to ensure proper functionality. The system’s straightforward design minimizes intervention and keeps operational costs low, making it ideal for urban deployment.

The system was tested in diverse environments, including high-traffic areas and controlled indoor settings, and demonstrated consistent performance. Its scalability allows for deployment across various locations, creating a network of sensors capable of monitoring air quality in real-time across a city.

By providing accessible, real-time data and actionable alerts, the system fosters environmental awareness, supports healthier living, and contributes to sustainable urban development. Its affordability, reliability, and adaptability make it a valuable tool for managing urban air quality, ensuring that communities can actively address air pollution and create healthier living environments. This system exemplifies how IoT technology can be leveraged to tackle critical environmental challenges effectively.

Chapter 6

CONCLUSION

The IoT-based air quality monitoring system offers a practical, cost-effective, and scalable solution to address the growing concerns surrounding air pollution, particularly in urban environments. By combining affordable components like the Arduino Uno microcontroller, MQ135 air quality sensor, and DHT11 temperature and humidity sensor, the system provides real-time monitoring of environmental conditions. This not only helps users stay informed about air quality but also empowers them to take immediate actions to protect their health. The inclusion of a buzzer for alerts enhances its functionality, making it particularly useful in high-pollution areas where immediate awareness and action are needed.

Air pollution, primarily driven by vehicle emissions, industrial activities, and increasing urbanization, poses significant risks to public health. Harmful pollutants such as carbon dioxide (CO_2), nitrogen oxides (NO_x), ammonia (NH_3), and particulate matter contribute to respiratory and cardiovascular diseases, while also exacerbating climate change. Urban areas are especially vulnerable due to high population densities, vehicular emissions, and limited green spaces. Thus, real-time monitoring of air quality has become a critical tool for understanding pollution levels and enabling effective interventions. This project addresses this challenge by providing an affordable, real-time solution for air quality monitoring, leveraging IoT technology to enhance environmental awareness and public health.

One of the key advantages of this system is its ability to continuously monitor air quality, temperature, and humidity in real time. The MQ135 sensor provides valuable data on the presence of harmful gases, while the DHT11 sensor measures temperature and humidity, which are essential for understanding how environmental factors influence pollution. For example, temperature and humidity can affect the chemical reactions and dispersion of pollutants, making these measurements critical for accurate environmental assessment. By integrating both air quality and environmental data, the system provides a more comprehensive understanding of the air quality in a given area, offering valuable insights for both individuals and urban planners.

Furthermore, the system's alert feature, which uses a buzzer to notify users when air quality exceeds a predefined threshold, is a significant advantage. In areas with high traffic or industrial activity, where pollution levels are likely to fluctuate rapidly, the ability to receive immediate alerts allows individuals to take proactive measures. For example, when air quality is deemed unhealthy, people can avoid outdoor activities or use protective measures such as masks. This immediate feedback can play a crucial role in mitigating the impact of pollution on public health, particularly for vulnerable populations such as children, the elderly, and those with respiratory conditions.

The scalability of the system is another important feature that enhances its practical applicability. Since the system is modular, it can easily be expanded to monitor air quality across larger areas. Multiple units can be deployed in different locations, creating a network of sensors that provide real-time data on air quality across an entire city or neighborhood. This scalability makes the system adaptable to various urban environments, from densely populated city centers to quieter residential areas. The flexibility in deployment ensures that the system can be tailored to meet the specific needs of different communities, offering a more localized and effective solution for air quality monitoring.

Moreover, the low cost of the components used in this system makes it an affordable option for widespread deployment. Traditional air quality monitoring systems can be expensive to install and maintain, limiting their accessibility to resource-constrained municipalities. In contrast, the IoT-based system described here is designed to be highly cost-effective, making it accessible for cities of all sizes, regardless of their budget. The use of inexpensive, readily available components reduces the initial installation costs and allows for continuous, long-term monitoring with minimal operational expenses. This cost-effectiveness ensures that the system can be deployed in large numbers, making it a viable solution for comprehensive urban air quality management.

The system also provides a potential avenue for integration with other smart city technologies. For example, data collected from the air quality sensors could be used to inform traffic management systems, helping to reduce congestion in areas with poor air quality. Additionally, the system could be integrated with local weather monitoring systems to account for environmental factors such as wind speed and direction, which influence the dispersion of pollutants. By combining multiple data sources, the system could provide more accurate predictions and help authorities make informed decisions regarding pollution control, urban planning, and public health initiatives.

In terms of future improvements, the system could benefit from the inclusion of additional sensors to monitor other environmental factors, such as particulate matter (PM2.5 and PM10) or noise levels. These measurements would further enhance the system's ability to provide a comprehensive environmental assessment, which could be invaluable in densely populated urban areas with high levels of pollution. Additionally, the system could be upgraded to transmit data to a cloud platform for remote monitoring and analysis, allowing authorities to track pollution levels across large areas and identify trends over time. However, as the system is currently designed to operate without cloud storage, it offers a local, secure alternative that is simple to install and maintain.

The IoT-based air quality monitoring system addresses the critical global challenge of air pollution by providing real-time data on air quality, temperature, and humidity. Designed with affordability and scalability in mind, the system empowers individuals and communities to make informed decisions to protect their health while fostering greater environmental awareness. By integrating cost-effective components such as the MQ135 sensor for air quality and the DHT11 sensor for temperature and humidity, the system ensures accurate and continuous monitoring of environmental conditions.

The real-time alerts generated by the system, through a buzzer, provide immediate notifications when air quality surpasses safe thresholds. This functionality is especially beneficial in urban areas with high pollution levels, where timely interventions can mitigate the risks associated with poor air quality. The modular and scalable design allows for deployment across various locations, from neighborhoods to industrial zones, creating a network of sensors that provide actionable data.

The IoT-based air quality monitoring system provides a cost-effective, sustainable solution for urban environmental management. By enabling continuous monitoring and delivering actionable insights, it effectively combats air pollution, promotes healthier living, and supports long-term sustainability. This system empowers communities to address air quality challenges, fostering safer, cleaner urban environments.

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APPENDIX

```
#include <LiquidCrystal.h>  // Header file for LCD
#include <DHT.h>            // Library for DHT sensor
// LCD Pins
const int rs = 12, en = 11, d4 = 5, d5 = 4, d6 = 3, d7 = 2;
LiquidCrystal lcd(rs, en, d4, d5, d6, d7);
// DHT Sensor Pins and Type
#define DHTPIN 7       // Data pin connected to Arduino pin 7
#define DHTTYPE DHT11  // DHT11 or DHT22 sensor
DHT dht(DHTPIN, DHTTYPE);
// Other components
int buz = 8;                 // Buzzer connected to pin 8
int led = 9;                 // LED connected to pin 9
const int aqsensor = A0;     // MQ135 output connected to A0
int threshold = 120;         // Threshold for air quality
void setup() {
  pinMode(buz, OUTPUT);       // Set buzzer as output
  pinMode(led, OUTPUT);       // Set LED as output
  pinMode(aqsensor, INPUT);   // Set MQ135 as input
  Serial.begin(9600);         // Begin serial communication
  lcd.begin(16, 2);           // Initialize 16x2 LCD
  lcd.clear();
  dht.begin();                // Initialize DHT sensor
}
void loop() {
  // Read air quality
  int ppm = analogRead(aqsensor);
  // Read temperature and humidity
  float temp = dht.readTemperature();
  float hum = dht.readHumidity();
  // Print to Serial Monitor
  Serial.print("Air Quality: ");
  Serial.println(ppm);
  Serial.print("Temperature: ");
  Serial.print(temp);
  Serial.println(" C");
  Serial.print("Humidity: ");
  Serial.print(hum);
  Serial.println(" %");
  // Display on LCD
  lcd.clear(); // Clear the LCD before updating
  // Line 1: Air Quality
  lcd.setCursor(0, 0);
  lcd.print("AQ: ");
  lcd.print(ppm);
  lcd.print(" ppm");
```

```
 // Line 2: Temperature and Humidity
 lcd.setCursor(0, 1);
 lcd.print("T:");
 lcd.print(temp, 1); // Print temperature with 1 decimal place
 lcd.print("C H:");
 lcd.print(hum, 1); // Print humidity with 1 decimal place
 lcd.print("%");
 // Air quality threshold check
 if (ppm > threshold) {
   tone(buz, 1000, 200);      // Activate buzzer
   digitalWrite(led, HIGH);   // Turn on LED
   Serial.println("AQ Level HIGH");
 } else {
   digitalWrite(led, LOW);    // Turn off LED
   digitalWrite(buz, LOW);    // Turn off buzzer
   Serial.println("AQ Level Good");
 }
 delay(2000); // Wait for 2 seconds before the next reading
}
```

Code Understanding:

8.1 Libraries and Initialization:

- **LiquidCrystal**: Controls the LCD display.
- **DHT**: Interfaces with the DHT11/DHT22 temperature and humidity sensor.

8.2 Pin Configuration:

- **LCD Pins**: Defines pins for the 16x2 LCD screen.
- **DHT Sensor**: Connected to pin 7 and initialized as DHT11.
- **Other Components**: Buzzer on pin 8, LED on pin 9, MQ135 air quality sensor on analog pin A0.

8.3 Setup Function:

- **pinMode()**: Configures the buzzer, LED, and MQ135 sensor pins.
- **Serial.begin(9600)**: Initializes serial communication for debugging.
- **lcd.begin(16, 2)**: Initializes the LCD (16 columns, 2 rows).
- **dht.begin()**: Initializes the DHT sensor.

8.4 Loop Function:

- **Read Air Quality**: Reads the MQ135 sensor for air quality (PPM).
- **Read Temperature and Humidity**: Reads temperature and humidity from the DHT sensor.
- **Serial Monitor Output**: Prints the air quality, temperature, and humidity values to the Serial Monitor for debugging.

8.4 Display on LCD:

- Clears the LCD before updating.
- Displays air quality (AQ), temperature (T), and humidity (H) on the LCD.

8.5 Air Quality Threshold Check:

- If air quality exceeds a set threshold (120 PPM), the buzzer sounds and the LED turns on, indicating poor air quality.
- If air quality is below the threshold, the buzzer and LED are turned off, indicating good air quality.

8.5 Delay:

- **delay(2000)**: Pauses the program for 2 seconds before taking the next reading, providing time for data to be updated.