IOT

AIR QUALITY MONITORING

PHASE-5 PROJECT REPORT

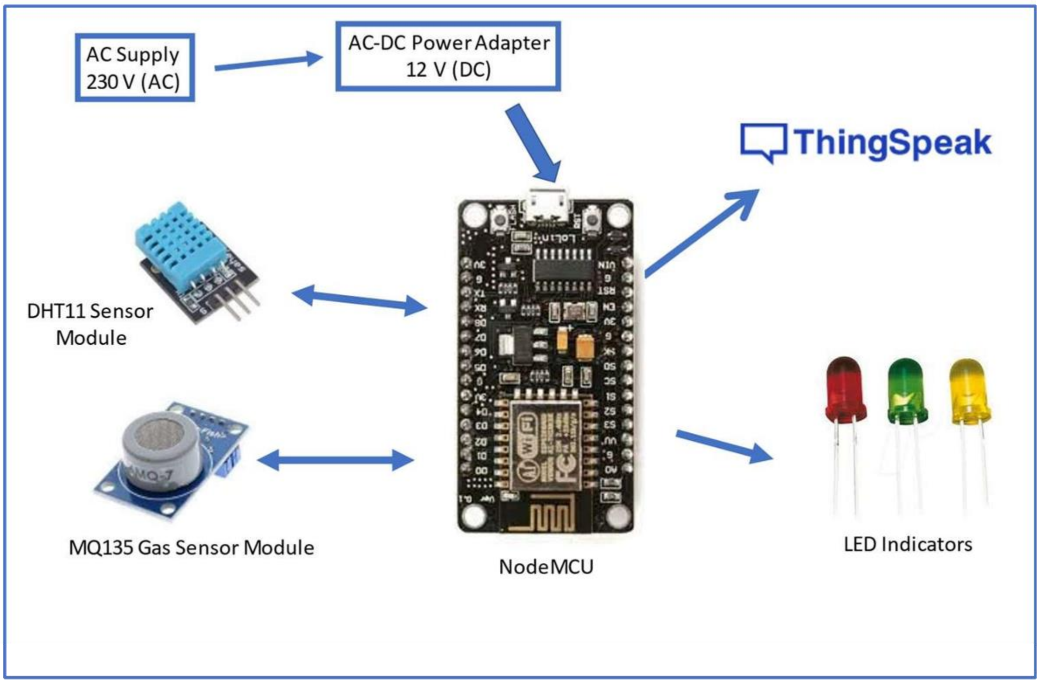
BY

TEAM LEADER: DINESH BOOPATHY C
TEAM MEMBER: DHANUSH P
TEAM MEMBER: JAYAKUMAR N
TEAM MEMBER: SUNIL KUMAR P

TABLE OF CONTENTS

ABSTRACT

Air pollution is one of the biggest threats to the present-day environment. Everyone is being affected by air pollution day by day including humans, animals, crops, cities, forests and aquatic ecosystems. Besides that, it should be controlled at a certain level to prevent the increasing rate of global warming. This project aims to design an IOT-based air pollution monitoring system using the internet from anywhere using a computer or mobile to monitor the air quality of the surroundings and environment. There are various methods and instruments available for the measurement and monitoring quality of air. The IoT-based air pollution monitoring system would not only help us to monitor the air quality but also be able to send alert signals whenever the air quality deteriorates and goes down beyond a certain level. In this system, Node MCU plays the main controlling role. It has been programmed in a manner, such that, it senses the sensory signals from the sensors and shows the quality level via led indicators. Besides the harmful gases (such as CO2, CO, smoke, etc) temperature and humidity can be monitored through the temperature and humidity sensor by this system. Sensor responses are fed to the Node MCU which displays the monitored data in the Thing Speak cloud which can be utilized for analyzing the air quality of that area. Indicates the working mechanism of the IoT-based Air Pollution Monitoring System.



PHASE-1
PROBLEM DEFINITION
&
DESIGN

PHASE 1

INTRODUCTION

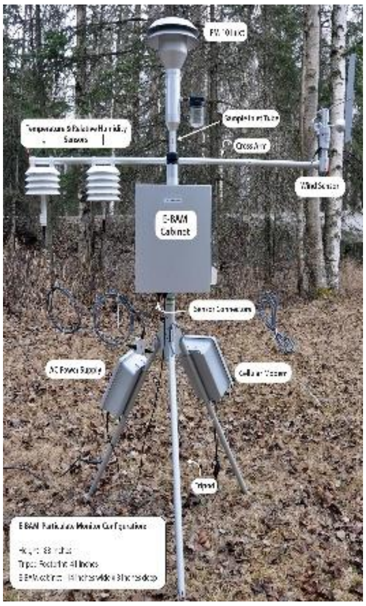
Air quality monitoring is the systematic and coordinated approach to assessing, regulating, and improving the quality of the air in a specific region or area. It involves monitoring air pollutants, setting standards and regulations, implementing strategies to reduce emissions, and educating the public about air quality issues. The primary goal is to protect human health the environment by minimizing the presence of harmful air pollutants and maintaining air quality at levels that are safe for people to breathe.

PROGRAM STATEMENT

In the context of software development, is a written description or document that outlines the purpose, objectives, and functionality of a software program or application. It serves as a blueprint for developers, designers, and stakeholders, providing a clear understanding of what the software is intended to achieve.

A Typical Program Statement Includes:

- Objective: A clear and concise statement of the program's goals and what it aims to accomplish.
- Scope: An outline of the features, functions, and capabilities that the program will include. This defines the boundaries of the project.
- Requirements: Specific technical and functional requirements, including any hardware or software dependencies.
- User Stories: If applicable, descriptions of how the software will be used from the perspective of different types of users.
- Functional Flow: A high-level overview of how the program will function, including key processes and interactions.
- Data Model: A description of the data that the program will use or generate, including databases or data structures.
- User Interface Design: If relevant, mock-ups or descriptions of the user interface, including screen layouts and navigation.
- Testing and Quality Assurance: Plans for testing the software to ensure it meets its requirements and functions correctly.
- Timeline and Milestones: A rough estimate of the project's timeline, including major milestones and deadlines. The program statement serves as a reference point throughout the software development process, helping all stakeholders stay aligned and focused on the project's objectives. It can also be used to evaluate the success of the completed software against the initial goals and requirements.



DESIGN THINKING

Is a human centred, problem-solving approach and mindset that is used to create innovative and effective solutions to complex problems. It places a strong emphasis on understanding the needs and perspectives of the people who will use or be affected by the solutions being developed. Here are the key principles and stages of the design thinking process:

- **Empathize:** This initial stage involves researching and understanding the needs, behaviors, and challenges of the people for whom you are designing. It often includes activities such as interviews, surveys, observations, and immersion in the users' environment.
- **Define:** In this stage, you distill the insights gathered during the empathize stage to define the problem or challenge you are trying to solve. It involves framing the problem statement in a way that is user-centric and actionable.
- **Ideate:** During the ideation stage, you generate a wide range of creative ideas and potential solutions without judgment. Techniques like brainstorming, mind mapping, and sketching are commonly used to encourage creative thinking.
- **Prototype:** This stage involves creating low-fidelity representations or prototypes of your ideas. Prototypes can be sketches, physical models, or interactive digital mock-ups. The goal is to quickly and cost-effectively test and iterate on your concepts.
- **Test:** You gather feedback on your prototypes by testing them with real users or stakeholders. This feedback helps refine and improve your solutions. Testing can be an iterative process, and you may cycle back through the stages to make further refinements.
- **Implement:** Once you have a refined and validated solution, you move into the implementation phase, where you develop and deploy the final product or solution.

- **Iterate:** Design thinking is an iterative process, and it often involves going back to earlier stages to make improvements based on new insights or changing circumstances.

Key Principles of Design Thinking Include:

1. **User-Centred**: It focuses on the needs, behaviors, and experiences of users or customers.
2. **Collaborative:** It encourages multidisciplinary teams to work together, bringing diverse perspectives to problem-solving.
3. **Terative**: It emphasizes the importance of refining and iterating on solutions based on feedback and testing.
4. **Creative:** It promotes creative thinking and ideation to generate innovative solutions.
5. **Holistic:** It considers the entire user journey and ecosystem rather than isolated components.
6. Design thinking is widely used in various fields, including product design, service design, business strategy, and social innovation, to tackle complex and ambiguous problems by placing people at the center of the design process.

PHASE-2
INNOVATION

PHASE -2

INTRODUCTION

- Air is getting polluted because of the release of toxic gases by industries, vehicle emissions and increased concentration of harmful gases and particulate matter in the atmosphere.
- The level of pollution is increasing rapidly due to factors like industries, urbanization, increase in population, vehicle use which can affect human health. Particulate matter is one of the most important parameters having a significant contribution to the increase in air pollution. This creates a need for measurement and analysis of real-time air quality monitoring so that appropriate decisions can be taken in a timely period.
- This paper presents real-time standalone air quality monitoring. Internet of Things (IoT)is nowadays finding profound use in each and every sector, plays a key role in our air quality monitoring system too. The setup will show the air quality in PPM on the webpage so that we can monitor it very easily.

STEPS FOR INNOVATION

Step-1: Refining the Phase-1:

IoT Concepts Used in the Project:

1. **Sensor Networks:** IoT relies on networks of sensors to collect data from the physical world. In your air quality monitoring project, you'll use various sensors to measure parameters like particulate matter, gases, temperature, and humidity.

2. **Data Transmission:** IoT devices need a means to transmit data. This can involve various communication technologies such as Wi-Fi, Bluetooth, or even LoRa for long-range communication in remote areas.

3. **Data Storage and Analysis:** IoT generates vast amounts of data. Storing this data securely and analyzing it to extract valuable insights are essential concepts. Cloud platforms like AWS or Azure can be used for data storage and analysis.

4. **Data Visualization:** Visualizing data in a user-friendly manner is crucial. Creating dashboards or mobile apps to display air quality data is an IoT concept you'll use.

5. **Energy Efficiency:** IoT devices often run on batteries, so optimizing energy consumption is vital. Low-power microcontrollers and energy harvesting methods can be applied.

Types of Sensors for Air Quality Monitoring:

1. **Gas Sensors:** These sensors can measure various gases like carbon dioxide (CO_2), carbon monoxide (CO), nitrogen dioxide (NO_2), and ozone (O_3). MQ-series gas sensors are commonly used for this purpose.

2. **Particulate Matter (PM) Sensors:** These sensors measure fine and ultrafine particles in the air, typically categorized as PM2.5 (particles with a diameter of 2.5 micrometers or smaller) and PM10. The SDS011 or PMS5003 are examples.

3. **Temperature and Humidity Sensors:** These sensors measure temperature and relative humidity, which can influence air quality. The DHT series sensors are widely used.

4. **Volatile Organic Compound (VOC) Sensors:** VOC sensors detect organic chemicals that can be harmful when present in the air. The CCS811 is an example.

Creating Virtual Circuits and Simulating Arduino Code in Tinkercad:

Tinkercad is a user-friendly online platform for creating virtual circuits and simulating Arduino code. Here's how to use it:

Creating a Virtual Circuit:

1. Go to the Tinkercad website (tinkercad.com) and create an account if you haven't already.
2. Click on "Circuits" in the top menu to access the circuit design section.
3. Start a new project by clicking "Create new circuit."
4. In the workspace, you'll find a variety of electronic components on the right-hand side. Drag and drop components onto the workspace to create your circuit.
5. Use wires to connect the components. Click on the component's pin, drag a wire, and connect it to another component's pin.
6. Configure the properties of each component by double-clicking on them.

Simulating Arduino Code:

1. After creating your circuit, click on the "Code" option at the top of the workspace.
2. You'll be presented with an integrated code editor. Write your Arduino code in this editor.
3. To run the simulation, click the "Start Simulation" button. You can see how your circuit behaves as the code runs.
4. Debug and test your code within the simulation environment. If there are issues, you can make changes and rerun the simulation.
5. Once you're satisfied with the simulation, you can save your project for future reference.

Step-2: Understanding The Problem:

1. Identify the Target Area:

- Determine the specific location or area where you intend to deploy your air quality monitoring system. This could be a city, industrial site, rural area, or any region of interest.

2. Understand the Air Quality Problem:

- Begin by understanding the air quality problem in your target area. Research historical data and reports related to air pollution in that location. Government environmental agencies and organizations often provide this information.

3. Identify Key Air Pollutants:

- Identify the primary air pollutants of concern for your target area. Common pollutants include:

- Particulate matter (PM2.5 and PM10)

- Ground-level ozone (O3)

- Nitrogen dioxide (NO2)

- Sulfur dioxide (SO2)

- Carbon monoxide (CO)

- Volatile organic compounds (VOCs)

- Research the sources, health effects, and environmental impact of these pollutants.

4. Review Air Quality Standards:

- Investigate the air quality standards and guidelines set by relevant environmental agencies. In the United States, for example, the Environmental Protection Agency (EPA) sets National Ambient Air Quality Standards (NAAQS). In the European Union, air quality standards are defined by the European Environment Agency (EEA).

5. Explore Regulations and Laws:

- Research local, regional, and national regulations related to air quality monitoring and emissions control. Understand the legal requirements for monitoring air quality and reporting pollutant levels.

6. Access Environmental Data:

- Look for databases and resources that provide real-time or historical air quality data. Government agencies often maintain databases that include air quality monitoring data collected from various monitoring stations.

7. Contact Environmental Experts:

- Reach out to experts in the field of environmental science or air quality monitoring. They can provide valuable insights, research papers, and guidance on understanding the air quality issues specific to your target area.

8. Assess Community Concerns:

- Consider the concerns and priorities of the local community regarding air quality.

Community input can provide valuable context and may influence the design of your monitoring system.

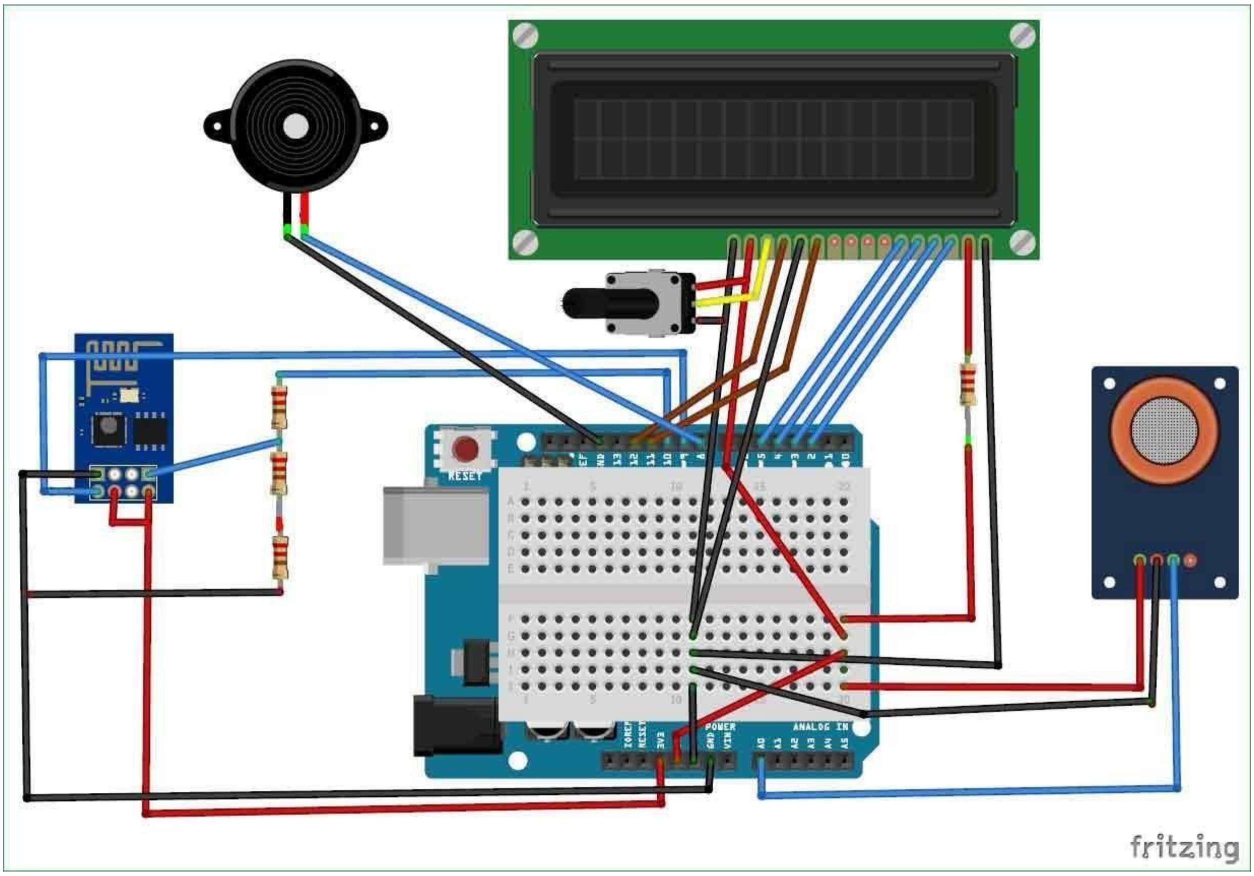
9. Environmental Impact Assessment (EIA):

- If your project involves significant environmental impact (e.g., in an industrial area), consult relevant authorities about the need for an Environmental Impact Assessment. This assessment helps understand the potential environmental consequences of your project.

10. International Guidelines:

- If applicable, consider international guidelines and standards such as those from the World Health Organization (WHO) for air quality and health.

Step-3: Choosing the Right IoT Hardware:



1. Identify Targeted Air Pollutants:

- Start by identifying the specific air pollutants you intend to measure based on your research in Phase-1. For example, if you're monitoring urban air quality, you might focus on PM2.5, NO2, CO, and O3.

2. Research Sensor Types:

- Conduct research on sensor types known for accuracy in measuring each of the targeted pollutants. For instance:

- PM2.5: Consider laser-based optical particulate matter sensors.

- NO2: Look into electrochemical sensors.

- CO: Explore metal oxide sensors.

- O3: Investigate ozone gas sensors.

3. Evaluate Sensor Accuracy:

- Review sensor datasheets, specifications, and independent research studies to assess the accuracy of these sensors in measuring the targeted pollutants. Pay attention to factors like measurement range, precision, and sensitivity.

4. Explore Cutting-Edge Sensor Technologies:

- Investigate cutting-edge sensor technologies that have the potential to enhance accuracy or offer unique features. This could include:

- Miniaturized Gas Chromatographs: These instruments can provide high-precision measurements of various gases but can be expensive and complex.

- Advanced Optical Sensors: Optical sensors, such as those based on spectroscopy or laserinduced fluorescence, can offer high accuracy and selectivity.

5. Consider Budget and Feasibility:

- Assess the budget and feasibility of implementing these cutting-edge sensor technologies. Some advanced sensors can be cost-prohibitive, require specialized knowledge, or have limited availability.

6. Sensor Calibration and Maintenance:

- Ensure that selected sensors are capable of calibration and maintenance, as regular calibration is essential for maintaining accuracy over time.

7. Sensor Integration:

- Consider how the selected sensors will be integrated into your air quality monitoring system. This includes sensor placement, data acquisition, and communication with the central monitoring unit.

8. Power Requirements:

- Evaluate the power requirements of the sensors and choose power sources (e.g., battery or solar) accordingly. Some advanced sensors may have higher power demands.

9. Test and Validation:

- Before finalizing sensor selection, conduct testing and validation to ensure that the sensors perform as expected in the actual environmental conditions of your target area. Compare sensor readings with reference instruments or data if possible.

10. Scalability and Maintenance:

- Consider the scalability of your sensor network. If you plan to deploy multiple sensors, ensure that they are manageable and maintainable over time.

Step-4: Innovative Sensor Selection:

Real-Time Data Calibration:

1. **Sensor Calibration:** Choose sensors that offer automatic or continuous calibration features. These sensors can adjust their measurements based on environmental conditions, ensuring accurate readings over time.

2. **Reference Sensors:** Use reference sensors or environmental monitoring stations as a benchmark for calibration. Compare the data from your sensors with data from these references, and calibrate as needed to align the measurements.

3. **Machine Learning:** Implement machine learning algorithms that can analyze historical data and perform dynamic calibration based on patterns and trends. This can help in fine-tuning sensor measurements.

4. **Feedback Loop:** Develop a feedback loop system where the sensor continuously compares its measurements to calibrated values and makes real-time adjustments when discrepancies are detected.

Self-Diagnosis Capabilities:

1. **Sensor Health Checks:** Opt for sensors equipped with built-in self-diagnosis routines. These routines can regularly assess the sensor's health and performance, detecting issues such as sensor drift or contamination.

2. **Fault Detection:** Implement algorithms that can analyze sensor output for anomalies. If the sensor detects an abnormal reading or deviation from the expected data pattern, it can trigger a self-diagnosis routine.

3. **Error Correction:** When the sensor identifies a problem, it can take corrective actions, such as recalibration or self-cleaning (if applicable), to rectify the issue and maintain measurement accuracy.

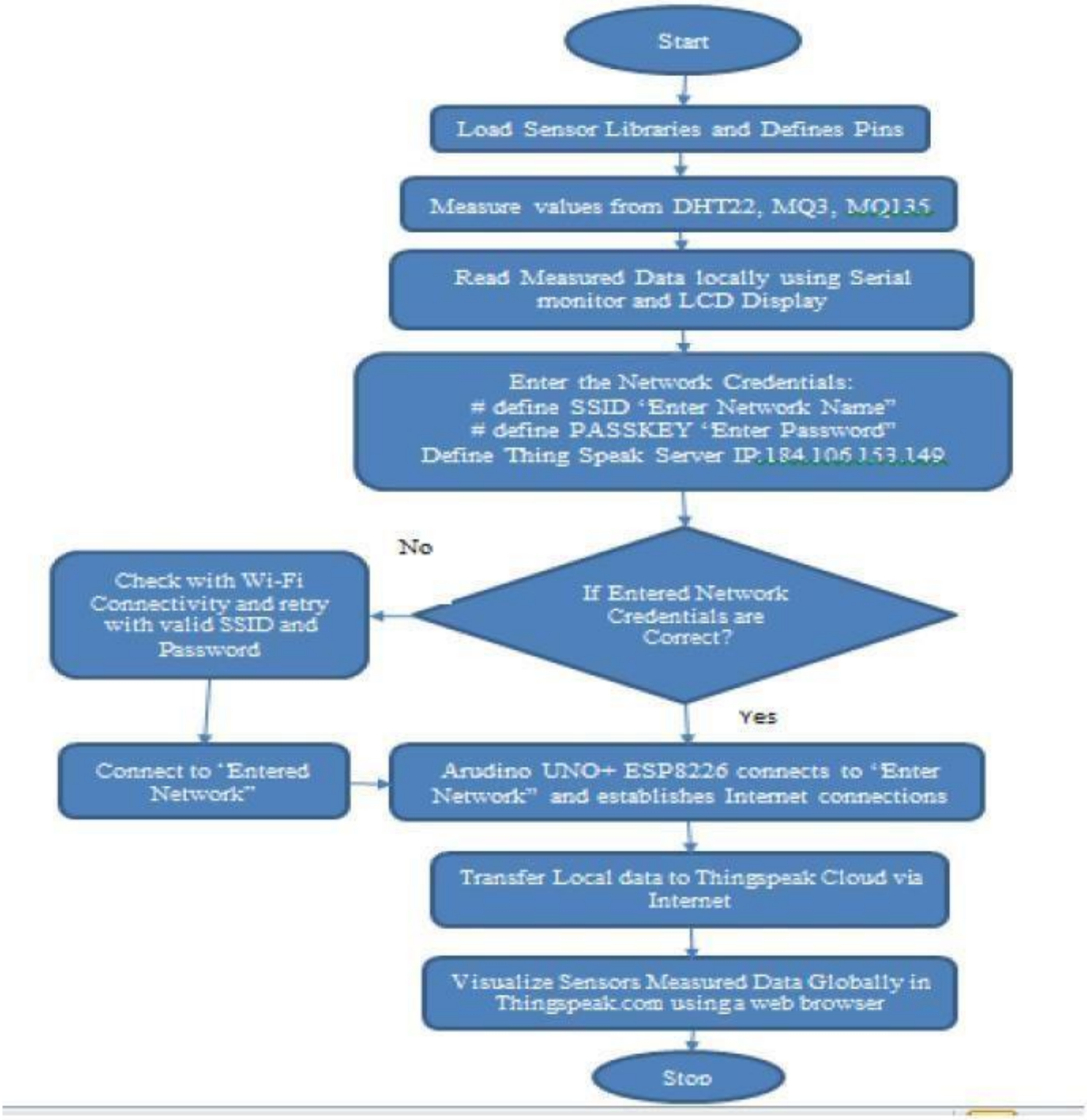
4. **Alerting Mechanism:** Set up an alerting mechanism that notifies you or relevant personnel when a sensor detects a problem or reaches a predefined threshold of uncertainty. This ensures prompt attention to maintenance or troubleshooting.

Project Benefits:

- Real-time data calibration and self-diagnosis enhance the reliability of your air quality monitoring system by minimizing sensor drift and measurement errors.

- Continuous monitoring and adjustment improve data accuracy over extended periods, making your project a valuable resource for stakeholders, researchers, and policymakers.

- The ability to offer consistent and dependable air quality data sets your project apart as a trustworthy and innovative solution for addressing air quality concerns.



Step-5: IoT Communication:

1. Defining communication objectives:

1. **Real-Time Data Transmission:** Transmit air quality data in real-time or near-real-time to provide immediate insights to stakeholders, including residents, local authorities, and researchers.

2. **Periodic Data Uploads:** In areas with limited connectivity, consider periodic data uploads (e.g., hourly or daily) to conserve power and bandwidth while still providing valuable air quality information.

3. **Data Integrity:** Ensure that data is transmitted accurately and securely to prevent data loss or corruption during transmission.

4. **Resilience:** Design the communication system to be resilient, with redundancy and selfhealing capabilities, to maintain data transmission even in the face of network disruptions.

5. **Low Power Consumption:** Minimize power consumption in sensor nodes to extend battery life in remote or off-grid locations. Implement power-efficient communication protocols and modes.

Evaluating the communication requirements of your air quality monitoring project is critical, especially when dealing with remote areas with limited connectivity. To ensure that data is reliably collected and transmitted, you can follow these steps:

2. Assess Connectivity Options:

- Evaluate the available connectivity options in the target area. This might include:

- Cellular networks (3G, 4G, or 5G).

- Wi-Fi networks (if available).

- LoRaWAN for long-range, low-power communication.

- Satellite communication (for extremely remote areas).

- Mesh networking for creating resilient, self-healing networks.

3. Consider Remote Area Challenges:

- In remote areas with limited connectivity, you may encounter challenges such as signal strength, network coverage gaps, and power constraints. Take these factors into account.

4. Innovative Approach - Mesh Networking:

- If the area lacks reliable connectivity, consider building a mesh network of sensors. Here's how you can implement this innovative approach:

- **Mesh Topology:** Set up your sensors in a mesh topology where each sensor node can communicate with neighboring nodes. This creates a self-organizing, self-healing network.

- **Relaying Data:** Data from sensors can hop from node to node until it reaches a central node with internet connectivity (gateway). This allows you to extend the range of your network beyond the limitations of individual sensor nodes.

- **Resilience:** Mesh networks are resilient because if one node fails or loses connectivity, data can find alternative routes to reach the central node.

- **Low Power:** Mesh networks can be designed for low power consumption, which is beneficial for remote areas with limited power sources.

5. Power Management:

- Implement power-efficient communication protocols and modes, especially in remote areas where power sources may be scarce. Ensure that sensors can operate for extended periods on available power.

6. Data Aggregation:

- Consider how data will be aggregated at the central node or gateway. Ensure that it can handle incoming data from multiple sensors and process it effectively.

7. Security and Data Integrity:

- Implement security measures to protect data as it travels through the network. Use encryption, authentication, and data validation mechanisms to ensure data integrity.

8. Redundancy and Backup:

- Plan for redundancy in your network to further enhance reliability. Redundant sensors or gateways can be crucial in maintaining continuous data transmission.

9. Scalability:

- Design your mesh network to be scalable. As your project expands or new monitoring locations are added, the network should accommodate additional nodes seamlessly.

10. Testing and Simulation:

- Conduct thorough testing and simulation of your mesh network in a controlled environment to identify potential issues and optimize network performance.

Step-6: Data Analysis and Processing:

Exploring machine learning techniques for innovative data analysis in your air quality monitoring project can bring significant benefits. Here's how you can justify and implement these techniques:

1. Complex Data Patterns:

- Air quality data can be complex, with multiple variables and non-linear relationships. Machine learning models are well-suited for capturing intricate patterns that may be challenging for traditional statistical methods.

2. Predictive Analytics:

- Machine learning models can be trained to predict air quality trends based on historical data. This predictive capability allows for early warnings and proactive measures to mitigate air pollution issues.

3. Anomaly Detection:

- Machine learning algorithms, such as isolation forests or autoencoders, can detect anomalies in air quality data. These anomalies may indicate sudden pollution events or sensor malfunctions.

4. Source Identification:

- Deep learning models, especially convolutional neural networks (CNNs) and recurrent neural networks (RNNs), can be used to identify pollution sources by analyzing data from multiple sensors and environmental factors.

5. Data Fusion:

- Machine learning can integrate data from various sources, including sensor readings, weather conditions, and geographical information, to provide a holistic view of air quality and pollution sources.

6. Feature Engineering:

- Machine learning allows for the automatic extraction of relevant features from raw data, potentially uncovering hidden patterns or relationships that are not apparent through manual analysis.

7. Scalability:

- Machine learning models can scale to handle large datasets and accommodate additional sensors or monitoring locations as your project expands.

8. Continuous Learning:

- Implement online learning techniques, enabling models to adapt to changing air quality conditions and sensor drift over time.

9. Visualization and Interpretability:

- Machine learning results can be visualized to provide intuitive insights into air quality trends, making the data more accessible to various stakeholders.

10. Early Warning Systems:

- Machine learning models can be used to build early warning systems that alert authorities and the public when air quality levels approach or exceed predefined thresholds, enhancing public safety.

11. Pollution Source Attribution:

- Deep learning models can analyze air quality data and meteorological conditions to attribute pollution events to specific sources, aiding regulatory agencies in enforcing pollution control measures.

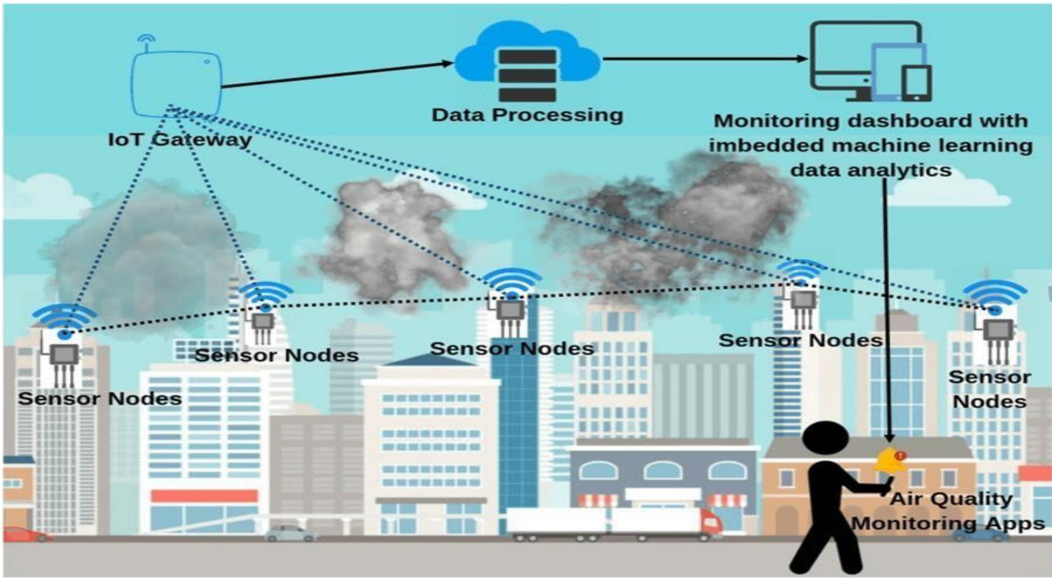
12. Research and Policy Support:

- Machine learning-based analysis can provide valuable data-driven insights for researchers, policymakers, and environmental agencies to make informed decisions and develop effective air quality management strategies.

13. Continuous Improvement:

- Machine learning models can continuously learn and improve as more data becomes available, leading to refined predictions and anomaly detection over time.

Step-7: User Interface and Visualization:



Justification:

1. **Enhanced User Engagement:** AR technology offers a unique and engaging way for users to interact with air quality data. It makes the data more accessible and engaging, encouraging users to stay informed about air quality conditions.

2. **Real-World Context:** By overlaying real-time air quality data onto a map of the area using AR, users can see how air quality conditions relate to their physical surroundings, providing a more intuitive and contextual understanding.

3. **Interactive Visualization:** AR enables interactive data visualization. Users can explore different areas on the map, view historical data, and access additional information by interacting with the AR elements.

4. **User Empowerment:** Providing users with a visually immersive AR experience empowers them to make informed decisions about their activities, such as choosing healthier routes for commuting or outdoor activities based on air quality.

5. **Public Awareness:** AR dashboards can contribute to raising public awareness of air quality issues, fostering a sense of responsibility and encouraging collective efforts to improve air quality.

Implementation:

Creating an AR-enhanced dashboard involves several key steps:

1. **Select AR Technology:**

-AR development platform or toolkit used here is Unity 3D with AR Foundation or ARKit/ARCore for mobile devices are popular choices.

2. **Map Integration:**

- Integrate a map component into your AR application. Use geospatial data and mapping APIs to display the target area.

3. **Data Integration:**

- Connect your air quality monitoring data sources to the AR application. Ensure that real-time data can be accessed and updated seamlessly.

4. **AR Data Overlay:**

- Develop a visual overlay that displays real-time air quality data on top of the map. Use graphical elements like color-coded heatmaps or icons to represent air quality levels.

5. **User Interaction:**

- Implement user-friendly interactions. Allow users to zoom in on specific areas, tap on icons for detailed information, or access historical data by navigating through time.

6. **Geolocation Services:**

- Incorporate geolocation services to pinpoint the user's location and provide localized air quality information. AR can then superimpose relevant data on the user's view.

7. **Customization and Personalization:**

- Give users the option to customize the dashboard, such as setting alert thresholds, choosing the type of air quality data displayed, or adjusting the visual style.

8. **User Education:**

- Include educational elements within the AR interface to help users understand the significance of air quality indices, health implications, and how to interpret the data.

9. **Cross-Platform Compatibility:**

- Ensure that your AR dashboard works seamlessly across various devices, including smartphones, tablets, and AR glasses, to maximize accessibility.

10. **Testing and User Feedback:**

- Conduct thorough testing to ensure the AR dashboard functions correctly and provides a smooth user experience. Gather user feedback to make improvements.

11. **Accessibility and Inclusivity:**

- Consider accessibility features for users with disabilities, such as voice commands or screen reader support.

12. **Data Sources and Reliability:**

- Ensure that the air quality data sources are reliable and up-to-date to provide accurate information to users.

Step-8: Energy Efficiency:

Justification:

1. **Sustainability:** Utilizing renewable energy sources like solar panels or piezoelectric devices aligns with sustainability goals, reducing the reliance on traditional power sources and minimizing the project's environmental footprint.

2. **Continuous Operation:** Energy harvesting techniques enable sensors to operate continuously without relying on conventional power sources, ensuring uninterrupted data collection and transmission, even in remote or off-grid areas.

3. **Cost Savings:** Once implemented, energy harvesting systems have minimal ongoing operational costs, making them a cost-effective choice over the long term, especially in locations with limited access to grid power.

4. **Extended Sensor Lifespan:** Ultra-low-power microcontrollers and efficient energy harvesting can significantly extend the lifespan of sensor nodes, reducing maintenance and replacement costs.

5. **Environmental Sensitivity:** Using renewable energy aligns with the environmentally sensitive nature of air quality monitoring projects, as it reduces carbon emissions and other pollutants associated with traditional power sources.

Implementation:

1. Solar Panels:

- Solar panels that are suitable for your project's energy requirements. Ensure they can charge batteries or capacitors for storing energy for use during nighttime or cloudy days.

2. Piezoelectric Devices:

- Piezoelectric devices can harvest energy from vibrations or mechanical movements. Determine if your monitoring location offers sources of mechanical energy, such as wind or vehicle vibrations, to harness.

3. Energy Storage:

- Incorporate energy storage components, such as rechargeable batteries or super capacitors, to store excess energy generated by harvesting devices for use when energy production is low.

4. Ultra-Low-Power Microcontrollers:

- Choose microcontrollers specifically designed for low-power operation. Microcontrollers from manufacturers like Texas Instruments and Silicon Labs are known for their energy efficiency.

5. Energy Management:

- Implement energy-efficient algorithms and strategies in your microcontroller code. Utilize sleep modes and wake-up triggers to minimize power consumption during idle periods.

6. Energy-Aware Sensor Sampling:

- Adjust sensor sampling rates based on air quality conditions. For example, increase the sampling frequency during pollution spikes and reduce it during periods of stable air quality to conserve power.

7. Power Monitoring:

- Implement power monitoring and management features that allow you to track the energy levels in your energy storage system and take appropriate actions, such as reducing sensor operation when power is low.

8. Backup Power:

- In cases of extended low-energy availability, consider incorporating backup power sources or energy-efficient power-down modes to ensure essential functions continue operating.

9. Efficiency Evaluation:

- Continuously evaluate the efficiency of your energy harvesting system and make adjustments as needed to maximize energy capture and utilization.

10. Monitoring and Maintenance:

- Implement remote monitoring of energy harvesting and storage systems to detect and address issues promptly. Regular maintenance ensures that the energy harvesting components are functioning optimally.

Step-9: Data Security and Privacy:

Implementing blockchain technology to secure and timestamp data in your air quality monitoring project can provide robust security, data integrity, and traceability benefits.

Justification:

1. **Data Integrity:** Blockchain's distributed ledger technology ensures that once data is recorded, it cannot be altered or deleted without consensus from network participants. This guarantees the integrity of air quality data.

2. **Immutable Timestamps:** Blockchain provides reliable timestamps for data entries. This feature helps establish the chronology of air quality measurements, which can be essential for identifying pollution sources or analyzing trends.

3. **Security:** Blockchain uses cryptographic techniques to secure data. Data stored on the blockchain is highly resistant to unauthorized access, tampering, or cyberattacks, enhancing overall security.

4. **Traceability:** Transactions on a blockchain are transparent and traceable. This traceability is valuable for auditing, accountability, and investigations into any discrepancies in air quality data.

5. **Decentralization:** Blockchain operates on a decentralized network of nodes, reducing the risk of a single point of failure. This enhances the resilience and availability of your air quality data.

6. **Privacy:** Data anonymization techniques protect the privacy of individuals and organizations contributing data to the monitoring system. Users can trust that their sensitive information remains confidential.

Implementation:

1. Choose a Blockchain Platform:

- Select a suitable blockchain platform based on your project's requirements. Public blockchains like Ethereum or private/consortium blockchains may be considered.

2. Data Structure:

- Define the structure of your data records to be stored on the blockchain. This should include air quality measurements, timestamps, sensor IDs, and any additional relevant information.

3. Data Encryption:

- Encrypt sensitive data before storing it on the blockchain to ensure confidentiality. Use secure encryption algorithms and key management practices.

4. Data Hashing:

- Generate cryptographic hashes of data entries and store them on the blockchain. These hashes serve as fingerprints, verifying the integrity of the original data.

5. Access Control:

- Implement access control mechanisms to restrict who can add or query data on the blockchain. This ensures that only authorized parties can interact with the system.

6. Privacy-Preserving Techniques:

- Utilize privacy-preserving techniques such as zero-knowledge proofs or differential privacy to anonymize sensitive data while still allowing for meaningful analysis.

7. Smart Contracts:

- Use smart contracts to automate processes such as data validation, timestamping, and consensus mechanisms. Smart contracts can execute predefined rules autonomously.

8. Consensus Mechanism:

- Select an appropriate consensus mechanism (e.g., proof of work, proof of stake, or other consensus algorithms) to secure the network and validate transactions.

9. Auditability:

- Implement audit trails that allow authorized parties to trace the history of data entries and transactions on the blockchain.

10. Compliance with Regulations:

- Ensure that your blockchain implementation complies with data protection regulations, such as GDPR, to safeguard user privacy.

11. Education and User Consent:

- Educate users about the blockchain technology used and obtain their informed consent for data collection, storage, and sharing.

Step-10: Testing and Validation:

1. Field Testing:

a. Diverse Weather Conditions:

- Conduct field tests in a variety of weather conditions to ensure that your monitoring system can withstand environmental challenges such as rain, snow, extreme temperatures, and high humidity. This helps validate the system's robustness and reliability. **b. Pollution Scenarios:**

- Simulate different pollution scenarios, including urban areas with high traffic, industrial zones, and rural regions, to assess the system's performance under varying air quality conditions. Collect data that represents the full range of pollution levels and pollutant types your system is designed to monitor.

c. Sensor Calibration and Validation:

- Regularly calibrate and validate the sensors in the field to ensure their accuracy and consistency. Compare sensor measurements with reference instruments to confirm the reliability of your data.

d. Real-World Data Collection:

- Collect real-world air quality data in the field to validate the accuracy of predictions made by your machine learning models. Ensure that the data aligns with model outputs. **e. Long-Term Monitoring:**

- Conduct long-term field tests to assess the system's performance over extended periods. This is particularly important for evaluating the durability of energy harvesting components and sensors.

2. Collaboration with Environmental Scientists:

a. Data Validation:

- Partner with environmental scientists to validate the accuracy and reliability of your air quality data. They can compare your measurements with data from established monitoring stations and provide expert validation. **b. Scientific Input:**

- Seek input from environmental scientists on data analysis techniques, model validation, and the interpretation of air quality trends. Their expertise can help ensure the scientific rigor of your project.

c. Environmental Impact Assessment:

- Collaborate with environmental scientists to assess the potential environmental impact of your monitoring system, especially in areas with sensitive ecosystems or protected areas. **d. Research Partnerships:**

- Explore research partnerships with universities or research institutions specializing in air quality and environmental science. These partnerships can provide access to resources, expertise, and validation opportunities. **e. Stakeholder Engagement:**

- Environmental scientists can help you engage with relevant stakeholders, such as regulatory authorities and community organizations, to ensure that your monitoring system aligns with regional air quality management goals.

f. Publication and Knowledge Sharing:

- Consider publishing research papers or reports in collaboration with environmental scientists to share the findings and innovations of your project with the scientific community and the public.

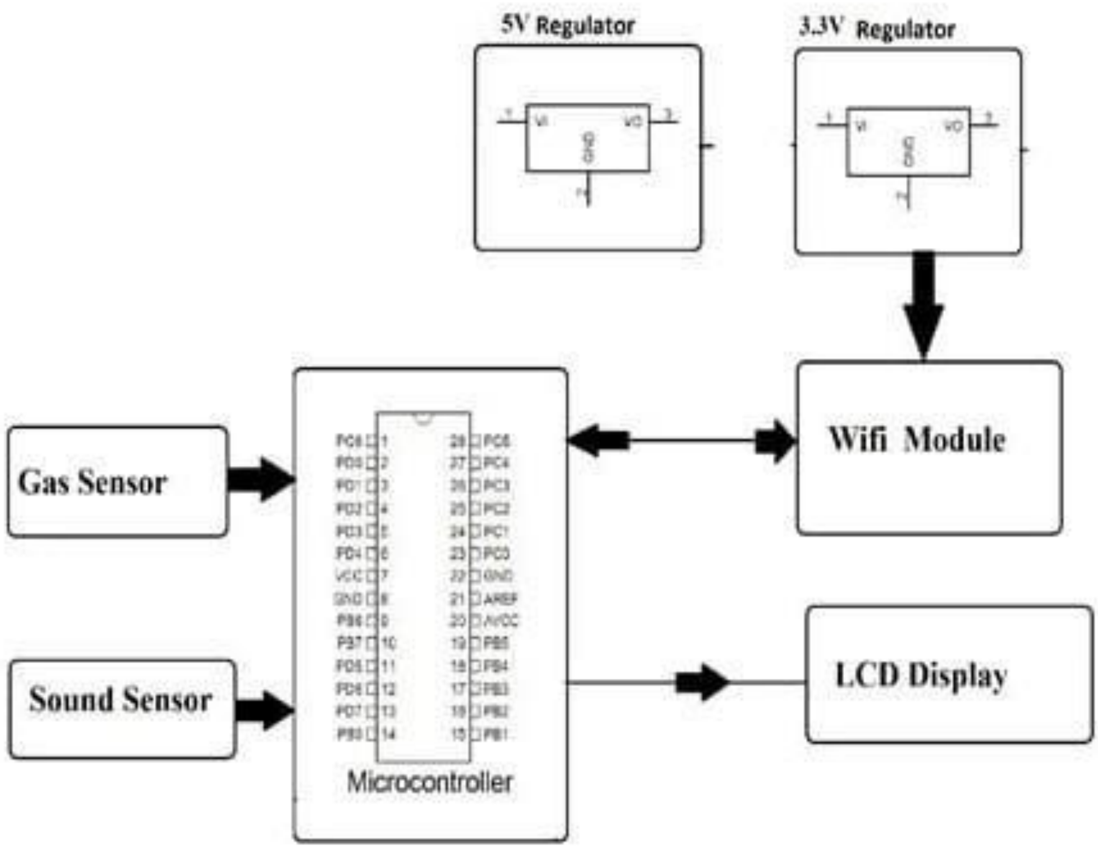
PHASE-3
DEVELOPMENT

PHASE-3

INTRODUCTION

- Air Quality Monitoring Networks allow the measurement, operation and predictive analysis of the evolution of air pollution in different areas (urban areas, industrial areas, special nature conservation areas, etc.) Some stations are equipped with meteorological sensors and/or noise level meters to measure noise levels.

BLOCK DIAGRAM



- An Air Quality Monitoring Station (AQMS) is a system that measures metrological parameters such as wind speed, wind direction, rainfall, radiation, temperature, barometric pressure and ambient parameters. The AQMS also integrates a series of ambient analyzers to monitor the concentration of air.
- Pollutants (such as SO2, NOx, CO, O3, THC, PM, etc.), continuously. HORIBA also provides mobile monitoring stations that can be used to monitor ambient conditions at multiple sites.

- HORIBA has more than 50 years experience providing ambient monitoring solutions, recognized around the world. HORIBA has supplied over 15,000 units with the major share in many regions. The monitoring station is tailor-made according to the customer's request. HORIBA can provide several types of stations, calibration equipment and more to meet your challenging monitoring requirements.
- The measured data can be remotely monitored and exported in various formats to the local central authorities. The data can be published via the Internet for easy public access to raise awareness on current air pollution levels. This way, the public can prevent outdoor activities and reduce health impacts during heavy polluted days.

RESOURCES REQUIRED

- Gas sensor
- Potentiometer
- 16x2 LCD Panel
- Arduino Uno R3
- Wires
- Piezo
- 220Ω Resistor
- 4.7 kΩ Resistor
- 1 kΩ Resistor
- Wokwi software

COMPONENT DESCRIPTION

- **Gas sensor:**

Air quality click is suitable for detecting ammonia (NH_3), nitrogen oxides (NO_x) benzene, smoke, CO_2, and other harmful or poisonous gases that impact air quality. The MQ-135 sensor unit has a sensor layer made of tin dioxide (SnO_2), an inorganic compound that has lower conductivity in clean air than when polluting gases are present. To calibrate Air quality, use the onboard potentiometer to adjust the load resistance on the sensor circuit.

Pin Description:

- the VDD power supply 5V DC
- GND used to connect the module to system ground

- DIGITAL OUT, you can also use this sensor to get digital output from this pin, by setting a threshold value using the potentiometer

ANALOG OUT, this pin outputs 0–5V analog voltage based on the intensity of the gas.

- <u>Potentiometer:</u>

A potentiometer is a three-terminal resistor with a sliding or rotating contact that forms an adjustable voltage divider. If only two terminals are used, one end and the wiper, it acts as a variable resistor or rheostat. The measuring instrument called a potentiometer is essentially a voltage divider used for measuring electric potential (voltage); the component is an implementation of the same principle, hence its name.

- <u>16x2 LCD Panel:</u>

A liquid-crystal display (LCD) is a flat-panel display or another electronically modulated optical device that uses the light-modulating properties of liquid crystals. Liquid crystals do not emit light directly, instead of using a backlight or reflector to produce images in color or monochrome. LCDs are available to display arbitrary images (as in a general-purpose computer display) or fixed images with low information content, which can be displayed or hidden, such as preset words, digits, and seven-segment displays.

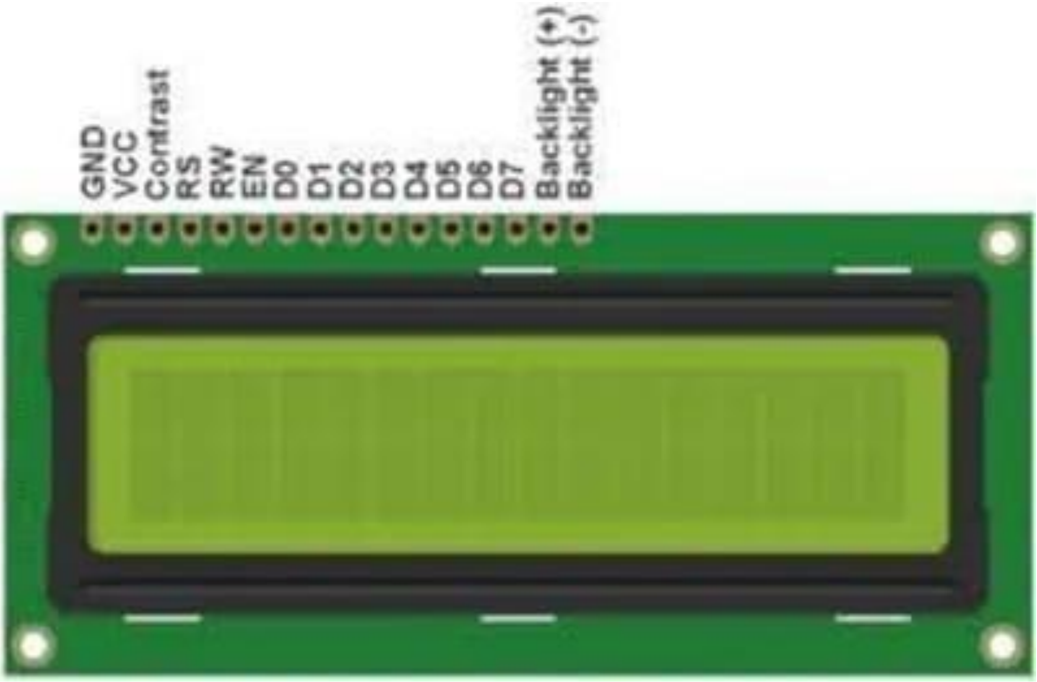
Pin Description:

- Connect pin 1 (VEE) to the ground.
- Connect pin 2 (VDD or VCC) to the 5V.
- Connect pin 3 (V0) to the middle pin of the 10K potentiometer and connect the other two ends of the potentiometer to the VCC and the GND. The potentiometer is used to control the screen contrast of the LCD. A potentiometer of values other than 10K will work too.

- Connect pin 4 (RS) to pin 12 of the Arduino.
- Connect pin 5 (Read/Write) to the ground of Arduino. This pin is not often used so we will connect it to the ground.
- Connect pin 6 (E) to pin 11 of the Arduino. The RS and E pin are the control pins that are used to send data and characters.
- The following four pins are data pins that are used to communicate with the Arduino.
- Connect pin 11 (D4) to pin 5 of Arduino.
- Connect pin 12 (D5) to pin 4 of Arduino.
- Connect pin 13 (D6) to pin 3 of Arduino.
- Connect pin 14 (D7) to pin 2 of Arduino.

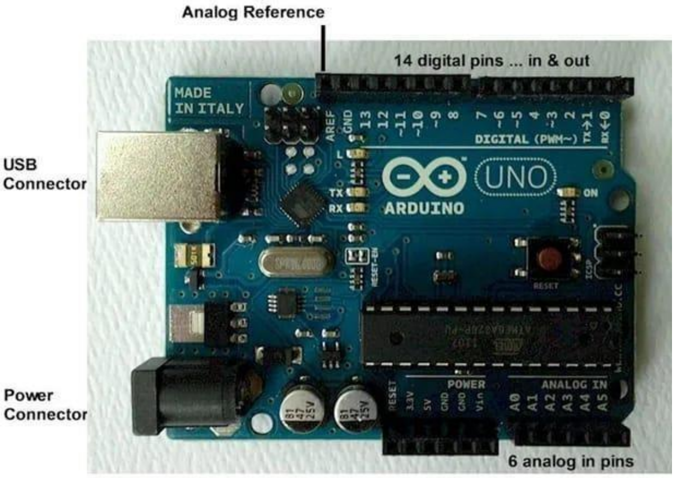
- Connect pin 15 to the VCC through the 220-ohm resistor. The resistor will be used to set the backlight brightness. Larger values will make the backlight much darker.

- Connect pin 16 to the Ground.



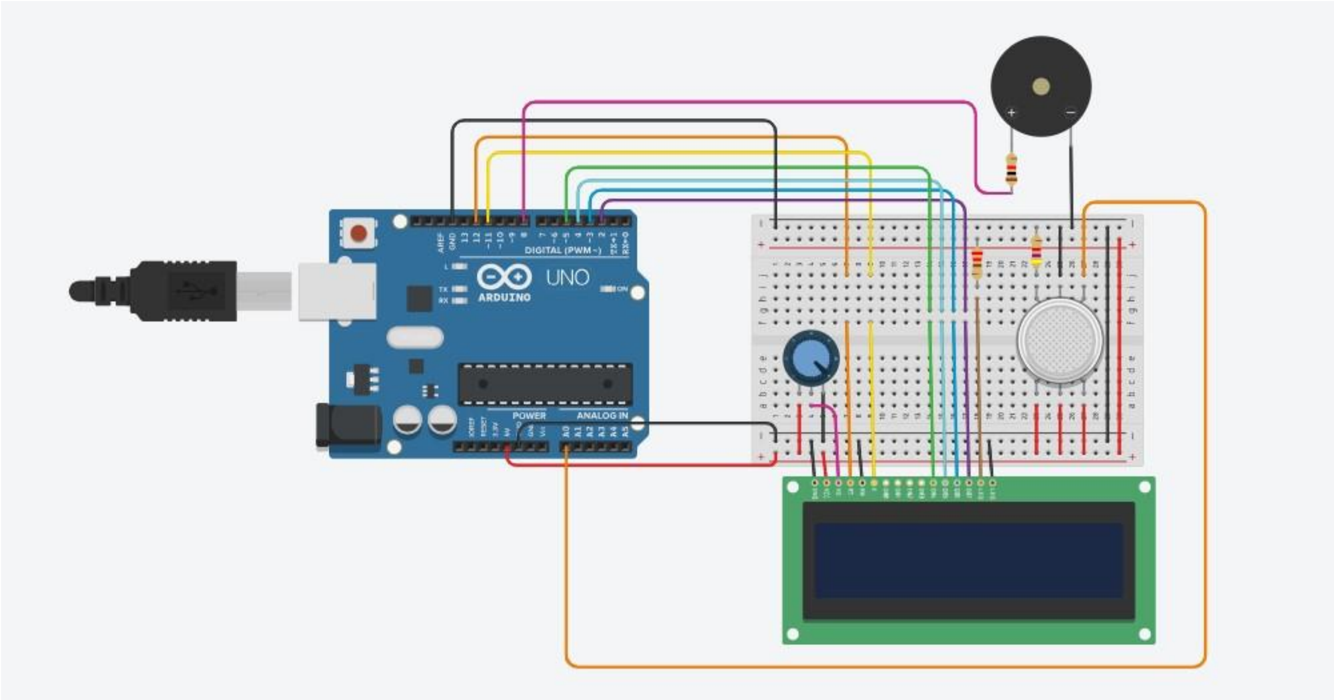
- Arduino:

Arduino is an open-source computer hardware and software company, project, and user community that designs and manufactures single-board microcontrollers and microcontroller kits for building digital devices and interactive objects that can sense and control objects in the physical world. Arduino board designs use a variety of microprocessors and controllers. The boards are equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards (shields) and other circuits. The boards feature serial communications interfaces, including Universal Serial Bus (USB) on some models, which are also used for loading programs from personal computers. The microcontrollers are typically programmed using a dialect of features from the programming languages C and C++. In addition to using traditional compiler toolchains, the Arduino project provides an integrated development environment (IDE) based on the Processing language project. Pin Description:



Power	Vin, 3.3V, 5V, GND	Vin: Input voltage to Arduino when using an external power source. 5V: Regulated power supply used to power microcontroller and other components on the board. 3.3V: 3.3V supply generated by on-board voltage regulator. Maximum current draw is 50mA. GND: ground pins.

CIRCUIT DESIGN



PROGRAM

```
// include the library code:
#include <LiquidCrystal.h>


// initialize the library with the numbers of the
interface pins
LiquidCrystal lcd(12, 11, 5, 4, 3, 2);


int pin8 = 8; int analogPin = A0;     int
sensorValue = 0;       // store the
value read


void setup() {
pinMode(analogPin,
INPUT);   pinMode(pin8,
OUTPUT);
```

```
  // set up the LCD's number of columns and
rows:
  lcd.begin(16, 2);
  // Print a message to the
LCD.    lcd.print("What  is
the             air             ");
lcd.print("quality
today?");
Serial.begin(9600);
lcd.display();
}

void loop() {

  delay(100);   sensorValue =
analogRead(analogPin);     // read the input pin
  Serial.print("Air Quality in PPM = ");
  Serial.println(sensorValue);           // debug value

  lcd.clear();
lcd.setCursor(0,0);
lcd.print ("Air Quality:
");   lcd.print
(sensorValue);

  if (sensorValue<=500)
   {
   Serial.print("Fresh
Air  ");      Serial.print
("\r\n");
lcd.setCursor(0,1);
lcd.print("Fresh Air");
```

```
  }
 else if( sensorValue>=500 && sensorValue<=650
)
  {
  Serial.print("Poor
Air");     Serial.print
("\r\n");
lcd.setCursor(0,1);
lcd.print("Poor
Air");
  }
 else if (sensorValue>=650 )
  {
  Serial.print("Very
Poor Air");    Serial.print
("\r\n");
lcd.setCursor(0,1);
lcd.print("Very        Poor
Air");
  }
   if (sensorValue >650) {     // Activate digital output     digitalWrite(pin8, HIGH);
 }
 else {     // Deactivate
digital output
digitalWrite(pin8,
LOW);
 }
}
```

PHASE-4
DEVELOPMENT-II

PHASE-4

INTRODUCTION:

- Air quality monitoring using the Internet of Things (IoT) is a cutting-edge approach to continuously and accurately assess the quality of the air we breathe. IoT technology has revolutionized the way we collect, analyze, and share real-time data on air pollution, making it more accessible and actionable for individuals, communities, and governments. This innovative method of monitoring and managing air quality has numerous benefits and is becoming increasingly crucial in the face of growing environmental concerns.

OVERVIEW OF AIR QUALITY MORNITERING:

- Air quality monitoring is the systematic process of measuring, analyzing, and assessing the concentration of various pollutants and gases present in the Earth's atmosphere. This comprehensive approach is essential for understanding the quality of the air we breathe, identifying sources of pollution, and implementing measures to mitigate its impact on human health and the environment.

Key Components of Air Quality Monitoring:

- **Pollutant Detection**: Air quality monitoring systems employ a variety of sensors and instruments to detect and measure air pollutants. These can include particulate matter (PM2.5 and PM10), gases such as carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), ozone (O_3), volatile organic compounds (VOCs), and more. Each sensor is designed to measure specific pollutants accurately.

- **Monitoring Stations**: Air quality monitoring stations are strategically located in urban, suburban, industrial, and rural areas to capture data representing different environmental conditions. The number and distribution of these stations depend on the specific monitoring objectives and regulatory requirements of a region.

- **Data Collection**: Monitoring stations continuously or intermittently collect data on pollutant concentrations. Some stations operate in real-time, providing immediate data updates, while others may record data at set intervals (e.g., hourly or daily). Collected data is sent to a central database for analysis.

- **Data Analysis**: Air quality data is processed and analyzed to understand pollutant levels, trends, and variations over time. This analysis can reveal patterns, sources of pollution, and the impact of air quality on human health and the environment.

- **Air Quality Index (AQI)**: To simplify the communication of air quality information to the public, many regions use the Air Quality Index (AQI). The AQI is a numerical scale that categorizes air quality into different levels, ranging from "Good" to "Hazardous," based on the concentration of key pollutants. Each level corresponds to specific health recommendations.

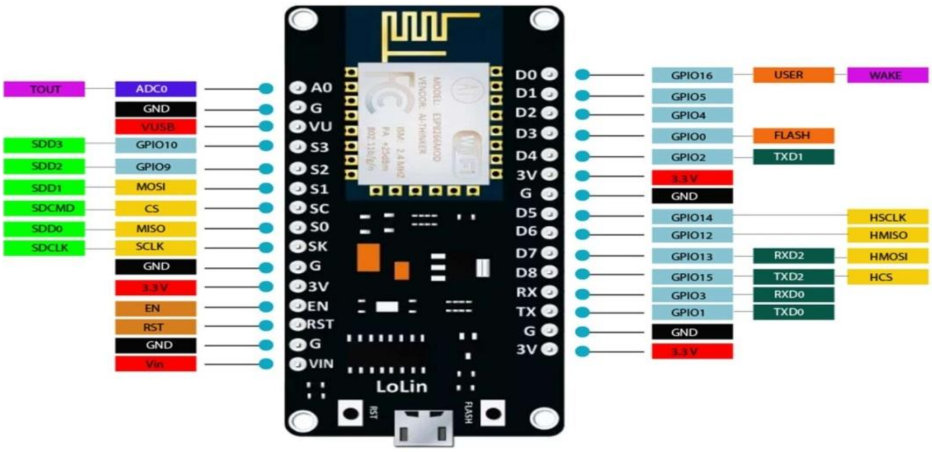
- ❖ **Health and Environmental Impact Assessment**: Air quality monitoring provides data that helps assess the potential health and environmental impacts of air pollution. This information is critical for understanding the risks associated with exposure to specific pollutants.

- ❖ **Regulatory Compliance**: Governments and environmental agencies establish air quality standards and regulations to limit pollutant concentrations. Air quality monitoring is crucial for ensuring compliance with these standards and for enforcing environmental laws.

- ❖ **Policy Development and Public Awareness**: The data collected through air quality monitoring informs the development of policies, regulations, and strategies to improve air quality. It also serves as a tool to raise public awareness about air pollution, its effects, and the importance of reducing emissions.

- ❖ **Research and Innovation**: Air quality monitoring supports ongoing research and innovation in the field of environmental science and technology. Researchers use this data to study air quality trends, develop new pollution control methods, and assess the effectiveness of pollution abatement measures.

PIN DIAGRAM:



BENEFITS OF AIR QUALITY MONITORING:

- ➢ **Protection of Public Health**:

- ❖ Air quality monitoring helps identify harmful pollutants in the atmosphere, allowing for early detection of elevated levels. This information enables individuals to take precautionary measures, such as staying indoors on days with poor air quality, reducing exposure to pollutants, and protecting their respiratory health.

- ❖ **Risk Assessment**: Monitoring data provides valuable insights into the potential health risks associated with air pollution. This information is crucial for assessing the impact of pollution on public health and can be used to guide healthcare and emergency response strategies.

- ❖ **Environmental Protection**: Monitoring air quality helps track the environmental impact of pollutants on ecosystems, soil, and water bodies. It allows for a better understanding of how pollution affects wildlife, vegetation, and aquatic life.
- ❖ **Data-Driven Policies**: Governments and regulatory bodies use air quality data to develop and implement effective environmental policies and regulations. These policies aim to limit emissions, reduce air pollution, and improve overall air quality.
- ❖ **Compliance with Standards**: Air quality monitoring ensures that industries and businesses comply with environmental regulations and standards. This is crucial for holding polluters accountable and reducing harmful emissions.
- ❖ **Public Awareness**: Air quality monitoring helps raise public awareness about the importance of clean air and the health risks associated with air pollution. This awareness can lead to increased support for environmental protection measures.
- ❖ **Research and Innovation**: Air quality data supports ongoing research and innovation in the field of environmental science and technology. Researchers use this data to study air quality trends, develop new pollution control methods, and assess the effectiveness of pollution abatement measures.
- ❖ **Emergency Response**: Air quality monitoring can serve as an early warning system for environmental disasters, industrial accidents, or events that lead to sudden increases in pollution levels. Timely alerts enable swift emergency responses and measures to protect public safety.
- ❖ **Urban Planning**: Urban planners use air quality data to make informed decisions about land use, transportation, and the location of residential and industrial areas. This helps create healthier, more sustainable cities with reduced air pollution.
- ❖ **Community Empowerment**: Access to real-time air quality data empowers individuals and communities to make informed decisions about outdoor activities, exercise, and daily routines. It allows people to take personal actions to reduce exposure to pollutants.
- ❖ **Improvement of Air Quality**: Over time, air quality monitoring can lead to improvements in air quality as regulatory measures and public awareness campaigns encourage the reduction of emissions and the adoption of cleaner technologies.
- ❖ **Accountability and Transparency**: Air quality data ensures transparency and accountability by providing concrete evidence of pollution levels. It enables stakeholders to hold governments and industries responsible for their environmental impact.
- ❖ **Healthcare Planning**: Healthcare providers can use air quality data to anticipate and manage increased healthcare needs during periods of poor air quality, particularly for individuals with pre-existing respiratory conditions.

PROCEDURE FOR AIR QUALITY MONITERING:

- The procedure for air quality monitoring involves a series of steps and considerations to ensure accurate and reliable data collection. Here's a general overview of the process:

  - **Site Selection**:

    - Determine the locations for monitoring stations: Select sites that represent different environmental conditions, including urban, suburban, rural, and industrial areas.

    - Consider proximity to pollution sources: Stations should be strategically located near potential pollution sources, such as factories, highways, or areas with high traffic.

  - **Equipment Setup**:

    - Install air quality monitoring equipment at selected sites. This equipment typically includes sensors, analyzers, and data loggers to measure and record air quality parameters.

    - Ensure that the equipment is properly calibrated to provide accurate measurements.

  - **Data Collection**:

    - Sensors and instruments continuously or periodically collect data on various air pollutants, such as particulate matter, gases, and volatile organic compounds.

    - Data can be collected in real-time or at specified intervals (e.g., hourly or daily).

  - **Data Transmission**:

    - Data collected by monitoring stations can be transmitted using various communication technologies, including wired connections, cellular networks, Wi-Fi, or satellite communication.

    - Ensure data transmission reliability to avoid data loss.

  - **Data Storage**:

    - Set up a central database or server to store the collected data securely. Cloud-based platforms are often used for remote data storage and accessibility.

  - **Data Analysis**:

- Analyze the collected data to assess air quality parameters, identify trends, and understand variations over time.
- Implement algorithms and statistical methods to process and interpret the data effectively.

❖ **Air Quality Index (AQI) Calculation**:

- Convert pollutant concentrations into an AQI to provide a simple and understandable measure of air quality for the public.
- AQI levels typically range from "Good" to "Hazardous," each corresponding to specific pollutant concentration ranges.

❖ **Data Reporting**:

- Develop user-friendly interfaces, such as websites, mobile apps, or public displays, to provide air quality information to the public.
- Generate reports and data visualizations, including maps and charts, to communicate air quality data effectively.

❖ **Alerts and Notifications**:

- Configure the system to send alerts and notifications to relevant authorities, stakeholders, and the public when air quality levels exceed predefined thresholds or become hazardous.

❖ **Quality Assurance and Calibration**:

- Regularly maintain and calibrate monitoring equipment to ensure accurate measurements.
- Implement quality assurance and quality control procedures to identify and address any issues with data collection and equipment performance.

❖ **Public Awareness and Education**:

- Develop educational campaigns to raise public awareness about air quality and the health risks associated with air pollution.
- Provide guidance on protective measures during days of poor air quality.

❖ **Policy Development and Decision-Making**:

- Use the collected air quality data to inform the development of environmental policies, regulations, and decision-making processes aimed at reducing pollution and improving air quality.

❖ **Research and Innovation**:

- Share data with researchers and environmental organizations to support ongoing studies and innovations in pollution control and environmental protection.

❖ **Maintenance and Upkeep**:

- Regularly maintain and inspect monitoring equipment to ensure its proper functioning.
- Update equipment and software as necessary to stay current with technological advancements.

IMPLEMENTATION OF AIR QUALITY MONITERING:

➢ The implementation of an air quality monitoring system involves a series of steps and considerations to establish an effective and reliable system. Here's an overview of the process:

❖ **Define Objectives and Scope**:

- Clearly define the goals and objectives of the air quality monitoring program. Determine what you want to achieve, such as assessing urban air quality, identifying pollution sources, or ensuring regulatory compliance.

❖ **Select Monitoring Locations**:

- Choose monitoring locations strategically to capture a representative sample of air quality conditions. Consider urban, suburban, rural, and industrial areas.
- Take into account proximity to pollution sources and population centers.

❖ **Select Monitoring Parameters**:

- Determine which air pollutants and parameters you will measure. Common pollutants include particulate matter (PM2.5 and PM10), gases (CO, NO_2, SO_2, O_3), and VOCs.
- Select the appropriate sensors and instruments for measuring the chosen parameters.

❖ **Acquire Monitoring Equipment**:

- Procure air quality monitoring equipment, which includes sensors, analyzers, data loggers, and communication devices.
- Ensure that the equipment is of high quality and properly calibrated.

❖ **Setup Monitoring Stations**:

- Install monitoring equipment at selected sites, ensuring that it is secure and protected from environmental factors like weather and vandalism.
- Establish power sources, including mains power or renewable energy options.

❖ **Data Collection and Transmission**:

- Set up data collection mechanisms. This can be continuous or periodic data collection, depending on the monitoring goals.
- Choose the appropriate communication technology for data transmission, such as wired connections, cellular networks, or satellite communication.

❖ **Data Management**:

- Establish a central database or server to store the collected data securely. Cloud-based platforms can be used for remote access and storage.
- Implement data management and storage best practices to ensure data integrity.

❖ **Data Analysis and Reporting**:

- Develop data analysis procedures to interpret air quality data effectively.
- Generate reports and data visualizations, such as maps and charts, to communicate air quality information to stakeholders and the public.

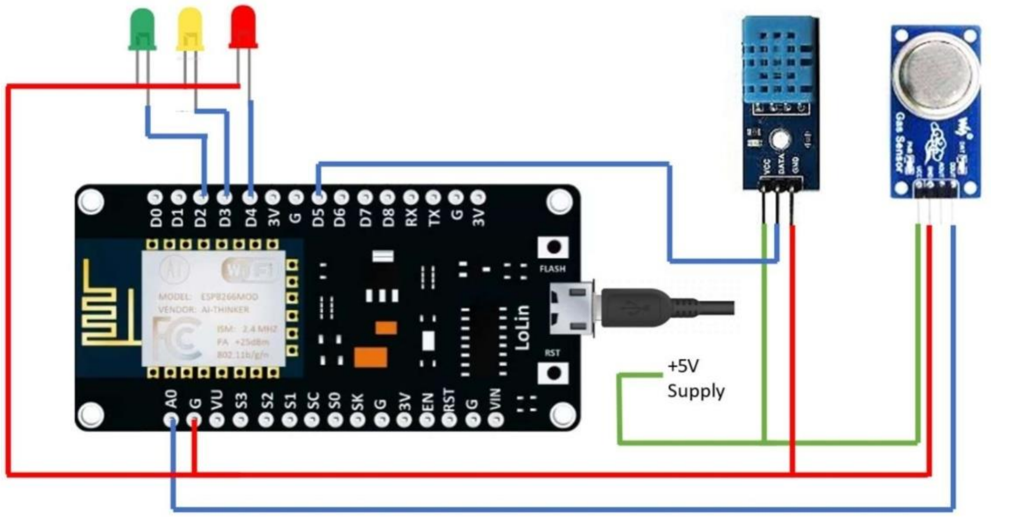
❖ **Air Quality Index (AQI) Calculation**:

- Convert pollutant concentrations into an AQI to provide a simplified, understandable measure of air quality.
- Define AQI levels, such as "Good," "Moderate," "Unhealthy for Sensitive Groups," and "Hazardous."

❖ **Alerts and Notifications**:

- Configure the system to send alerts and notifications when air quality levels exceed predefined thresholds or pose health risks. These alerts can be sent to relevant authorities and the public.

CIRCUIT DIAGRAM:



CODE:

```
import network
import time
from machine import Pin,ADC
import dht
import ujson
from umqtt.simple import MQTTClient

# MQTT Server Parameters
MQTT_CLIENT_ID = "micropython-weather-demo"
MQTT_BROKER    = "broker.mqttdashboard.com"
MQTT_USER      = ""
MQTT_PASSWORD  = ""
MQTT_TOPIC     = "wokwi-weather"

sensor = dht.DHT22(Pin(15))
MQ7=ADC(Pin(35))
MQ8=ADC(Pin(32))
button=Pin(34,Pin.IN)
led=Pin(33,Pin.OUT)
min_rate=0
max_rate=4095

print("Connecting to WiFi", end="")
sta_if = network.WLAN(network.STA_IF)
sta_if.active(True)
sta_if.connect('Wokwi-GUEST', '')
while not sta_if.isconnected():
  print(".", end="")
  time.sleep(0.1)
print(" Connected!")

print("Connecting to MQTT server... ", end="")
client = MQTTClient(MQTT_CLIENT_ID, MQTT_BROKER, user=MQTT_USER, password=MQTT_PASSWORD)
client.connect()
```

```
print("Connected!")

prev_weather = ""
while True:
  CO_sensor=(MQ7.read())*100/(max_rate)
  print("CO Sensor value: " + "%.2f" % CO_sensor +"%")
  Hydrogen_sensor=(MQ8.read())*100/(max_rate)
  print("Soil Sensor value: " + "%.2f" % Hydrogen_sensor +"%")
  button_value=button.value()
  if button_value == True:
    led.value(000)
    print("It's Raining")
  else:
    led.value(0)
  print("Measuring weather conditions... ", end="")

  sensor.measure()
  message = ujson.dumps({
    "temp": sensor.temperature(),
    "humidity": sensor.humidity(),
  })


  if message != prev_weather:
    print("Updated!")
    print("Reporting to MQTT topic {}: {}".format(MQTT_TOPIC, message))
    client.publish(MQTT_TOPIC, message)
    prev_weather = message
  else:
    print("No change")
  time.sleep(1)
```

C++:

```
#include <Adafruit_Sensor.h>
#include <DHT.h>
#include <ESP8266WiFi.h>
#include <Adafruit_MQTT.h>
#include <Adafruit_MQTT_Client.h>

// Replace these with your Wi-Fi credentials.
const char* WIFI_SSID = "YourWiFiSSID";
const char* WIFI_PASS = "YourWiFiPassword";

// Replace with your Adafruit IO credentials.
#define ADAFRUIT_IO_USERNAME "YourAdafruitUsername"
#define ADAFRUIT_IO_KEY "YourAdafruitAIOKey"

// Define the DHT sensor.
#define DHT_PIN 2           // The pin where your DHT sensor is connected.
#define DHT_TYPE DHT22      // DHT sensor type (DHT11, DHT22, AM2302, etc.)

DHT dht(DHT_PIN, DHT_TYPE);

WiFiClient client;

Adafruit_MQTT_Client mqtt(&client, "io.adafruit.com", 1883, ADAFRUIT_IO_USERNAME,
ADAFRUIT_IO_KEY);
```

```
// Define MQTT feeds.
Adafruit_MQTT_Publish temperature = Adafruit_MQTT_Publish(&mqtt, ADAFRUIT_IO_USERNAME
"/feeds/temperature");
Adafruit_MQTT_Publish humidity = Adafruit_MQTT_Publish(&mqtt, ADAFRUIT_IO_USERNAME
"/feeds/humidity");

void setup() {
  Serial.begin(115200);

  // Connect to Wi-Fi.
  WiFi.begin(WIFI_SSID, WIFI_PASS);
  while (WiFi.status() != WL_CONNECTED) {
    delay(500);
    Serial.println("Connecting to WiFi...");
  }

  Serial.println("Connected to WiFi");

  // Connect to Adafruit IO.
  mqtt.connect();
  Serial.println("Connected to Adafruit IO");
}

void loop() {
  // Read temperature and humidity data from the DHT sensor.
  float temperatureValue = dht.readTemperature();
  float humidityValue = dht.readHumidity();

  // Publish data to Adafruit IO.
  if (!isnan(temperatureValue)) {
    temperature.publish(temperatureValue);
    Serial.print("Temperature: ");
    Serial.println(temperatureValue);
  } else {
    Serial.println("Failed to read temperature");
  }

  if (!isnan(humidityValue)) {
    humidity.publish(humidityValue);
    Serial.print("Humidity: ");
    Serial.println(humidityValue);
  } else {
    Serial.println("Failed to read humidity");
  }

  delay(60000); // Delay for 60 seconds (adjust as needed).
}
```

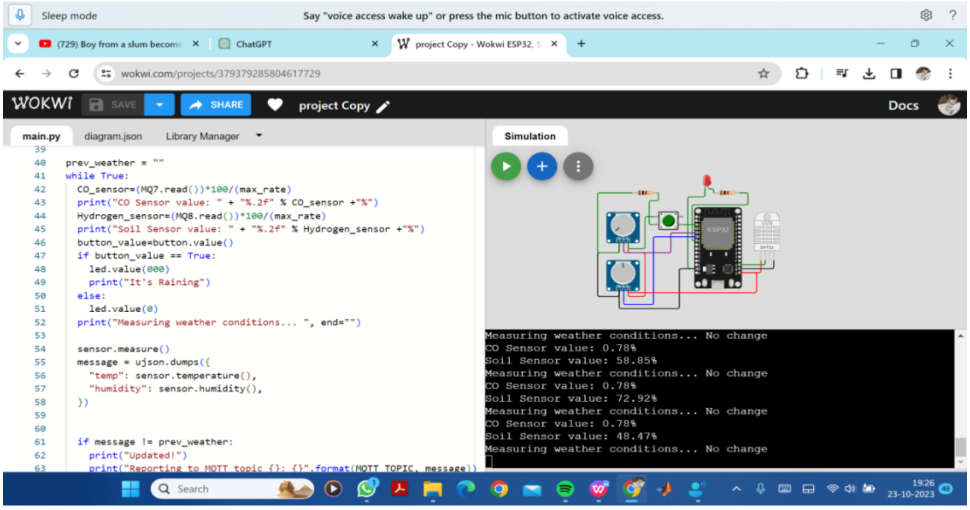
C program:

```
#include <Adafruit_Sensor.h>
#include <DHT.h>
#include <ESP8266WiFi.h>
#include <Adafruit_MQTT.h>
#include <Adafruit_MQTT_Client.h>

// Replace these with your Wi-Fi credentials.
const char* WIFI_SSID = "YourWiFiSSID";
const char* WIFI_PASS = "YourWiFiPassword";
```

```
// Replace with your Adafruit IO credentials.
#define ADAFRUIT_IO_USERNAME "YourAdafruitUsername"
#define ADAFRUIT_IO_KEY "YourAdafruitAIOKey"

// Define the DHT sensor.
#define DHT_PIN 2           // The pin where your DHT sensor is connected.
#define DHT_TYPE DHT22      // DHT sensor type (DHT11, DHT22, AM2302, etc.)

DHT dht(DHT_PIN, DHT_TYPE);

WiFiClient client;

Adafruit_MQTT_Client mqtt(&client, "io.adafruit.com", 1883, ADAFRUIT_IO_USERNAME,
ADAFRUIT_IO_KEY);

// Define MQTT feeds.
Adafruit_MQTT_Publish temperature = Adafruit_MQTT_Publish(&mqtt, ADAFRUIT_IO_USERNAME
"/feeds/temperature");
Adafruit_MQTT_Publish humidity = Adafruit_MQTT_Publish(&mqtt, ADAFRUIT_IO_USERNAME
"/feeds/humidity");

void setup() {
  Serial.begin(115200);

  // Connect to Wi-Fi.
  WiFi.begin(WIFI_SSID, WIFI_PASS);
  while (WiFi.status() != WL_CONNECTED) {
    delay(500);
    Serial.println("Connecting to WiFi...");
  }

  Serial.println("Connected to WiFi");

  // Connect to Adafruit IO.
  mqtt.connect();
  Serial.println("Connected to Adafruit IO");
}

void loop() {
  // Read temperature and humidity data from the DHT sensor.
  float temperatureValue = dht.readTemperature();
  float humidityValue = dht.readHumidity();

  // Publish data to Adafruit IO.
  if (!isnan(temperatureValue)) {
    temperature.publish(temperatureValue);
    Serial.print("Temperature: ");
    Serial.println(temperatureValue);
  } else {
    Serial.println("Failed to read temperature");
  }

  if (!isnan(humidityValue)) {
    humidity.publish(humidityValue);
    Serial.print("Humidity: ");
    Serial.println(humidityValue);
  } else {
```

```
    Serial.println("Failed to read humidity");
  }

  delay(60000); // Delay for 60 seconds (adjust as needed).
}
```

OUTPUT:



CONCLUSION:

- In conclusion, air quality monitoring is a critical e with far-reaching implications for public health, environmental sustainability, and policy development. The assessment and management of air quality have become increasingly vital in our rapidly urbanizing world, where pollution sources are diverse and ever-evolving. Monitoring air quality, whether through traditional methods or using the power of the Internet of Things (IoT), offers a range of benefits and plays a crucial role in addressing the challenges associated with air pollution.