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Air Quality Index Surveillance Using Mobile Devices

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Abstract: *Air quality monitoring through fixed-site stations has traditionally been the primary method for recording Air Quality Index (AQI) and pollution levels. However, fixed stations often face limitations due to their static nature, as readings can be heavily influenced by local factors such as nearby industrial activities or temporary construction, leading to data that may not represent the wider area's air quality accurately. To overcome these issues, mobile air quality monitoring solutions, including drone-based sensors, are being explored. Drones can collect real-time pollution data across multiple locations, offering a dynamic and broader view of environmental conditions. This mobile approach helps in minimizing localized biases, provides a more accurate regional AQI average, and allows for faster identification of pollution hot spots. By integrating mobile monitoring with traditional methods, authorities can achieve more reliable air quality assessments, enabling better decision-making for environmental management and public health protection.Moreover, mobile systems offer flexibility in tracking pollution trends over time and space, making them valuable tools for emergency response and long-term planning. As urban environments continue to grow and change, adopting innovative monitoring techniques becomes increasingly essential for sustainable development*

Keywords: Air Quality Index (AQI), fixed monitoring stations, mobile monitoring, drone-based sensors, real-time data collection, regional AQI measurement

I. INTRODUCTION

Traditional air quality monitoring stations, though commonly used, have a major drawback — they're stuck in one place. Since they can only measure pollution levels in their immediate area, they miss out on what's happening in nearby neighborhoods, different parts of the city, or rural regions. This narrow view makes it hard to truly understand the air people are breathing across a wider area.

The problem gets even more complicated when you consider where these stations are located. A monitor near a busy road or industrial zone might show pollution levels that are much higher than average. Meanwhile, one placed in a quieter, greener area might make the air seem cleaner than it really is elsewhere. This mismatch can mislead communities, causing them to either downplay or overestimate the health risks from air pollution. That, in turn, affects how well public health plans and environmental policies work.

There's also the issue of timing. Fixed stations aren't great at catching sudden changes or pollution spikes, especially if they happen away from the station's location. That delay can mean missed opportunities for timely warnings, like telling people to stay indoors, or taking quick action — such as adjusting traffic flow or controlling emissions — when pollution levels soar.

Because of these limitations, there's a growing need for mobile air quality monitoring solutions. Devices mounted on drones, cars, or even carried by hand can move through different areas, collecting real-time data that shows pollution levels on a much finer scale. These systems help uncover local pollution hot spots and give a clearer picture of the air quality people are actually experiencing. Without this kind of flexible, detailed monitoring, efforts to protect public health and create smarter environmental policies will keep falling short — simply because we're not seeing the whole picture.

A. Problem Statement.

Traditional stationary air quality monitoring stations, while widely used, suffer from significant limitations in spatial coverage. Being fixed in one location, these stations can only provide data for their immediate surroundings. Their readings often fail to capture the localized variations in pollution that occur across different neighbourhoods, urban zones, and rural areas. This limited perspective creates gaps in understanding the true air quality conditions experienced by communities spread over a larger region.

The issue is further complicated by the influence of local pollution sources. Stations located near industrial areas, construction sites, or busy roads may record artificially high pollution levels that do not accurately reflect the overall air quality of a wider region. On the other hand, stations positioned in greener or less congested areas may under-report pollution levels. Such inconsistencies mean that communities may either underestimate or overestimate the health risks they face, leading to poor public health planning and ineffective environmental interventions.

The static nature of traditional monitoring also restricts the ability to detect pollution hot spots and sudden changes in air quality. Without real-time, mobile data collection, authorities and individuals may be unaware of short-term pollution events or emerging environmental threats. This lag in information impacts timely decision-making for both public health advisories and immediate regulatory actions such as traffic management or industrial controls during high pollution episodes.

Given these limitations, there is a pressing need for mobile air quality monitoring solutions capable of gathering high-resolution, real-time data across diverse environments. Mobile systems, such as those using drones, vehicles, or handheld sensors, can dynamically monitor air quality across different locations, revealing hyper-local pollution patterns and improving the accuracy of regional assessments. Without adopting such advanced, flexible monitoring technologies, efforts to manage air quality, protect public health, and develop effective policies will continue to be hindered by incomplete and non-representative data

B. Existing System

The existing air quality monitoring system used by the Delhi Pollution Control Committee (DPCC) relies on fixed stations deployed across various locations to measure critical parameters like AQI and pollution indicators. While valuable for localized data, these stations face major limitations, often capturing pollution levels heavily influenced by their immediate surroundings, such as emissions from nearby industries or temporary activities like construction. This localized bias leads to a skewed understanding of broader regional air quality. Fixed stations also lack flexibility to monitor dynamic pollution sources like traffic, seasonal burning, and changing weather patterns, limiting their ability to track shifting pollution trends. Furthermore, due to the high cost and maintenance demands, only a limited number of stations can be installed, resulting in significant gaps in spatial coverage, especially in rapidly growing or densely populated areas. Real-time data delivery is also inadequate, delaying responses to pollution events and hindering effective policy action. Despite these challenges, fixed stations remain the backbone of monitoring systems, but the need for more adaptable, mobile, and real-time monitoring solutions, such as drone-based or mobile stations, has become clear to provide a more accurate, dynamic, and comprehensive understanding of air quality for better environmental management.

II. PROPOSED SYSTEM

A. Architecture of Proposed System.

The proposed AQI Mobile Monitoring System enhances environmental data collection using vehicle- and drone-mounted sensors. Vehicle-based monitoring is ideal for urban and industrial areas, while drones provide access to remote or disaster-affected zones. The system measures key pollutants (PM2.5, PM10, NO_2, SO_2, CO, O_3) with accuracy comparable to traditional stations.

It features edge computing for local data processing, reducing latency and bandwidth use. Connectivity is ensured through LoRaWAN, Wi-Fi, 5G, and satellite links, allowing real-time monitoring across varied environments. With dynamic routing and advanced communication, the system delivers high-resolution, real-time air quality data to support faster decisions, greater public awareness, and better environmental policies.

B. Advantages of Proposed System.

- Comprehensive Coverage
- Real-Time Data Collection
- Dynamic and Flexible Monitoring
- Efficient Data Processing and Transmission
- Cost-Effective and Scalable

III. LITERATURE SURVEY

Abdulmuhsin S. Shihab investigates air quality levels in Mosul city using two different Air Quality Index (AQI) models. The first model relies on the highest sub-index based on USEPA pollutants standards, while the second, aggregated air quality index (AAQI), considers the weights of all pollutants. Air quality data was collected over a year from a fixed monitoring station at the public library. The study found that the AAQI values were consistently higher than those of the USEPA model. The dominant air quality category in winter and spring was "Moderate," while in summer and autumn, "Unhealthy for sensitive groups" prevailed. The AAQI model also showed "Unhealthy" conditions in autumn. The study ranked the major pollutants as PM10, SO2, NO2, CO, and O3 in terms of their contribution to poor air quality. The conclusion suggests that the AAQI model is more comprehensive and suitable for effective environmental management [1].

Silvian-Marian Petric, Iulia Stamatescu, Ioana Făgărășan, Giorgian Neculoiu, Nicoleta Arghira, and Oana Flangea propose a solution to address the challenges of real-time air quality monitoring with sufficient spatial and temporal resolution at a low cost. The paper highlights the limitations of traditional air quality monitoring systems and introduces an innovative approach using Internet of Things (IoT) technology to create a low-cost, energy-autonomous air quality monitoring system. By integrating hardware and software, the solution is designed for smart cities and aims to provide real-time, accurate air quality data. The results demonstrate the feasibility and effectiveness of this approach, offering a viable solution for air quality monitoring with reduced costs and improved energy efficiency [2].

Souptik Das, Rahul Nandy, Sourish Chakraborty, Srijan Bhattacharya, and Dipanjan Jana propose an IoT-enabled industrial air quality monitoring device that integrates an MQ-135 gas sensor for precise monitoring of air quality and detection of contaminants like alcohol. The device uses a Node MCU ESP8266 Wi-Fi module to transmit real-time data to a smart device (such as a smartphone) via an IoT platform, enabling efficient remote monitoring and management. This approach leverages recent technological advancements in IoT and Cloud Computing to allow continuous and effective air quality monitoring [3].

Zeba Idrees, Zhuo Zou, and Lirong Zhe propose a novel air quality monitoring system that leverages edge-computing-based IoT to address the limitations of existing systems. These systems often struggle with insufficient spatial and temporal resolutions, high costs, and lack of real-time capabilities. The proposed system collects air quality data using sensors, which is then processed and analyzed by an edge computing device. The infrastructure is developed using an Arduino board and the IBM Watson IoT platform. By reducing the computational load on battery-powered sensors by 70%, the system achieves higher efficiency. The system incorporates algorithms to correct low-cost sensor errors and manage cross-sensitivity issues, ensuring data accuracy of 75–80%. Additionally, a strategy for data transmission minimizes network traffic and power consumption, resulting in a 23% reduction in power usage. Experimental evaluations confirm the effectiveness of the system in providing real-time, low-cost air quality monitoring [4].

Uma M., Swetha M., Manisha S.V., Revathi S.V., and Anand Kannan propose a project that utilizes embedded technology to monitor and analyze environmental conditions using smart sensors. The system integrates hardware and software, with the Arduino (ATMEGA328 microcontroller) serving as the primary controller. Sensors such as temperature, humidity, gas, and sound sensors collect real-time data about the environment. This data is transmitted to a cloud server via an IoT module, enabling remote monitoring and analysis of climate and pollution levels. By automating data collection and broadcasting, the system reduces the need for human intervention, saves time, and improves efficiency. The main objective of the system is to observe and assess the environment, allowing for better management of pollution and climate conditions [5].

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Anitha N., Anne Caroline S., Shalini P., and Trisha V. developed a system that aims to enhance indoor air quality by monitoring and analyzing pollutants such as dust, pollen, and smoke using an Arduino UNO integrated with an optical dust sensor and an MQ-135 sensor. These sensors continuously measure air quality, detecting particulate matter and harmful gases, respectively. The collected data is used to calculate the Air Quality Index (AQI), which provides a real-time assessment of air quality. The AQI value is then displayed on an LCD screen, offering users instant feedback on the surrounding air quality. If the AQI exceeds a safe threshold (specifically >400 ppm), indicating dangerous levels of pollutants, the system triggers an alert. This alert includes blinking LEDs to visually warn individuals of the harmful air conditions. The system provides a practical and affordable solution for monitoring and improving indoor air quality, promoting healthier environments by alerting users when air quality becomes hazardous[6].

IV. SYSTEM DESIGN AND METHODOLOGY

A. Design

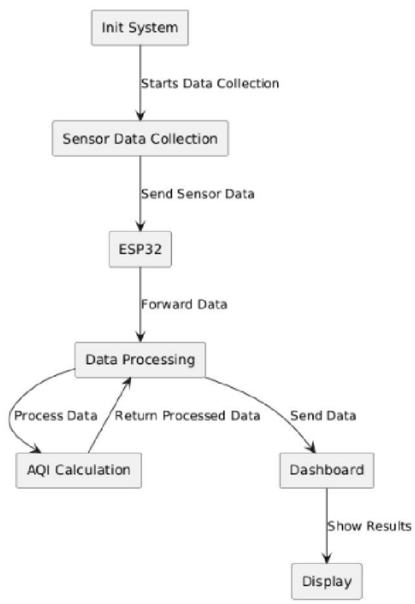

Figure 1: System Design

The diagram illustrates the flow of data in an air quality monitoring system, beginning with the initialization process that activates sensor data collection. The raw sensor data is transmitted to an ESP32 microcontroller, which acts as the central processing unit for managing incoming data. This data is then sent to a processing module that prepares it for key calculations.

Next, the processed data is used by an AQI calculation component to determine the air quality index, with the results sent back to the data processing stage for further handling. This ensures that the AQI values are integrated into the overall data stream for visualization.

Finally, the processed AQI information is sent to a dashboard interface, which displays the results to users through a visual display. This setup enables real-time monitoring of air quality, providing accessible insights through a user-friendly display.

B. Methodology

The process of calculating the Air Quality Index (AQI) begins with selecting relevant pollutants as per Indian standards, typically including at least three parameters such as PM2.5 or PM10, carbon monoxide (CO), ozone (O_3), sulfur dioxide (SO_2), or nitrogen dioxide (NO_2). Once pollutants are identified, concentration data are collected, averaged over 16 hours, and truncated to the nearest integer to maintain consistency. Using the Indian AQI breakpoints, each pollutant's concentration is mapped to specific AQI categories, which are divided into six levels: Good, Satisfactory, Moderate, Poor, Very Poor, and Severe. These categories are defined by specific breakpoint ranges, with each range associated with corresponding AQI values.

For each pollutant, the sub-index (Ip) is calculated using a linear interpolation formula that considers the pollutant's concentration and its associated breakpoints and AQI values. For example, if the concentration of PM2.5 is 110 µg/m³, the relevant breakpoints and AQI values are used in the formula to compute Ip. After determining the sub-indices for all pollutants, the highest sub-index value is selected as the overall AQI, reflecting the worst air quality condition among the parameters. This overall AQI is then classified into one of the predefined categories to provide an easily understandable assessment of air quality.

Finally, the calculated AQI value is utilized for visualization and reporting purposes. It can be displayed through charts, dashboards, or alerts, enabling real-time monitoring and effective communication of air quality status to the public. This systematic approach ensures that AQI computation remains consistent, accurate, and aligned with Indian standards, facilitating informed decision-making and timely responses to air pollution levels.

V. MODULES

1. Data Collection Module

The Data Collection Module is the foundational component of the air quality monitoring system. Its primary function is to gather real-time data on environmental pollutants from a wide range of locations. This is achieved by integrating two types of sensors:

Particulate Matter (PM) Sensors: These sensors are responsible for detecting and quantifying fine particulate matter in the air, specifically PM2.5 and PM10. These particles are harmful when inhaled and are typically emitted from vehicles, construction sites, factories, and even natural sources like dust storms.

Electrochemical Gas Sensors: These are used for detecting and measuring gaseous pollutants, including Carbon Monoxide (CO), Nitrogen Dioxide (NO_2),Sulfur Dioxide (SO_2), and Ozone (O_3). These pollutants originate from industrial emissions, vehicle exhaust, and chemical reactions in the atmosphere.

To enhance spatial coverage and improve data reliability, this module leverages mobile platforms such as smartphones and drones. These mobile units are equipped with sensor arrays and are deployed in various environments—urban, industrial, and rural—to capture pollutant concentrations in real-time. The use of drones especially allows the system to collect data from hard-to-reach or hazardous locations, while mobile devices offer flexibility and scalability for data gathering in dynamic environments.

2. Computing Module:

The Computing Module serves as the processing unit of the system and is built around the ESP32 development kit, a powerful microcontroller with built-in Wi-Fi and Bluetooth capabilities. This module receives raw data from the sensors in real-time and performs preliminary data processing tasks locally.

Processing the data on the ESP32 reduces latency and bandwidth consumption, which is particularly useful when operating in remote areas with limited connectivity. The raw data from sensors—typically voltage signals or resistance changes—is converted into meaningful pollutant concentrations using calibration curves and sensor-specific formulas.

Once the concentration values are obtained, the ESP32 then calculates the Air Quality Index (AQI). The AQI is a standardized scale that translates complex pollutant data into a single number and category (e.g., Good, Moderate, Unhealthy) that is easier for users to understand. This conversion involves predefined mathematical models and health-based thresholds defined by environmental agencies such as the EPA or WHO. By performing this computation locally, the module ensures rapid feedback and enables real-time decision-making.

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3. User Dashboard Module:

The User Dashboard Module is the front-end interface through which users can interact with the system. It visualizes the processed air quality data in an intuitive and user-friendly manner, making it accessible to both experts and the general public.

This module displays real-time AQI values and pollutant-specific concentration levels using a variety of visual elements. These include:

Graphs that show pollutant trends over time (e.g., hourly, daily, weekly).

Charts that compare pollutant levels across different locations.

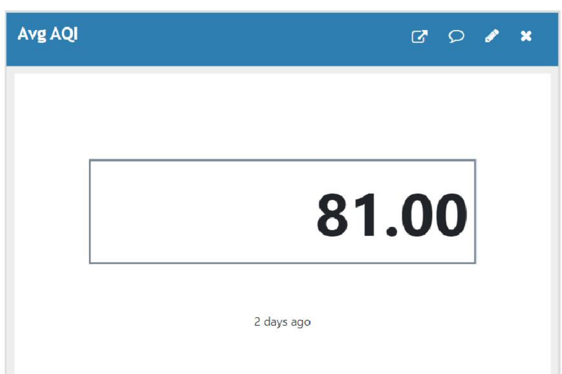
Numeric readouts that display actual AQI values and pollutant concentrations.

Additionally, the dashboard may include color-coded indicators to represent AQI categories (e.g., green for good, red for unhealthy), geographic maps to show pollution heatmaps, and alerts to notify users when pollutant levels exceed safe thresholds. The goal of this module is to empower users citizens, environmentalists, policymakers with actionable insights that can guide personal behaviour or inform policy decisions.

VI. IMPLEMENTATION

This section presents a detailed overview of the development of an AQI (Air Quality Index) surveillance model designed to monitor and track air quality using data collected exclusively from surveillance drones. These drones are deployed across diverse geographical and environmental contexts to capture localized air quality readings in real time. Various preprocessing techniques were implemented to manage noise, data gaps, and environmental variability inherent in drone-based sensing. Comparative evaluations were conducted across different drone flight patterns, altitudes, and pollutant concentration levels. Supporting tables illustrate system performance and reliability, helping identify the most effective configurations for consistent AQI monitoring. These findings contribute to the creation of resilient, mobile surveillance systems suitable for both urban and remote deployments.

VII. RESULT



Average aqi

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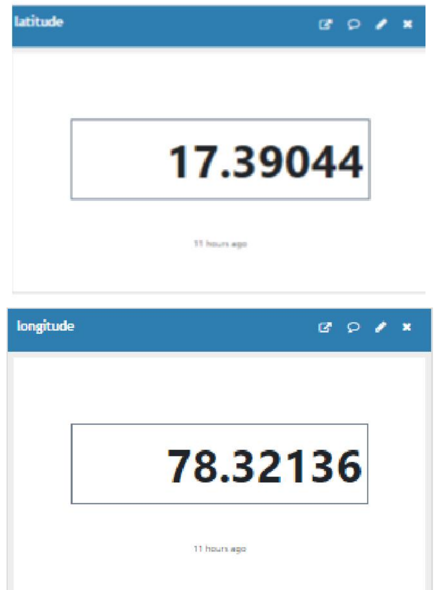
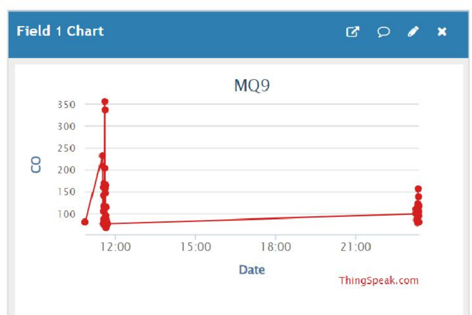
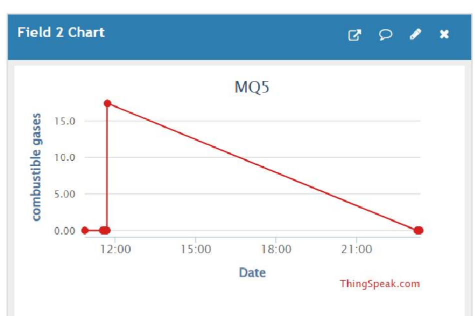


Location



CO readings



Combustible gases

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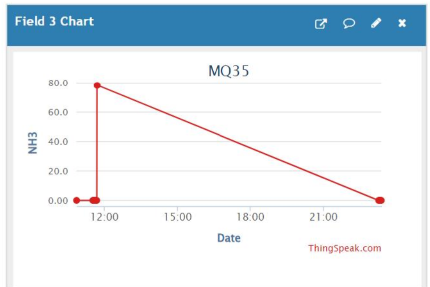
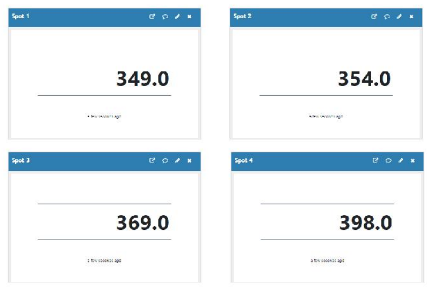


NH3 readings



Individual spot AQIs

VIII. CONCLUSION

Air Quality Index (AQI) mobile monitoring systems are reshaping the landscape of environmental monitoring by addressing the limitations of traditional stationary stations. These systems provide high-resolution, real-time data that captures localized pollution variations and hotspots, offering a more dynamic understanding of air quality. By equipping vehicles, drones, and individuals with portable sensors, AQI mobile monitoring systems ensure comprehensive spatial coverage that is otherwise unachievable.

The integration of these systems with mobile applications and online platforms enables seamless data access, empowering individuals and communities with actionable insights. During periods of high pollution, vulnerable populations can take precautions, and authorities can implement timely interventions, such as traffic rerouting or industrial activity regulation.

Beyond immediate responses, the detailed data generated by these systems aids long-term air quality management. Policymakers can leverage this information to evaluate the effectiveness of existing regulations and design targeted strategies for pollution control. The ability to identify and track pollution sources fosters more informed decision-making and promotes environmental accountability.

Furthermore, AQI mobile monitoring systems contribute to public awareness by directly involving communities in environmental protection efforts. The accessibility of real-time AQI data inspires collective action, enhancing the impact of pollution mitigation strategies.

In essence, these systems bridge the gap between traditional methods and modern technological capabilities, revolutionizing air quality monitoring. By offering detailed, timely, and accessible information, AQI mobile monitoring systems empower individuals, communities, and policymakers to safeguard public health and ensure sustainable environmental management.

IX. ACKNOWLEDGEMENT

We would like to extend our heartfelt thanks to all those who contributed to the successful development and implementation of our project on Air Quality Index (AQI) Monitoring Using Mobile Devices. This project, focused on decentralized data collection and localized processing, was made possible through the combined efforts of dedicated individuals and mentors.

We are especially grateful to our academic guides and technical advisors, whose expertise in sensor integration, embedded system design, and mobile device interfacing was instrumental in turning our concept into a practical solution. Their input on environmental data collection, real-time signal processing, and data visualization enabled us to build a functional and accurate AQI monitoring system.

We also wish to acknowledge the individuals and teams who supported our testing activities across varied locations. Their cooperation was essential for gathering diverse environmental samples and for validating the effectiveness of our mobile measurement approach in both static and dynamic conditions.

Special thanks go to those who offered valuable insights into offline data handling, local storage techniques, and device-to-device communication methods. Their support helped us ensure consistent system performance without relying on cloud infrastructure.

Finally, we are deeply thankful to our peers, lab coordinators, and families for their continuous encouragement and logistical support throughout this journey. This project highlights the potential of mobile and embedded technologies to contribute meaningfully to environmental monitoring and public well-being.

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