International Research Journal of Education and Technology

Peer Reviewed Journal, **ISSN: 2581-7795**

AIR SENSE – AIR QUALITY TREND & HEALTH RISK PREDICTION

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Abstract

Air pollution has become one of the most serious environmental challenges affecting human health and the ecosystem. Increasing industrialization, urbanization, and transportation activities have significantly increased the emission of harmful pollutants into the atmosphere. Monitoring air quality has therefore become essential to ensure a healthy living environment. The AirSense system is designed to monitor and analyze air quality levels in real time using environmental sensors and data analysis techniques. The system collects important atmospheric parameters such as particulate matter (PM2.5), carbon dioxide (CO_2), temperature, and humidity. These values are processed and analyzed to determine the quality of the surrounding air.The collected data is stored and displayed through interactive dashboards and visual graphs, enabling users to easily understand environmental conditions. The system also includes an alert mechanism that notifies users when pollution levels exceed safe limits. This feature helps individuals take preventive actions to reduce exposure to harmful pollutants. The AirSense system aims to improve environmental awareness and provide a cost-effective solution for monitoring pollution levels in different locations.

Keywords: Air Quality Monitoring, IoT Sensors, Pollution Detection, Environmental Monitoring, AirSense System.

1. Introduction

Air pollution is a major environmental problem affecting both developed and developing countries. Rapid industrial growth, increased vehicle emissions, and energy production activities have led to a significant rise in atmospheric pollutants. These pollutants include particulate matter, carbon monoxide, sulfur dioxide, nitrogen oxides, and other harmful gases.

Exposure to polluted air can cause several health issues such as asthma, bronchitis, lung infections, cardiovascular diseases, and even premature death. According to environmental studies, poor air quality is responsible for millions of deaths worldwide every year.

Monitoring air pollution is essential for understanding environmental conditions and implementing effective pollution control measures. Traditional air monitoring stations are expensive and limited to specific locations, making it difficult to monitor pollution levels in all areas.

The **AirSense system** provides an alternative solution by using affordable sensor technology to collect environmental data. By continuously measuring air quality parameters, the system allows users to observe pollution levels in real time.

The system also provides graphical visualizations and historical data analysis, helping users understand pollution trends over time. This information can assist communities, researchers, and policymakers in making informed decisions regarding environmental protection.

Keywords: Air Pollution, Environmental Monitoring, Health Impact, Smart Monitoring System, Air Quality Index.

2. Literature Review

The field of air quality monitoring has seen significant advancements over the past decade, driven largely by the proliferation of IoT technology and the decreasing cost of sensor components. Numerous researchers and organizations have developed systems aimed at providing accessible, real-time environmental data. Kumar et al. (2020) proposed an IoT-based

air quality monitoring system that utilized multiple gas sensors connected to a microcontroller. The system transmitted data to a cloud platform via Wi-Fi and displayed results on a web interface. Their study demonstrated the feasibility of lowcost sensor networks for urban pollution monitoring.

However, the system lacked advanced analytics capabilities and relied on manual threshold configuration for alerts. Rao and Sridhar (2021) developed a smart environmental monitoring system using Raspberry Pi and a suite of gas sensors.

Their system incorporated basic machine learning models to classify air quality levels and predict short-term pollution trends. While the system performed well in controlled environments, its scalability in outdoor, large-scale deployments was limited. A study by Zhang et al. (2022) examined the use of wireless sensor networks (WSN) combined with cloud computing for distributed air quality monitoring. Their work highlighted the importance of data fusion techniques in improving measurement accuracy across multiple sensor nodes.

The study also identified latency and connectivity issues as key challenges in real-world deployments. More recent work by Patel et al. (2023) introduced a mobile-integrated air quality monitoring system that allowed users to receive real-time alerts and view environmental data through a smartphone application.

Their system incorporated GPS tagging to associate pollution data with geographic locations, enabling pollution mapping. Despite these innovations, the system faced challenges related to sensor calibration and battery life in outdoor deployments. Existing systems have collectively highlighted several key challenges in the domain of air quality monitoring including high implementation costs, limited geographic coverage, poor user interface design, and lack of predictive analytics capabilities.

The AirSense project seeks to address these shortcomings by providing a cost-effective, scalable, and user-friendly platform that integrates real-time monitoring, cloud analytics, and interactive visualizations into a unified system.

Keywords: Air Monitoring Research, IoT Sensors, Environmental Data Analysis, Pollution Detection, Smart Monitoring Systems, Wireless Sensor Networks.

3. Proposed System

The AirSense system is a multi-layered smart environmental monitoring platform designed to deliver continuous, accurate, and actionable air quality insights. The system architecture is structured across four functional layers: the Sensing Layer, the Communication Layer, the Processing and Storage Layer, and the Visualization and Alert Layer. Each layer plays a specific role in the overall data pipeline, from environmental data collection to user-facing dashboards and notifications. 3.1 System Architecture The sensing layer consists of environmental sensors deployed at target monitoring locations. These sensors continuously measure air quality parameters and generate raw data signals. The communication layer handles wireless data transmission using protocols such as MQTT and HTTP over Wi-Fi networks. The processing layer receives, cleans, and analyzes the incoming data to compute AQI scores and detect pollution anomalies. The visualization layer presents the processed data through interactive dashboards and generates alerts when pollution levels exceed predefined thresholds.

3.2 Key Features

• Real-time monitoring of PM2.5, CO2, temperature, and humidity parameters. • Wireless data transmission to cloud storage for secure and reliable data management. • Air Quality Index (AQI) calculation based on standard environmental guidelines. • Interactive visualization dashboards with trend charts, gauges, and heatmaps. • Automated SMS, email, and push notification alerts for threshold violations. • Historical data storage and retrieval for long-term environmental trend analysis. • Scalable architecture supporting multiple sensor nodes across different locations. **Keywords:** AirSense Architecture, Sensor-Based Monitoring, Environmental Data Collection, RealTime Monitoring, AQI, Alert System, IoT Platform.

4. Methodology & Implementation

The implementation of the AirSense system follows a structured, phased methodology designed to ensure systematic development, testing, and deployment. The process is divided into five key phases: requirement analysis, hardware setup, software development, system integration, and performance evaluation.

4.1 Phase 1 — Requirement Analysis

In the initial phase, system requirements were identified through a review of existing air quality monitoring literature and consultation with environmental science references. Key pollutants to be monitored were selected based on their prevalence in urban environments and their impact on human health. Hardware components, communication protocols, and software tools were selected based on cost, availability, and performance criteria.

4.2 Phase 2 — Hardware Setup & Sensor Integration

Environmental sensors including the MQ-135 gas sensor for CO2 and harmful gas detection, the DHT22 sensor for temperature and humidity measurement, and a dust sensor for PM2.5 particulate matter detection were integrated with an ESP32 microcontroller. The sensors were calibrated using reference measurements to ensure data accuracy. The ESP32 was programmed to read sensor values at regular intervals (every 30 seconds) and transmit the data wirelessly via the MQTT protocol.

4.3 Phase 3 — Software Development & Data Pipeline

The software backend was developed using Python and Node.js to handle incoming sensor data. A data preprocessing module was implemented to clean raw sensor readings, remove outliers, and handle missing data. The Air Quality Index (AQI) was computed from PM2.5 concentrations using the standard AQI breakpoint formula defined by environmental protection agencies. Processed data was stored in a MySQL database structured with tables for sensor readings, AQI scores, location metadata, and alert logs.

4.4 Phase 4 — Dashboard Development & Visualization

An interactive visualization dashboard was developed using Grafana integrated with the MySQL database. The dashboard includes real-time gauge indicators for each monitored parameter, time-series line charts showing pollution trends over hourly, daily, and weekly intervals, and color-coded AQI status indicators. The alert system was configured to send automated email and SMS notifications when any parameter exceeded its defined safe threshold. Alert logs are maintained in the database for audit and review purposes.

4.5 Phase 5 — Testing & Validation

The system was tested in three distinct environments: an indoor office setting, an outdoor roadside location, and an industrial area near a manufacturing facility. Testing was conducted

over a period of two weeks to capture varied pollution patterns across different times of day and weather conditions. Sensor readings were validated against reference measurements taken using a certified air quality meter to evaluate accuracy and reliability.

Keywords: Data Collection, Sensor Integration, Data Processing, Environmental Analytics, AQI Calculation, System Implementation, Dashboard Development.

5. Results and Analysis

The AirSense system was successfully deployed and tested across three monitoring environments over a two-week evaluation period. The system demonstrated reliable data collection, accurate AQI computation, and effective visualization of environmental conditions. The results confirmed the system's ability to detect pollution patterns and respond appropriately to threshold violations.

5.1 Environmental Monitoring Results

The following table summarizes the observed parameter ranges and their corresponding status during the evaluation period:

Parameter	Safe Limit	Observed Range	Status
PM2.5 (Particulate Matter)	< 35 µg/m³	12 – 89 µg/m³	Moderate to Unhealthy
CO2 (Carbon Dioxide)	< 1000 ppm	400 – 1450 ppm	Good to Moderate
Temperature	18°C – 30°C	22°C – 38°C	Within / Above Range
Humidity	30% – 60%	40% – 75%	Within / High
AQI (Air Quality Index)	0 – 50 (Good)	42 – 168	Good to Unhealthy

5.2 Pollution Trend Observations

Significant pollution patterns were identified during the testing period. PM2.5 levels showed a consistent increase during peak traffic hours (7:00 AM – 9:00 AM and 5:00 PM – 8:00 PM), with readings reaching up to 89 µg/m³ near roadside locations. CO2 levels were notably elevated in indoor settings during periods of high occupancy, reaching 1,450 ppm in a closed

conference room, while outdoor levels remained close to the global baseline of 400–420 ppm. Temperature and humidity readings varied with weather conditions but remained within expected seasonal ranges for the testing region. AQI values computed from PM2.5 data ranged from 42 (Good) during early morning hours to 168 (Unhealthy) during evening traffic peaks. These findings highlight the strong correlation between urban traffic density and deteriorating air quality.

5.3 Alert System Performance

The alert system performed reliably throughout the testing period. A total of 47 threshold violation events were recorded across all monitoring locations, with 100% alert delivery success for email notifications and 96% for SMS notifications. Alert response time averaged 12 seconds from the moment a threshold violation was detected to user notification delivery, demonstrating the near-real-time responsiveness of the system. Confidential | Department of Computer Science & Engineering Page 7 AirSense: Smart Air Quality Monitoring & Analysis System Project Report | 2025

5.4 Sensor Accuracy Evaluation

Sensor readings were compared against measurements taken with a certified portable air quality monitor. The MQ-135 sensor demonstrated an average deviation of ±5.2% from reference CO2 measurements. The DHT22 sensor achieved temperature accuracy within ±0.5°C and humidity accuracy within ±2%, consistent with manufacturer specifications. The dust sensor for PM2.5 showed an average deviation of ±8.3%, which is within acceptable limits for low-cost environmental monitoring applications.

Keywords: Data Visualization, Pollution Trends, Environmental Analysis, AQI Results, System Performance, Sensor Accuracy, Alert System.

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Keywords: Data Visualization, Pollution Trends, Environmental Analysis, AQI Results, System Performance, Sensor Accuracy, Alert System.

6. Discussion

The results of the AirSense system evaluation demonstrate its effectiveness as a practical, lowcost solution for real-time air quality monitoring. The system successfully achieved all primary objectives, collecting reliable environmental data, computing AQI scores, delivering timely alerts, and presenting data through intuitive visual dashboards. The observed pollution patterns align with established research findings on urban air quality dynamics.

The strong correlation between peak traffic hours and elevated PM2.5 concentrations confirms the dominant role of vehicular emissions in urban air pollution. These insights can be directly leveraged by traffic management authorities to implement targeted interventions such as odd-even vehicle restrictions or enhanced public transport services during high-pollution periods. Indoor CO2 monitoring results highlight a frequently overlooked aspect of air quality — indoor air pollution.

The elevated CO2 concentrations observed in occupied indoor spaces underscore the importance of adequate ventilation systems in buildings. Organizations can use AirSense data to optimize HVAC system scheduling and improve occupant comfort and productivity. While the system performed well overall, several limitations were identified during evaluation. Low-cost sensors are inherently susceptible to calibration drift over time, which may require periodic recalibration to maintain accuracy. Environmental factors such as extreme humidity, temperature fluctuations, and dust accumulation on sensor surfaces can also influence measurement reliability. Power supply stability is another consideration for outdoor deployments, where continuous power may not always be available. Despite these limitations, the AirSense platform demonstrates compelling potential for largescale environmental monitoring applications.

The modular architecture allows for straightforward component upgrades, including the integration of higher-precision sensors or expanded parameter sets such as NO2, O3, or SO2 monitoring. The scalability of the cloud backend also supports the deployment of dense sensor networks across wide geographic areas.

Keywords: Environmental Awareness, Smart Monitoring, Pollution Control, System Evaluation, Indoor Air Quality, Urban Analytics, Environmental Technology.

7. Future Work & Conclusion

7.1 Future Enhancements The AirSense platform presents numerous opportunities for future development and enhancement that can significantly expand its capabilities and impact:

• Machine Learning Integration: Advanced ML algorithms such as LSTM (Long ShortTerm Memory) networks and ARIMA models can be applied to historical pollution data to generate accurate short-term and long-term pollution forecasts. Predictive analytics can provide early warnings of anticipated pollution spikes, enabling proactive public health measures. • Mobile Application Development: A dedicated mobile application for iOS and Android platforms would allow users to monitor air quality data, receive real-time alerts, and access historical pollution trends from anywhere. Location-based services can deliver personalized air quality reports based on the user's current GPS coordinates.

• Expanded Sensor Coverage: Deploying additional sensor nodes across multiple geographic locations — including residential neighborhoods, schools, parks, and industrial zones — would create a comprehensive city-wide air quality monitoring network. This data can be used to generate pollution maps and identify high-risk zones requiring immediate intervention.

• Integration with Smart City Platforms: AirSense data can be integrated with existing smart city management systems to support data-driven urban planning, traffic management, and public health policy formulation.

• Energy Harvesting: Incorporating solar-powered energy harvesting modules would enable truly autonomous outdoor sensor deployments with minimal maintenance requirements.

• Blockchain for Data Integrity: Implementing blockchain-based data logging can ensure the immutability and traceability of environmental records, which is particularly valuable for regulatory compliance and environmental auditing purposes.

7.2 Conclusion

The AirSense Smart Air Quality Monitoring and Analysis System successfully demonstrates how affordable sensor technology, wireless communication, cloud computing, and data visualization can be combined to create a powerful and accessible environmental monitoring platform. The system's ability to collect real-time data, compute standardized AQI values, identify pollution trends, and deliver timely alerts makes it a valuable tool for promoting environmental awareness and supporting public health protection. The evaluation results confirmed that the system achieves reliable performance across varied environmental conditions, with sensor accuracy levels appropriate for community-level monitoring applications. The insights generated by AirSense can directly inform decision-making by individuals, organizations, and regulatory authorities seeking to mitigate the effects of air pollution.

As air quality continues to emerge as a critical public health and environmental issue globally, platforms like AirSense represent an important step toward democratizing access to environmental data. With further development incorporating machine learning, expanded sensor networks, and mobile integration, AirSense has the potential to become a cornerstone of smart city environmental management infrastructure.

Keywords: Machine Learning, Predictive Monitoring, Smart City, Environmental Technology, AirSense, IoT Monitoring, Future Development, Sustainable Technology.

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