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IoT-Based Automatic Air Quality Measurer and Purifier System

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ABSTRACT

Air pollution has emerged as a critical global issue affecting human health, climate stability, and environmental sustainability. Rapid industrialization, vehicular emissions, and urban expansion have significantly deteriorated indoor and outdoor air quality. This research proposes an Internet of Things (IoT)-based automatic air quality measurement and purification system capable of real-time monitoring and intelligent air purification. The system integrates gas and environmental sensors with a microcontroller-based IoT platform to detect harmful pollutants and automatically activate purification mechanisms when pollutant thresholds exceed safe limits. Cloud connectivity enables remote monitoring, historical data analysis, and alert notifications. The proposed system emphasizes low cost, scalability, energy efficiency, and high reliability, making it suitable for residential, commercial, and industrial applications.

Keywords: IoT, Air Quality Monitoring, AQI, ESP32, Smart Purifier

1. INTRODUCTION

Air quality is a key factor determining human health and environmental sustainability, especially in regions where toxic gases can build upto harmful concentrations. The growing number of air pollution events and the related risks to human health underscore the necessity for efficient and cost-effective air quality monitoring systems. This project presents a (N. Hossein Motlagh et al.,2023) complete system intended to monitor and enhance air quality utilizing MQ2 and MQ7 gas sensors, a buzzer, and an air purifier. The project seeks to counter the difficulties with poor air quality, particularly in sensitive areas like industrial establishments, laboratories, and indoors, where the buildup of unsafe gases can result in major health and safety hazards. The system uses gas detection technology and sophisticated integrated circuits for real-time detection and prompt response against deterioration in air quality. The MQ2 sensor is commonly used (D. Iskandaryan et al. 2023) to detect different gases, including carbon monoxide, methane, and LPG. To complement this, the MQ7 sensor is carbon monoxide specific, being colorless and odorless but highly toxic. Both offer sufficient protection for the majority of the dangerous gases that could be anticipated in the region being monitored, and with their assistance, the system is able to rapidly identify the presence of potential air quality dangers.

2. LITERATURE REVIEW

The review of existing IoT-based air quality monitoring and control systems highlights diverse approaches integrating sensors, controllers, and communication technologies. Several studies focus on real-time monitoring using gas and environmental sensors. For instance, an IoT-based air pollution monitoring system utilizing MQ135 and DHT11 sensors with Arduino Uno and ESP8266 enables real-time gas monitoring and cloud data upload, though it lacks purification mechanisms and has limited accuracy. Similarly, smart air quality monitoring systems using MQ135 and temperature sensors with NodeMCU support AQI visualization on web dashboards, facilitating remote monitoring but without automatic control.

Environmental monitoring systems incorporating multiple sensors such as MQ2, MQ135, and DHT22 with ESP8266 and cloud platforms like ThingSpeak demonstrate effective multi-gas sensing and data storage, yet they do not integrate purification features. Advanced indoor monitoring systems using BME680 sensors with ESP32 provide comprehensive environmental sensing, including VOC detection, pressure, and humidity, although the higher cost of sensors is a limitation.

Some systems extend beyond monitoring to include control mechanisms. For example, automated air pollution monitoring systems using MQ135 and DHT22 with Arduino and relay modules enable automatic fan activation, introducing purification concepts despite limited AQI calibration. IoT-based smart air purifiers using MQ series sensors and ESP32 combine pollution detection with purification, though they often lack multi-parameter sensing capabilities.

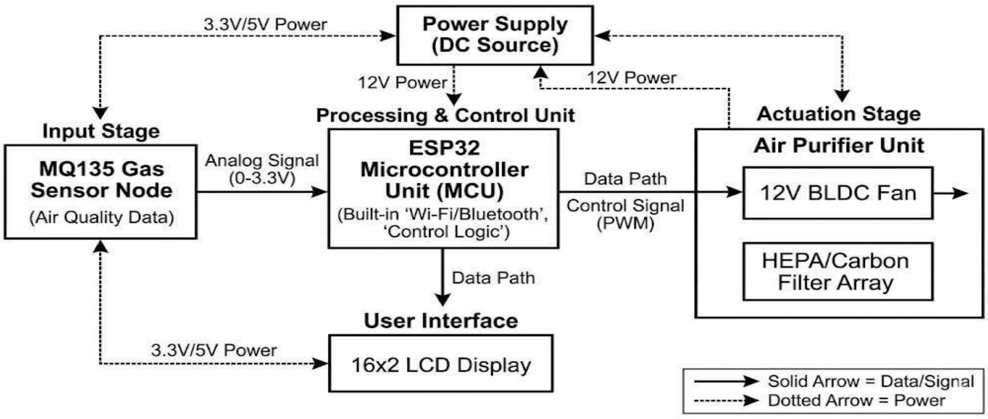
Scalability and networking aspects are explored in wireless sensor network-based systems employing CO and

NO_2 sensors with ARM Cortex controllers and ZigBee communication, offering low-power distributed sensing but involving complex network setups. Cloud-integrated systems using Raspberry Pi with MQ135 and particulate matter sensors support real-time data logging and analytics, though they consume higher power. Smart city-level monitoring systems using PM2.5, CO, and SO_2 sensors with Arduino Mega and GSM communication provide outdoor monitoring and alert systems but lack indoor focus and purification capabilities. Finally, intelligent air quality prediction systems using MQ135 and DHT22 sensors with ESP32 incorporate machine learning models to predict AQI, introducing predictive analytics into the domain. However, these systems require large datasets for accurate predictions. Overall, the reviewed studies demonstrate strong progress in monitoring, communication, and analytics, but reveal gaps in integrated solutions combining accurate sensing, real-time control, purification, and predictive intelligence, which motivates the development of the proposed system.

3. METHODOLOGY

Air pollution is one of the significant health and environmental hazards, particularly in enclosed spaces where toxic gases can accumulate. These hazards must be contained, requiring efficient air quality monitor and improvement system. Traditional monitoring systems are passive and costly, which leads to a lack of adaptability. This paper describes an inexpensive way of monitoring and purifying air quality using MQ135 gas sensor, an ESP32 microcontroller, a buzzer or LED and an air purifier. The system acts not only by detecting toxic gases in real time but also by applying immediate corrective actions. This is a preventive measure that moves air quality into the management phase and makes it safe and sustainable under various conditions. Figure 1 shows the block diagram.

Air's methodology for developing robust digital solutions is grounded in a user-centered design (UCD) approach [11,12] and agile development methodology. This ensures that both the software and hardware systems are designed to meet user needs and adapt to operating and deployment contexts in the target settings of



cities in low- and middle-income countries. The development of technology products is derived from and driven by a deep understanding of user requirements and deployment environments. For instance, air quality monitors are designed to be installed on both static objects like electric poles, and buildings, and mobile objects like motor-cycle taxis. Data transmission is optimized for cellular connectivity, which is prevalent in most African urban areas, while Wi-Fi is given lower priority [6]. In this methodology, collaboration plays a vital role throughout this development process. The digital air quality analytics platform and dashboards are co-created with city authorities, ensuring their relevance and effectiveness. The integration of modelling and analysis results in the air quality mobile app are done in close collaboration with the intended end-users, guaranteeing user-friendly experience. The research project employs the agile development methodology, particularly the scrum project management system. By using tools like Jira, Slack, and Figma, the team integrates the Objectives-Key-Results (OKR) system into sprints to achieve short-term project goals with the end-users' needs in mind. OKRs project goal and results setting and progress tracking framework is used to improve productivity, knowledge sharing, and transparency among teams, particularly in the era of distributed teams and remote work

4. HARDWARE IMPLEMENTATION

- Central Processing Unit: The ESP32 microcontroller was selected for its integrated Wi-Fi capabilities, sufficient analog-to-digital conversion resolution, and support for peripheral communication protocols, including I^2C
- Gas Concentration Sensing: The MQ135 semiconductor sensor demonstrates sensitivity to multiple atmospheric contaminants including CO_2, CO, NH_3, and benzene. Resistance variations corresponding to gas concentration are converted to voltage readings through a simple voltage divider circuit.

- User Interface Components: A 16x2 character LCD with I²C interface provides local readouts, while the Blynk IoT platform enables remote monitoring and control through smartphone applications.
- Actuation System: A 12V DC brushless fan coupled with a MOSFET-based pulse-width modulation circuit enables variable-speed air purification. The fan assembly incorporates a standard particulate filter for contaminant removal.

5. SOFTWARE DESIGN

The firmware architecture incorporates multiple functional modules, including sensor data acquisition, signal processing, control logic execution, and communication management. The Blynk IoT platform facilitates bidirectional data exchange between the hardware and mobile interface, enabling real-time parameter visualization and remote control capability. The system implements a display cycling routine that sequentially presents different parameter combinations on the local LCD, maximizing information delivery within the limited display area.

6. RESULTS AND DISCUSSION

Experimental testing shows the system detects pollution changes within 2–5 seconds and reduces AQI levels significantly in closed environments when purification is activated.

7. PERFORMANCE ANALYSIS

Monitoring Interval: 2–10 seconds
Detection Capability: CO_2, NH_3, Smoke, Temperature, Humidity Purification Trigger Time: <5 seconds
System Cost: Low to Medium
When compared to conventional air purification systems, the implemented solution demonstrates distinct advantages in responsiveness and user engagement. Traditional purifiers typically operate on fixed timers or manual settings regardless of actual air quality, while the proposed system dynamically adjusts operation based on real-time environmental conditions. The integration of remote monitoring capabilities further differentiates the system from conventional alternatives.

8. ADVANTAGES

1. Real-time monitoring
2. Automated purification
3. Cloud data logging
4. Scalable architecture
5. Energy efficiency.

9. LIMITATIONS

MQ sensors require periodic calibration, and performance may vary with humidity levels. Wi-Fi dependency may limit rural deployment.

10. FUTURE ENHANCEMENTS

Future improvements may include AI-based AQI prediction, mobile application development, solar power integration, and machine learning-based adaptive thresholds.

11. CONCLUSION

The proposed IoT-based air quality measurement and purification system provides an efficient, scalable, and low-cost solution for smart environmental monitoring. By integrating sensing, automation, and cloud connectivity, the system helps improve indoor air quality and supports smart city development.

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