



## **An Intelligent Air Pollution Detector Using IoT and Sensor Networks**

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### **ABSTRACT**

Air pollution has become one of the major environmental and public health challenges across the world. Increasing industrialization, urbanization, vehicular emissions, and harmful gases have significantly affected air quality. Continuous exposure to polluted air can lead to respiratory diseases, cardiovascular problems, and other health-related issues. Traditional air quality monitoring systems are often expensive and limited to fixed locations, making real-time monitoring difficult for common users. This research paper presents an Air Quality and Pollution Detection System based on Internet of Things (IoT) technology for real-time monitoring and analysis of environmental conditions. The proposed system uses sensors such as MQ135, MQ7, DHT11/DHT22, and particulate matter sensors to detect harmful gases, temperature, humidity, and air quality parameters. An Arduino Uno microcontroller is used for data collection and local data processing. The collected data is processed onboard and displayed on a 16x2 I2C LCD module, with provisions for serial communication to external logging or monitoring systems. The proposed system aims to provide a low-cost, portable, and efficient solution for monitoring air pollution levels in residential, industrial, and urban areas. The system can help users identify harmful pollution conditions and take preventive actions. The implementation demonstrates accurate monitoring, fast response time, and efficient real-time data processing. Future enhancements may include machine learning-based pollution prediction, wireless connectivity modules, and integration with smart city infrastructures.

**Keywords:** air quality monitoring, Arduino, sensors, air pollutants, IoT, environmental sensing.

### **1. INTRODUCTION**

The escalating rate of global urbanization and industrialization has positioned air pollution as one of the most critical environmental threats to human health and ecological stability. According to the World Health Organization, ambient and indoor air pollution contribute to millions of premature deaths annually, exacerbating respiratory diseases and degrading urban microclimates. Historically, tracking these atmospheric shifts relied heavily on sparse, government-operated ground monitoring networks. While highly accurate, these traditional systems require substantial capital investment, maintain slow response times, and fail to provide the high-density spatial resolution necessary to capture abrupt, localized pollution events.



To address these limitations, recent environmental engineering and computer science research has shifted heavily toward Internet of Things (IoT)-enabled Air Quality Monitoring (AQM) architectures. By combining microcontrollers such as Arduino, Raspberry Pi, and similar embedded platforms with affordable chemical and particulate sensors, contemporary frameworks enable extensive real-time spatial mapping and continuous environmental monitoring. Furthermore, recent breakthroughs in material science have accelerated sensor miniaturization, low-power room-temperature operation, and the integration of advanced sensing technologies. These advancements support the continuous monitoring of hazardous compounds including particulate matter (PM<sub>2.5</sub> and PM<sub>10</sub>), carbon oxides (CO<sub>x</sub>), ammonia (NH<sub>3</sub>), and nitrogen dioxide (NO<sub>2</sub>), even within resource-constrained edge environments.

Within the domain of low-cost environmental monitoring systems, semiconductor gas sensors such as the MQ135 have emerged as effective solutions for detecting a wide range of harmful gases, including ammonia (NH<sub>3</sub>), nitrogen oxides (NO<sub>x</sub>), smoke, alcohol vapors, benzene, and carbon dioxide (CO<sub>2</sub>). Due to their affordability and adaptability, these sensors are widely adopted in IoT-enabled pollution detection applications. However, one major limitation of metal oxide semiconductor sensors is their sensitivity to environmental variations such as temperature and humidity. Variations in atmospheric conditions directly influence the conductivity of the sensing layer, leading to inaccurate voltage outputs, sensor drift, and false air quality readings.

To overcome these limitations, the proposed system integrates the MQ135 gas sensor with the DHT11 temperature and humidity sensor. The DHT11 continuously monitors ambient temperature and relative humidity conditions surrounding the gas sensing environment. By simultaneously collecting environmental and gas concentration data, the system establishes a localized microclimatic profile that improves the reliability of air quality measurements. This combined sensing architecture enables real-time calibration and compensation of sensor outputs, thereby reducing environmental interference and enhancing the overall accuracy of the Air Quality Index (AQI) estimation.

However, despite the rapid deployment of low-cost IoT sensor nodes, several technical challenges remain unresolved. Raw sensor data generated at the edge often suffers from environmental noise, sensor drift, signal instability, and cross-sensitivity to external atmospheric conditions. Traditional linear and static analytical models frequently fail to reconcile these dynamic variations or accurately forecast Air Quality Index (AQI) trends. Consequently, modern research has increasingly incorporated machine learning (ML) and deep learning frameworks such as Long Short-Term Memory (LSTM) networks, adaptive filtering algorithms, and predictive analytics into environmental monitoring pipelines. These intelligent systems efficiently extract complex non-linear spatiotemporal patterns from large environmental datasets, enabling automated event-driven decision-making such as smart ventilation triggering, pollution alerts, and proactive public health warnings.

Building upon these advancements, this paper presents an integrated low-cost real-time IoT-based air quality and pollution detection system. The proposed architecture utilizes an optimized hardware configuration consisting of an Arduino Uno microcontroller, MQ135 gas

sensor, DHT11 temperature and humidity sensor, 16x2 I2C LCD display, and the Arduino IDE for software development and system integration. The system continuously captures environmental data, processes sensor outputs locally using the ATmega328P onboard processor, and displays real-time information on the connected LCD module. By evaluating the proposed framework under dynamic environmental conditions, this study contributes toward the development of scalable, energy-efficient, and economically viable smart environmental monitoring solutions suitable for smart homes, industrial safety systems, and smart city infrastructures.

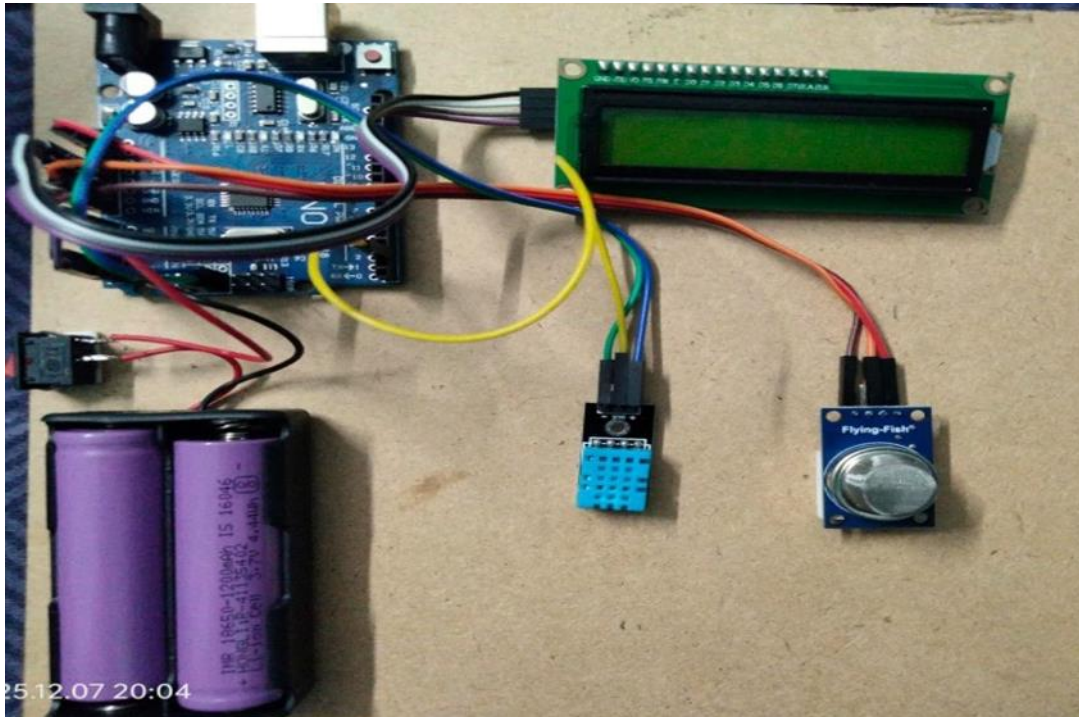


Fig. 1. Prototype Hardware Setup of the Proposed Air Quality Monitoring System

#### *A. Contributions of the Proposed Work*

To address the challenges associated with low-cost pollution monitoring systems, this research presents an IoT-enabled air quality detection framework with the following major contributions:

**Synergistic Sensor Integration:** The proposed system combines the MQ135 gas sensor with the DHT11 temperature and humidity sensor to create a compact and cost-effective environmental monitoring platform capable of detecting both gaseous pollutants and surrounding atmospheric conditions.

**Environmental Compensation Mechanism:** A software-assisted calibration approach is implemented to minimize the effects of humidity and temperature fluctuations on MQ135 sensor readings. This compensation mechanism improves measurement stability and reduces false pollution alerts.

**Real-Time Local Monitoring Architecture:** The system utilizes an Arduino Uno microcontroller with onboard ADC and digital I/O capabilities to acquire, process, and



display sensor data locally on a 16x2 I2C LCD module, enabling continuous real-time environmental observation without dependency on external cloud infrastructure.

Scalable Smart Environment Application: The proposed architecture is suitable for deployment in smart homes, industrial environments, educational institutions, and smart city infrastructures due to its portability, low power consumption, and scalability.

## **2. LITERATURE REVIEW**

### ***A. Evolution of Low-Cost IoT Air Quality Monitoring Systems***

Early iterations of automated Air Quality Monitoring Systems (AQMS) relied heavily on legacy 8-bit microcontrollers such as the ATmega328P platform, commonly deployed on Arduino Uno and Arduino Nano boards, often paired with wireless modules like the ESP8266 or basic RF links to stream sensor metrics. These systems demonstrated the feasibility of decentralized monitoring and established the Arduino ecosystem as a dominant platform for low-cost embedded environmental sensing. While effective for basic multi-sensor suites, existing literature reveals processing bottlenecks when deploying complex synchronous data pipelines. As noted in previous studies, handling multiple synchronous analog and digital signals on a single-core 8-bit processor limits the node's ability to apply real-time calibration matrices without inducing processing latency.

The Arduino platform, particularly the Uno board built around the ATmega328P microcontroller, remains widely adopted due to its simplicity, extensive community support, broad library ecosystem, and compatibility with a large range of peripheral modules. Researchers have successfully employed Arduino-based architectures for sensor acquisition, analog signal processing, threshold-based alerting, and LCD visualization within resource-constrained embedded environments. This architectural simplicity makes Arduino boards a strong candidate for educational deployments, residential monitoring nodes, and cost-sensitive industrial sensing applications where wireless connectivity is handled by supplementary modules rather than built-in SoC capabilities.

### ***B. Analytical Characteristics and Cross-Sensitivity of the MQ135 Sensor***

In low-cost environmental monitoring frameworks, the MQ135 SnO<sub>2</sub>-based semiconductor sensor remains one of the most widely adopted solutions for multi-gas profiling. Literature extensively documents its sensitivity toward key atmospheric pollutants, including Ammonia (NH<sub>3</sub>), Carbon Dioxide (CO<sub>2</sub>), Nitrogen Oxides (NO<sub>x</sub>), smoke particles, and Volatile Organic Compounds (VOCs). However, a persistent challenge highlighted across several studies is the sensor's cross-sensitivity to environmental changes. To convert raw analog sensor voltages into meaningful Parts-Per-Million (PPM) concentration values, standard methodologies utilize logarithmic curve-fitting models expressed as:

$$\text{PPM} = a \times (R_s/R_o)^b$$

where  $R_s$  represents the sensor resistance,  $R_o$  denotes the calibrated baseline resistance, and  $a$  and  $b$  are gas-specific scaling constants derived from datasheet calibration curves.



Despite its flexibility and affordability, semiconductor gas sensing introduces a known physical vulnerability. The oxygen adsorption layer formed on the tin-dioxide sensing surface exhibits strong dependency on external thermodynamic conditions. Variations in ambient temperature and relative humidity directly alter the baseline resistance ( $R_0$ ), producing sensor drift and false-positive pollution spikes during environmental transitions.

### **C. Microclimatic Compensation Strategies Using the DHT11 Sensor**

To mitigate the cross-sensitivity limitations associated with the MQ135 sensor, recent literature emphasizes the integration of multi-sensor fusion strategies, particularly through the inclusion of digital microclimate sensors such as the DHT11. The DHT11 employs a capacitive humidity sensing element and an integrated thermistor to provide calibrated digital outputs for ambient temperature and relative humidity.

Historically, many IoT-based architectures simply logged these atmospheric parameters as auxiliary metadata alongside gaseous pollutant readings. However, recent engineering advancements demonstrate that DHT11 metrics can be computationally integrated into the MQ135 calibration pipeline to improve sensor reliability and environmental adaptability.

By implementing a software-driven correction mechanism:

$$R_{\text{corrected}} = R_s \times f(T, RH) \tag{2}$$

where  $T$  represents ambient temperature,  $RH$  represents relative humidity, and  $f(T, RH)$  denotes the environmental compensation function, the system dynamically compensates for humidity-induced resistance fluctuations and thermal drift within the gas sensing layer.

Furthermore, hybrid machine learning frameworks have demonstrated that combining gaseous pollutant concentrations with localized thermodynamic variables significantly improves the predictive accuracy of Air Quality Index (AQI) forecasting models. Advanced time-series architectures such as Long Short-Term Memory (LSTM) networks and Gated Recurrent Units (GRUs) are capable of extracting complex spatiotemporal relationships from environmental datasets, enabling more accurate pollution prediction and automated environmental decision-making.

Table 1: Summary of Existing Literature and Research Gaps

<b>Author / Study Focus</b>	<b>Hardware Architecture</b>	<b>Primary Parameters</b>	<b>Key Limitations/ Research Gaps</b>
Traditional AQMS	Arduino Uno + ESP8266	CO <sub>2</sub> , NH <sub>3</sub> , Smoke	High processing latency and restricted data throughput due to single-core bottle-necks.

Edge-Compute Models	ESP32 + MQ-Series Sensor Suite	Harmful Gaseous Toxins	Primarily focused on cloud telemetry while neglecting real-time environmental drift compensation.
Microclimate Fusion Models	Raspberry Pi / Complex SoC	Gaseous Matter + Temp/Humid	High computational cost and elevated power consumption unsuitable for long-term battery-powered edge deployment.
This Proposed Work	Arduino Uno + MQ135 + DHT11	Air Quality, Temp, Humidity	Provides low-cost, real time environmental compensation with local LCD-based display and scalable IoT integration.

### 3. PROPOSED METHODOLOGY

The primary objective of the proposed system is to establish a low-cost, real-time, and reliable framework for localized environmental and air quality monitoring. The architecture integrates a centralized Arduino Uno microcontroller with diverse solid-state and digital sensor nodes. The methodology follows a continuous data acquisition, signal conditioning, algorithmic processing, and visual rendering pipeline.

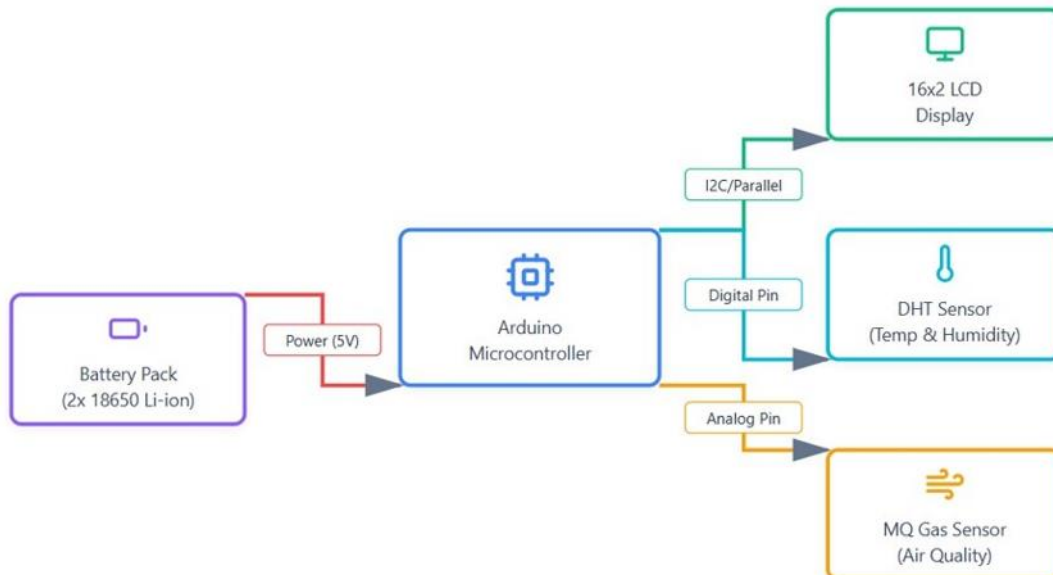


Fig. 2. Functional Data Flow and System Block Diagram

### A. Data Acquisition and Sensing Phase

The system relies on multi-parametric data collection executed by two primary hardware sensor modules:

**Atmospheric Thermistor and Capacitive Grid (DHT11/DHT22):** This sensor measures ambient temperature and relative humidity (RH). The raw physical inputs undergo internal analog-to-digital conversion within the module. The resulting data is transmitted via a single-wire bi-directional synchronous serial protocol to the Arduino microcontroller, minimizing hardware pin constraints.

**Metal Oxide Semiconductor Gas Sensor (MQ135):** The MQ135 sensor targets localized air pollutants such as Carbon Dioxide (CO<sub>2</sub>), Ammonia (NH<sub>3</sub>), benzene, smoke particles, and volatile gases. The sensing layer changes its electrical conductivity according to surrounding gas concentration levels, thereby altering the surface resistance ( $R_s$ ). This variation produces an analog output voltage ( $V_{out}$ ) corresponding to the level of pollution present in the environment.

### B. Hardware Interfacing and Signal Processing Layer

At the core of the system is the Arduino Uno board powered by the ATmega328P microcontroller. This unit acts as the primary hardware interface and processing engine responsible for sensor acquisition, environmental computation, and output rendering.

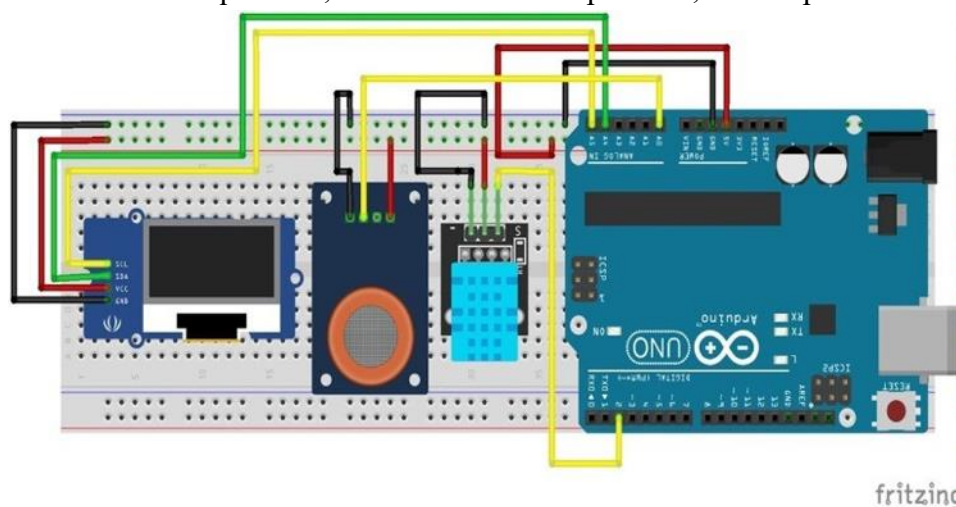


Fig. 3. I2C LCD Interface with Arduino Microcontroller

**Analog-to-Digital Conversion (ADC):** The analog output voltage from the MQ135 sensor is routed to the Arduino's onboard 10-bit ADC channel through analog pin A0. The microcontroller converts the incoming voltage range (0V – 5V) into discrete digital values ranging from 0 to 1023 according to:

$$\text{ADC Code} = \frac{V_{in}}{V_{ref}} \times 1023 \quad (3)$$

where  $V_{in}$  represents the input sensor voltage and  $V_{ref}$  denotes the reference voltage (5V for



Arduino Uno).

**Calibration and Baseline Mapping:** The firmware processes the digitized sensor values using predefined calibration constants and baseline environmental thresholds to generate meaningful air quality metrics and environmental readings.

**Digital Communication Execution:** The Arduino microcontroller acquires temperature and humidity data from the DHT11 sensor using timing-controlled digital communication protocols through the assigned GPIO interface pin. The Arduino DHT library handles the single-wire synchronous serial protocol, abstracting low-level timing management and providing calibrated temperature and humidity readings directly to the application layer.

### ***C. Network Bus Simplification via I2C Protocol***

To reduce wiring complexity and optimize hardware deployment, the proposed system employs the Inter-Integrated Circuit (I2C) communication protocol instead of traditional parallel LCD interfacing.

Traditional 16x2 Liquid Crystal Displays generally require multiple digital GPIO pins for data transmission and control operations. By integrating an I2C serial-to-parallel expander module (PCF8574), the display communication is simplified into two active signal lines:

**Serial Data Line (SDA):** Handles bidirectional transmission of processed sensor metrics between the Arduino microcontroller (Master) and the LCD display module (Slave). This line is connected to analog pin A4 on the Arduino Uno.

**Serial Clock Line (SCL):** Carries synchronization clock pulses generated by the Arduino to regulate communication timing. This line is connected to analog pin A5 on the Arduino Uno.

This I2C interfacing approach significantly reduces the GPIO pin footprint from the typical 6-pin parallel configuration to just two active signal lines, freeing valuable I/O resources for additional peripheral integration.

### ***D. Visual Output Routine***

The finalized environmental data is displayed using a time-multiplexed rendering mechanism on the 16x2 LCD module. Due to the limited display resolution, the firmware sequentially alternates between thermal parameters (temperature and humidity) and gaseous pollution metrics.

The Arduino executes a continuous non-blocking loop that refreshes the LCD contents at predefined intervals, ensuring real-time updates while maintaining low computational overhead and power consumption. This design allows the system to provide continuous environmental monitoring suitable for smart-home and smart-city applications.

### ***E. Abbreviations and Acronyms***

In this research work, several abbreviations and technical acronyms are utilized to simplify the representation of electronic components, environmental parameters, and communication protocols. All abbreviations are defined during their initial occurrence to maintain technical clarity and consistency throughout the paper.

The term Internet of Things (IoT) refers to interconnected smart devices capable of exchanging data through network communication frameworks. Air Quality Monitoring



(AQM) denotes the continuous observation and analysis of atmospheric pollutants within a surrounding environment. Air Quality Index (AQI) is a numerical representation used to quantify pollution intensity and environmental safety levels.

The MQ135 sensor is employed as a semiconductor-based gas sensing module capable of detecting pollutants such as Carbon Dioxide (CO<sub>2</sub>), Ammonia (NH<sub>3</sub>), Nitrogen Oxides (NO<sub>x</sub>), and smoke particles. The DHT11 sensor is used for measuring ambient temperature and relative humidity (RH). The Arduino Uno platform, built around the ATmega328P microcontroller, functions as the primary embedded processing unit responsible for sensor interfacing, data acquisition, and local output rendering.

For communication and display interfacing, the Inter-Integrated Circuit (I2C) protocol is utilized to minimize hardware complexity and GPIO utilization. Additionally, Analog-to-Digital Conversion (ADC) techniques are implemented within the Arduino microcontroller to transform analog sensor voltages into processable digital values for environmental analysis.

### ***F. Units***

The proposed environmental monitoring framework follows the International System of Units (SI) for all scientific measurements and computational evaluations. Temperature values are measured in degrees Celsius (°C), relative humidity is expressed as percentage (%), and gaseous pollutant concentrations are represented in Parts Per Million (PPM).

Voltage outputs generated by the MQ135 gas sensor are analyzed in volts (V), while current consumption within the embedded circuitry is represented in milliamperes (mA). The Arduino Uno board operates at a regulated 5V supply voltage, compatible with standard USB power sources or 7V-12V DC barrel jack input.

For consistency and dimensional accuracy, the system avoids mixing SI and CGS measurement conventions within computational equations and experimental evaluations. Decimal values are represented using leading zeros (e.g., 0.25 instead of .25), ensuring standardized numerical formatting throughout the research manuscript.

Additionally, environmental metrics obtained from sensor nodes are normalized before display and serial logging to preserve calibration consistency and minimize computational drift during long-duration monitoring cycles.

### ***G. Equations***

Mathematical formulations are employed within the proposed framework to model sensor calibration, analog signal conversion, and environmental compensation mechanisms. Equations are sequentially numbered to simplify referencing and analytical interpretation.

The MQ135 gas sensing mechanism estimates pollutant concentration levels through resistance-ratio calibration techniques expressed as:

$$\text{PPM} = a \times R_s^b / R_o \quad (1)$$

To convert the analog output voltage generated by the MQ135 sensor into digital values, the Arduino's internal Analog-to-Digital Converter (ADC) performs the following operation:

$$\text{ADC Code} = (V_{i_n} / V^{\text{ref}}) \times 1023 \quad (2)$$

To compensate for environmental variations caused by temperature and humidity fluctuations, the corrected sensor resistance is estimated using:

$$R_{\text{corrected}} = R_s \times f(T, RH) \quad (3)$$

Equation (1), Equation (2), and Equation (3) collectively form the mathematical foundation of the proposed air quality monitoring and calibration framework.

#### 4. FUTURE SCOPE

While the developed prototype successfully demonstrates a low-cost and real-time approach for monitoring localized temperature, humidity, and gaseous air pollution, environmental sensing technologies continue to evolve rapidly. The current framework provides a strong foundation that can be expanded through advanced sensing modules, intelligent analytics, wireless cloud integration, renewable energy systems, and smart-city deployment architectures.

##### *A. Advanced Sensor Integration and Parametric Expansion*

The present system primarily relies on the MQ135 sensor for generalized gas detection and the DHT11 module for environmental measurements. Future versions of the system can improve sensing accuracy and pollutant specificity through the integration of specialized environmental sensors.

**Particulate Matter Monitoring:** Future implementations may incorporate optical particulate matter sensors such as PMS5003 or SDS011 to measure particulate concentrations including PM1.0, PM2.5, and PM10. These sensors use laser-based light scattering mechanisms to determine airborne particle density with higher precision and can be interfaced with the Arduino via UART or I2C communication protocols.

**Targeted Gas Detection:** The MQ-series sensors exhibit cross-sensitivity toward environmental changes. Replacing or supplementing them with Non-Dispersive Infrared (NDIR) sensors such as the MH-Z19B can improve Carbon Dioxide (CO<sub>2</sub>) selectivity and overall measurement accuracy.

**Volatile Organic Compound (VOC) Monitoring:** Additional environmental sensing modules such as the SGP30 or BME680 can be integrated to detect hazardous Volatile Organic Compounds (VOCs), Carbon Monoxide (CO), ethanol, and formaldehyde with enhanced sensitivity.

##### *B. Transition Toward High-Performance IoT Architectures*

The current prototype utilizes an ATmega328P-based Arduino Uno platform suitable for lightweight embedded operations with local display output. However, future versions can transition toward more advanced IoT-enabled microcontrollers.

**ESP32-Based Architecture:** The ESP32 provides a 32-bit dual-core architecture with integrated Wi-Fi and Bluetooth Low Energy (BLE) support. Compared to the Arduino Uno, the ESP32 offers significantly improved processing capability, built-in wireless communication, reduced hardware complexity, and enhanced real-time networking support.

**Edge Computing Capability:** Future systems may perform local preprocessing, anomaly detection, environmental filtering, and adaptive calibration directly on the edge device before transmitting data to cloud platforms.



### ***C. Cloud Integration and IoT Visualization***

Although the current prototype displays environmental parameters locally through a 16x2 LCD module, future implementations can support persistent internet connectivity through the addition of wireless communication modules such as the ESP8266 Wi-Fi module or SIM800L GSM module.

**IoT Dashboard Integration:** Environmental metrics can be transmitted using lightweight communication protocols such as MQTT and HTTP APIs to cloud platforms including ThingSpeak, Firebase, Blynk, and Adafruit IO.

**Historical Environmental Data Storage:** Cloud-hosted databases such as InfluxDB and Firebase Realtime Database can store long-term environmental records for pollution trend analysis and predictive forecasting.

### ***D. Predictive Analytics Using Machine Learning***

**Air Quality Forecasting:** Machine learning algorithms such as Long Short-Term Memory (LSTM) networks, Random Forest regression models, and Gated Recurrent Units (GRUs) can analyze historical environmental datasets to forecast future Air Quality Index (AQI) levels.

**Automated Sensor Calibration:** Future systems can incorporate self-calibration algorithms capable of dynamically adjusting correction factors using nearby reference monitoring stations.

### ***E. Power Optimization and Renewable Energy Systems***

**Sleep Mode Firmware Optimization:** Future firmware architectures may implement power-down sleep modes available on the ATmega328P microcontroller, allowing the Arduino to enter ultra-low-power states between periodic sensing intervals.

**Solar Energy Harvesting:** The integration of photovoltaic solar panels, Lithium-Ion charging circuits such as TP4056, and intelligent power management modules can transform the device into a self-sustaining environmental monitoring platform.

### ***F. Automated Environmental Control and Alert Systems***

**Smart Ventilation and HVAC Automation:** The monitoring framework can interface with relays, exhaust systems, air purifiers, or smart HVAC infrastructure to automatically trigger ventilation whenever hazardous gas concentrations exceed predefined safety thresholds.

**Emergency Notification Infrastructure:** Future implementations may support automated SMS alerts and mobile push notifications using GSM modules or cloud APIs whenever critical pollution levels are detected.

### ***G. Decentralized Smart-City Sensor Networks***

**LoRaWAN and Mesh Communication:** Long-range communication technologies such as LoRaWAN and RF mesh networking can enable low-power distributed monitoring among multiple Arduino-based sensor nodes.

**GIS-Based Pollution Mapping:** By integrating GPS modules and Geographic Information System (GIS) platforms, collected environmental data can be transformed into dynamic pollution heatmaps for smart-city planning.

### ***H. Summary of Structural Enhancements***



The following table summarizes the major technological limitations of the current prototype along with the proposed future enhancements.

Table 2: Future Enhancements and System Evolution

Technical Element	Current Prototype	Future Enhancement Objective
Sensing Layer	MQ135 + DHT11	Integration of PM sensors, NDIR modules, and VOC sensing systems.
Computational Core	ATmega328P Arduino Uno	ESP32-based dual-core architecture with Wi-Fi, BLE, and edge-computing.
Data Visualization	16x2 I2C LCD Display	Cloud dashboards, mobile applications, and web-based analytics.
Data Intelligence	Threshold-Based Monitoring	Machine learning-driven AQI prediction and self-calibration.
Power Management	Continuous 5V External Supply	Solar-powered autonomous sensing nodes with deep-sleep optimization.
Network Architecture	Single Independent Sensor Node	Large-scale decentralized mesh networking for smart-city monitoring.

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