"Design and Experimental Analysis of a Low-Cost Multi-Gas Air Quality Monitoring System with MQ135 Sensor Using Arduino"

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ABSTRACT

This project focuses on the measurement and analysis of multi-gases such as carbon dioxide (CO_2), alcohol (ethanol), benzene, and ammonia using a low-cost gas detection system based on Arduino. The main aim is to develop an affordable and easy-to-use system that can monitor harmful gases in the environment. In this system, MQ135 gas sensor is connected to an Arduino microcontroller to detect the presence and concentration of gases. The sensor sends data to the Arduino, which processes the information and displays the results. The device is tested using gases like carbon dioxide (CO_2), alcohol (ethanol), benzene, and ammonia to check its performance and accuracy. The results show that the system can successfully detect these gases and provide useful information about their levels. The proposed system is low-cost, simple to build, portable device and suitable for use in homes, industries, and laboratories. It can help improve safety by providing early warning of harmful gases. This project demonstrates an effective way to monitor air quality using basic electronics and programming.

Index terms: MQ 135 Gas Sensors, Arduino Uno, Harmful Gases, Low Cost and Portable Device.

INTRODUCTION

Air pollution has become one of the most critical environmental challenges in the modern world due to rapid industrialization, urbanization, and increased vehicular emissions. The release of harmful gases such as carbon dioxide (CO_2), ammonia (NH_3), nitrogen oxides (NO_x), and volatile organic compounds (VOCs) into the atmosphere has significantly affected air quality, leading to severe health and environmental consequences [1]. The deterioration of air quality has been linked to various respiratory diseases, cardiovascular disorders, and ecological imbalances. According to environmental studies, continuous exposure to polluted air can lead to long-term health risks, emphasizing the need for effective monitoring and control systems [1]. Therefore, real-time air quality monitoring has become essential for assessing pollution levels and ensuring environmental safety.

Traditional air quality monitoring systems are generally expensive, bulky, and require sophisticated instrumentation, making them unsuitable for widespread deployment. These systems often rely on advanced analytical techniques such as gas chromatography and spectrometry, which, although accurate, are not cost-effective for everyday applications [2]. Hence, there is a growing demand for low-cost, portable, and efficient monitoring solutions. In recent years, the development of embedded systems and sensor technology has enabled the design of compact and affordable air quality monitoring devices. Microcontroller-based systems, particularly those using the Arduino Uno, have gained significant popularity due to their simplicity, flexibility, and ease of programming [3]. These systems can be integrated with gas sensors to measure environmental parameters in real time.

In this project the MQ135 Gas Sensor is used for detecting air pollutants due to its sensitivity to a range of gases. It operates on the principle of semiconductor gas sensing, where the resistance of the sensing material changes

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in response to gas concentration [4]. This property allows the conversion of chemical information into electrical signals, which can be processed and analyzed. The working principle of semiconductor gas sensors is based on surface adsorption phenomena. Oxygen molecules adsorb onto the surface of the sensing material and capture free electrons, increasing the resistance. When reducing gases are present, they react with the adsorbed oxygen, releasing electrons back into the material and decreasing the resistance [5]. This change in resistance is directly related to the concentration of gases in the environment. The integration of the MQ135 sensor with the Arduino Uno allows the measurement of gas concentration through analog-to-digital conversion. The analog signal generated by the sensor is converted into digital form using the built-in ADC of the microcontroller. Mathematical models are then applied to determine parameters such as sensor resistance (Rs), calibration resistance (Ro), and gas concentration in parts per million (PPM) [4].

This project focuses on the design and development of a low-cost and portable air quality monitoring system that utilizes the MQ135 sensor and Arduino Uno to measure and display air quality in real time. The device is tested using gases like carbon dioxide (CO_2), alcohol (ethanol), benzene, and ammonia to check its performance and accuracy. The results show that the system can successfully detect these gases and provide useful information about their levels. The system aims to provide a simple yet effective solution for environmental monitoring, particularly in indoor and urban environments.

Technical Description

Our project is the gas detecting system which detects multi-gases like carbon dioxide (CO_2), ammonia (NH_3), benzene (C_6H_6), and alcohol vapors.

System Components

This system composed of four principal elements shown in figure 1.

(A) The first component is an Arduino board, a microcontroller board based on the ATmega328 microprocessor. This part controls the other components that are going to be used.
(B) Next is the MQ 135 gas sensor for measuring the multi-gases concentration in air.
(C) LCD display module that shows the analog value from the sensor which are used to convert output voltage (V_{out}).
(D) The final component is the control panel, consisting of a breadboard with a power supply charging module, +9 V chargeable batteries and a switch. This component is used to provide the power to whole system will make it portable.

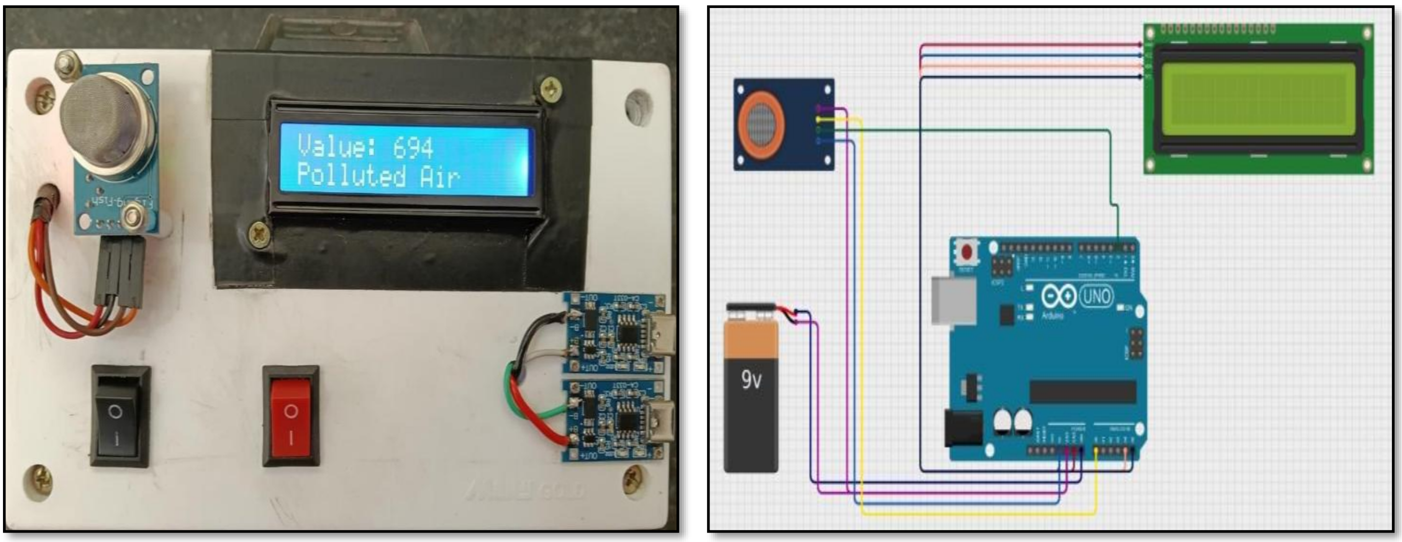

Figure 1. Photo of gas detecting system(left) and Diagram of the praposed gas detecitng system (right) consist of four principal elemnts: (A) Arduino board, (B) MQ135 sensor, (C) LCD display, and (D) Control pannel with chargeble battry system.

The connections of these four elements as shown in d figure 1. Before starting multi-gases measurements, the code must be loaded onto the Arduino board, which in turn is connected to a standard USB port on any laptop or desktop computer to supply power and enable data acquisition. Others power sources for the Arduino, such as mains or battery, are also possible. Moreover, connecting it to a battery will make it mobile.

The sensor output is processed using the Arduino platform, and analog values for different air which are shown by LCD display are recorded for analysis of concentration of multi-gases in ppm by mathematical formulas.

Gas Concentration Calculation Methodology

Followings are the steps to measure the value of gas concentration in ppm manually:

Step-1: To get (measure) the output voltage from the MQ135 Gas Sensor using an Arduino Uno, we need to placed sensor near the gas and read the analog value from the sensor pin and convert it into output voltage (V_{out}).

Step-2: For Arduino voltage calculation: V_{out} = (Analog Value/1023) × 5. (Where, **1023** = maximum ADC value and **5 V** = Arduino reference voltage).

Step-3: Calculate Sensor Resistance R_s: $R_s = (V_c - V_{out}/V_{out}) \times R_L$. (Where, V_c= Source Voltage = 5V and R_L = Load Resistance = 10KΩ)

Step-4: Calculate Ratio = (R_s/R_0), Where, R_0 = Sensor resistance in clean air (calibrated value) = 76 KΩ for MQ135 sensor.

Step-5: CO_2 Concentration Formulas**:**

For the MQ135 carbon dioxide curve, a commonly used approximation is: $CO_2(\text{ppm}) = 116.6020682 \times (\text{Ratio})^{-2.769034857}$.

Similarly, approximation consider for multi gases are given below:

Ammonia (NH_3) concentration in ppm = NH_3 (ppm) = $102.2 \times (R_s/R_0)^{-2.473}$

Benzene (C_6H_6) concentration in ppm = $24.45 \times (R_s / R_0)^{-2.35}$

Alcohol (C_2H_5OH) concentration in ppm = $77.250 \times (R_s/R_0)^{-3.18}$

In this project we developed the Arduino program logically using above mathematical operations, that shown the multi-gas concentration (in ppm) in air.

Arduino Program and Flowchart

For presentation here take CO_2 gas sensing for MQ135 gas sensor. The complete Arduino program and flowchart to interface the MQ135 Gas Sensor with Arduino Uno and display CO_2 (approx.) on a 16×2 LCD shown in figure 2.

```
#include <LiquidCrystal.h>

// LCD pins: RS, EN, D4, D5, D6, D7
LiquidCrystal lcd(7, 6, 5, 4, 3, 2);

// MQ135 settings
#define MQ135_PIN A0
float RLOAD = 10000.0;   // 10k ohm
float RZERO = 76000.0;   // Calibrated value (change after
calibration)

void setup() {
  lcd.begin(16, 2);
  lcd.print("Air Quality");
  delay(2000);
  lcd.clear();

  Serial.begin(9600);
}

void loop() {
  int adcValue = analogRead(MQ135_PIN);

  // Convert ADC to voltage
  float voltage = adcValue * (5.0 / 1023.0);

  // Calculate Rs
  float rs = ((5.0 / voltage) - 1.0) * RLOAD;

  // Ratio Rs/R0
  float ratio = rs / RZERO;

  // CO2 approximation formula
  float co2 = 116.6020682 * pow(ratio, -2.769034857);

  // Display on LCD
  lcd.setCursor(0, 0);
  lcd.print("CO2 Level:");

  lcd.setCursor(0, 1);
  lcd.print(co2);
  lcd.print(" ppm   ");

  // Serial monitor output
  Serial.print("CO2 ppm: ");
  Serial.println(co2);

  delay(2000);
}
```

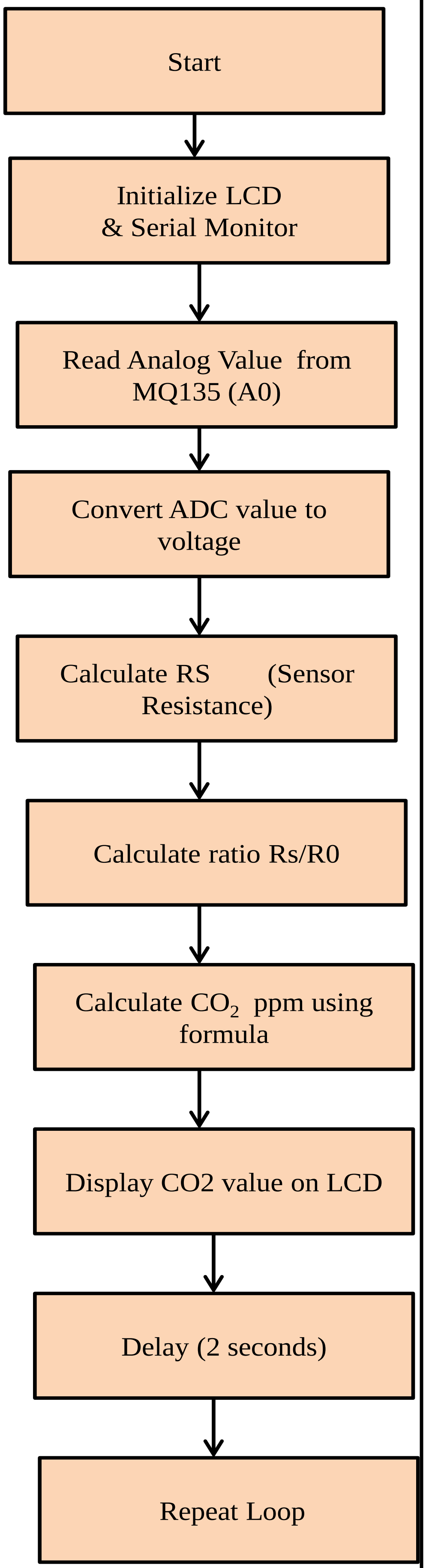

Figure 2 complete Arduino program and flowchart to interface the MQ135 Gas Sensor with Arduino Uno and display CO_2 (approx.) on a 16×2 LCD.

RESULT AND DISCUSSION

We now present multi-gas sensing activities implemented in various purposes in order to show how suitable this measurement system is for different activities such as indoor and outdoor monitoring, driver alcohol detection system, educational use, and basic environmental analysis.

Measuring CO_2 levels in air at different places using MQ135 sensor:

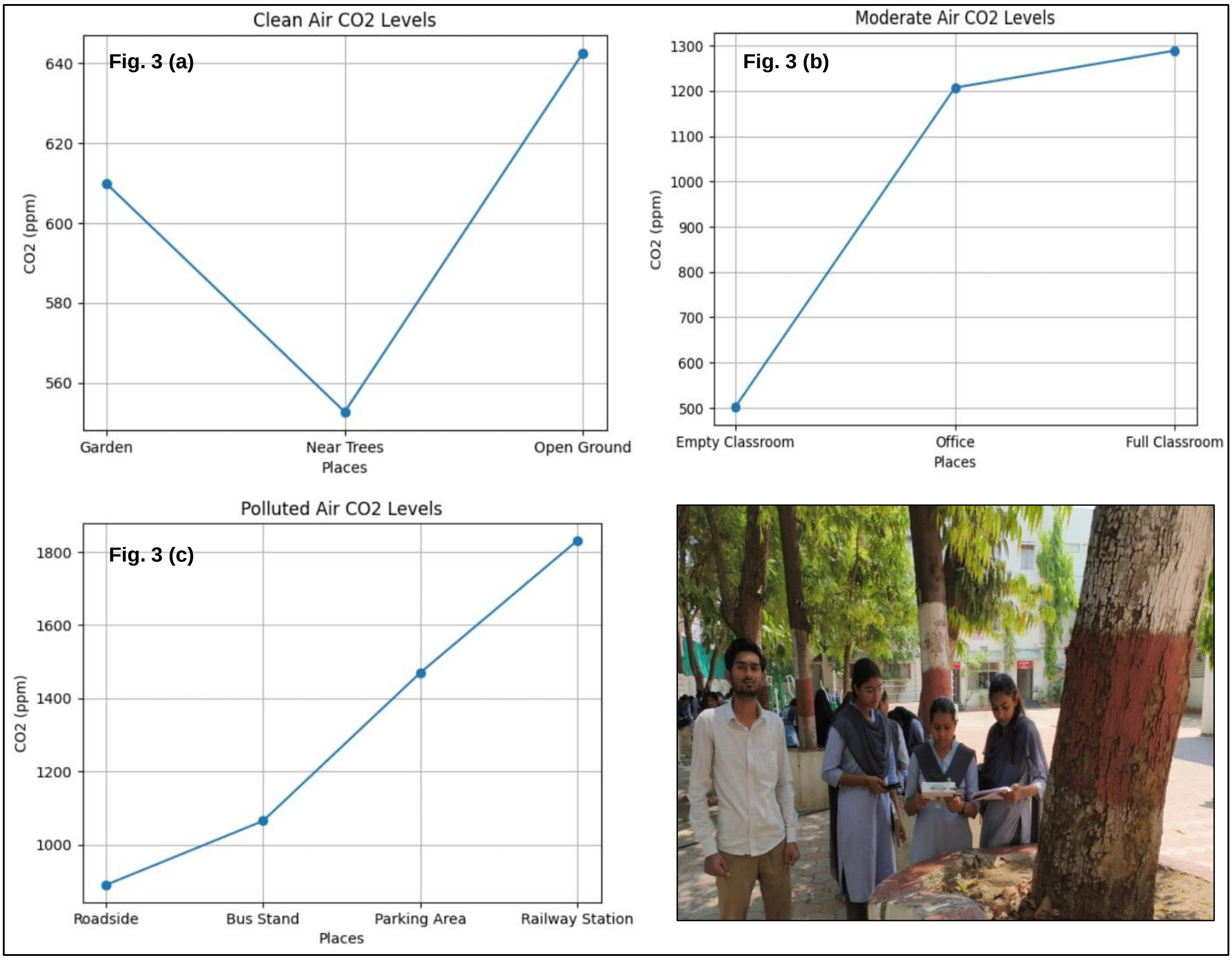

Figure 3 (a), 3 (b) and 3 (c) shows the graphs of CO_2 concentration in ppm at various palace. We measure the CO_2 levels in air under indoor and outdoor activities.

We perform the experimental analysis of level of CO_2 in air at different places. Put the sensor in the particular place such as garden, near trees, open ground, crowd places, vehicle traffic places and record the reading of level of CO_2 (ppm) in air at mention places. The graphs in figure 3 (a), (b) and (c) show the variation of CO_2 level in air as per the places.

Measuring the level of ammonia (NH_3), benzene (C_6H_6), and alcohol vapors in air using MQ135 sensor:

The sensor is placed inside a closed container with ammonia (NH_3) solution in a beaker. Initially the percentage of alcohol in beaker is 25 ml; sensor shows the ppm value of concentration of ammonia vapor in air. While the percentage of alcohol is increasing (from 25 ml to 50 ml, 75 ml up to 100 ml) in beaker, sensor shows the non-liner increasing the ppm value of concentration of ammonia vapor in air as shown in fig. 4 (a). The same procedure is repeated for the benzene and alcohol solution. We also got non-liner behavior of sensor for the respective chemicals as shown in fig. 4 (a) and 4 (b). The last picture shows the experimental setup to measure the concentration of multi-gases.

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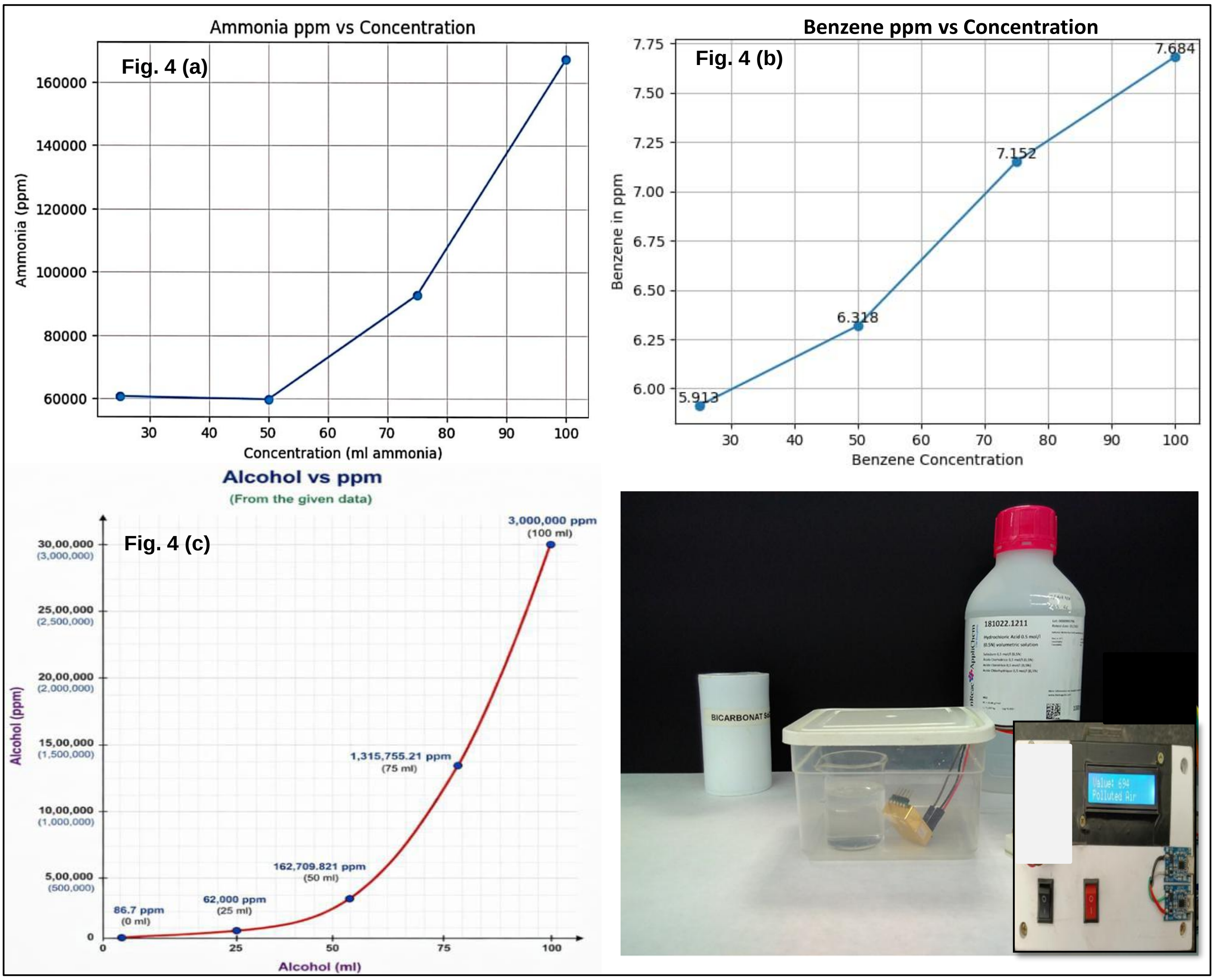

Figure 4 (a), (b) and (c) shows the variation of ammonia, benzene and alcohol gas concentration in ppm with the different percentages of respective chemicals in ml. The last picture shows the experimental setup to measure the concentration of multi-gases.

Proposed System Enhancements

The following enhancements are proposed to improve the system's accuracy, reliability, and usability:

Integration of Additional Gas Sensors

The MQ135 sensor, while versatile, has cross-sensitivity issues and cannot reliably distinguish between individual gases in complex mixtures. To extend the detection capability and improve specificity, the following additional sensors are proposed for future integration:

Table 1: Proposed additional sensors for system enhancement.

Sensor	Target Gas	Purpose
MQ-7	Carbon Monoxide (CO)	Detect odorless, highly toxic CO from vehicle exhaust and combustion
MQ-2	LPG, Smoke, Propane	Enhance safety in kitchens and industrial settings
MQ-3	Alcohol (Ethanol)	More specific alcohol detection for breathalyzer applications
DHT11/DHT22	Temperature & Humidity	Enable environmental compensation for more accurate ppm readings

Improved Calibration Method

The non-linear response of the MQ135 sensor makes it susceptible to drift and environmental interference. A two-point calibration method combined with temperature and humidity compensation is proposed. By reading the DHT11/DHT22 sensor values, correction factors can be applied to the resistance ratio calculation as follows:

$R_0(\text{corrected}) = R_0 \times f(T, RH)$

where f(T, RH) is an empirically derived correction function based on temperature (T) and relative humidity (RH). Additionally, periodic re-calibration using known gas concentrations (reference standards) is recommended to counteract long-term sensor drift. Implementing a moving average filter in the Arduino code will further reduce noise in sensor readings.

Wireless Communication Module (ESP8266 Wi-Fi)

The current system is limited to local LCD display. To enable remote monitoring and data logging, integration of the ESP8266 Wi-Fi module is proposed. The Arduino Uno communicates with the ESP8266 via serial (UART) communication. Sensor data can be transmitted to a cloud platform such as ThingSpeak, Blynk, or a custom MQTT broker, allowing continuous data logging and remote access.

The proposed wireless architecture is: MQ135 Sensor → Arduino Uno (data processing) → ESP8266 (Wi-Fi) → Cloud Server → Mobile Application / Web Dashboard. This transforms the system from a standalone local device into an IoT-enabled air quality monitoring node, enabling multi-point deployment and centralized data analysis.

Mobile Application for Remote Monitoring

A companion mobile application is proposed using the MIT App Inventor or Flutter framework. The app would connect to the cloud server and provide the following features:

- Real-time display of CO_2, NH_3, benzene, alcohol, temperature, and humidity values.
- Historical data logging with time-stamped graphs for trend analysis.
- Customizable threshold-based alerts and push notifications when gas levels exceed safe limits.
- Air Quality Index (AQI) display with color-coded safety indicators aligned with WHO and EPA standards.

This mobile interface will significantly improve the system’s usability for non-technical users including homeowners, teachers, and health workers.

CONCLUSION

This project successfully presents the design and implementation of a low-cost air quality monitoring system using Arduino Uno and the MQ135 gas sensor. The system detects harmful gases such as carbon dioxide (CO_2), ammonia (NH_3), benzene (C_6H_6), and alcohol vapors. The MQ135 sensor works on the principle of resistance variation with gas concentration. The Arduino Uno processes this data using its built-in ADC and displays real-time values on an LCD module. Experimental results show that the system responds effectively to changes in air quality. Although the sensor exhibits non-linear behavior, calibration and mathematical modeling allow estimation of gas concentration in PPM. Overall, the system is cost-effective, portable, and suitable for indoor and outdoor monitoring, driver alcohol detection system, educational use, and basic environmental analysis.

Discussion of Advantages and Limitations with System Enhancements of The Device

On the basis of the experiences presented above, we can highlight some advantages and limitations of the device.

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Advantages:

The entire cost of the setup is around $ 17, which is 15 times cheaper than some commercial sensors. The device can be used in multiple situations (inside a closed container, in a classroom, outdoors, etc.). The Arduino setup can be used from multiple approaches. Obviously, it enables inquiry-based instruction, in which students design their own experiments and carry out their own measurements using the device.

Limitations in Results and Future System Enhancements:

The sensor MQ 135 limited for specific gases. The analog output value depends on power stability. The environmental conditions are influence the output value. The sensor drifts over time.

To address the key limitations of the MQ135 sensor, including limited gas specificity, sensitivity to environmental conditions, and long-term drift, this work proposes integration of additional sensors (MQ-7, MQ-2, MQ-3, DHT22), a temperature-humidity-based calibration compensation method, wireless connectivity via the ESP8266 module, and a mobile application for remote monitoring and data logging. These enhancements will transform the system into a fully IoT-enabled, multi-sensor environmental monitoring platform suitable for wider deployment. Future work will focus on hardware integration, field validation of the enhanced system, and development of a cloud-based dashboard for centralized environmental analysis.

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