Standalone Air Pollution Monitoring For Stone Crushing Operation Plant Using Stm32

A MINI PROJECT REPORT

Submitted by

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BONAFIDE CERTIFICATE

Certify that this project report title "**Standalone Air Pollution Monitoring For Stone Crushing Operation Plant Using Stm32** " is the bonafide work of MARISELVAM.G (22EC057), VINOTHKUMAR.R (22LEC09) who carried out the project work under my supervision.

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ABSTRACT

Stone crushing operations generate large quantities of dust and fine particulate matter, leading to significant air pollution and health hazards for workers. In remote or unregulated environments, there is often a lack of continuous and real-time monitoring systems to detect harmful levels of air pollutants. This project presents a stand-alone embedded system using the STM32 microcontroller to monitor air quality around stone crushing units. The system integrates an MQ135 gas sensor to detect air pollution levels and a digital LDR sensor to detect human presence. When pollution exceeds a predefined threshold and the LDR detects human activity nearby, a warning message is sent via USART communication to an external interface, such as a computer or display. Additionally, a GPIO pin activates a visual indicator (LED or alarm) to alert nearby workers. The system operates independently without the need for internet or cloud services, making it ideal for rugged, standalone deployment in remote or developing regions. This design helps improve worker safety and promote environmental awareness in industries with high particulate emissions.

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IDE	INTEGRATED DEVELOPMENT ENVIRONMENT
USART	UNIVERSAL SYNCHRONOUS / ASYNCHRONOUS RECEIVER TRANSMITTER
ADC	ANALOG TO DIGITAL CONVERER
VEE	CONTRAST CONTROL

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Air pollution is a major concern in industrial areas, especially in sectors like stone crushing where dust and harmful gases are continuously released. These pollutants pose severe risks to both environmental quality and human health, particularly respiratory problems among workers exposed to high particulate concentrations. Traditional monitoring systems are often centralized, costly, and require internet connectivity or manual observation. To address this challenge, we propose a low-cost, embedded, real-time air pollution monitoring system tailored for stone crushing operations using the STM32 microcontroller platform.

This system employs the MQ135 gas sensor, capable of detecting various air contaminants including ammonia, sulfur, benzene, and smoke. An LDR (Light Dependent Resistor) is used to digitally sense the presence of workers near the monitoring unit. When pollution levels exceed a safe threshold (e.g., ADC value > 1100) and human presence is detected, the system activates an alert mechanism using a GPIO-controlled output and transmits a warning message via USART. The implementation is designed for standalone operation, with no dependence on cloud services, making it reliable for industrial field environments with limited infrastructure.

The embedded code is written in C using STM32 CMSIS libraries, enabling efficient ADC configuration, GPIO control, and serial communication. The project serves as a proof-of-concept for deploying localized, real-time air monitoring solutions in hazard-prone industrial zones, aiming to reduce health risks and promote occupational safety.

CHAPTER2

LITERTURE REVIEW

1] **Kalajdjieski, J., Risteska Stojkoska, B., and Trivodaliev, K. (2020)** proposed an IoT-based framework for air pollution monitoring in smart cities. Their study emphasizes a scalable, sensor-based system that integrates real-time air quality data with cloud computing platforms. This framework supports decision-making for environmental policy by offering reliable and continuous air pollution data collection across urban areas, promoting improved city planning and public health safety.

2] **Priyadharshini, S., and Shanthi, V.K. (2019)** developed an air quality monitoring system using the ESP8266 microcontroller and the MQ-135 sensor. Their system captures pollutants such as CO and CO_2 and sends the data to a cloud server via Wi-Fi. The study highlights low-cost implementation, compact size, and suitability for deployment in both urban and semi-urban areas, enabling continuous monitoring and public awareness.

3] **Manoj, S.R., Vishnu, S., and Pradeep, R. (2021)** designed a smart air pollution monitoring system using NodeMCU and the MQ-135 sensor. Their system uses Wi-Fi to upload data to the cloud and provide real-time access to pollution levels. The research focused on cost-effectiveness and flexibility, proposing it as a viable solution for smart cities to monitor and manage air quality.

4] **Shah, H.N., Khan, Z., Merchant, A.A., and Moghal, M. (2018)** designed an IoT-based air pollution monitoring system to detect and report harmful gases in the environment. Their system utilizes sensors such as MQ-135 to measure pollutants like CO, CO_2, and NO_2, and relays the data to a cloud interface via Wi-Fi. The researchers highlighted the affordability and scalability of their solution, making it suitable for both urban and rural deployment.

5] **Smith, A.L., Patel, J.K., and Desai, M.R. (2022)** proposed a real-time air quality monitoring system using IoT in urban areas. Their solution leverages embedded sensors connected to cloud-based dashboards to track pollution levels. The paper emphasizes the system's reliability in dense urban areas and its role in timely decision-making for environmental safety.

6] **Snyder, E.G., Watkins, T.H., Solomon, P.A., and Eben, E. (EPA, USA)** presented a paradigm shift in air pollution monitoring through advanced sensor technologies. Their work advocates transitioning from traditional, stationary monitoring stations to distributed, IoT-enabled low-cost sensors. This transformation facilitates greater spatial and temporal resolution in pollution data, thereby empowering communities with more granular and actionable environmental insights.

7] **Kim, H.C., Lee, J.H., and Park, S.H. (2023)** implemented an IoT-based air quality monitoring system using Raspberry Pi. Their system collects environmental data and provides local processing for environmental health tracking. The use of Raspberry Pi enhances computation while maintaining low power consumption, making it suitable for industrial and community-based deployments.

8] **Naik, Y. et al. (2019)** explored air quality monitoring through mobile sensing in metropolitan cities. Their system collects pollution data via smartphones integrated with sensors, offering high mobility and flexibility. The approach focuses on mapping pollution in real time across city areas, presenting a dynamic and innovative method for urban air quality assessment.

9] **Parmar, G., Lakhani, S., and Chattopadhyay, M.K. (2015)** proposed an IoT-based air pollution monitoring and forecasting system that not only measures pollutants but also predicts future air quality trends using data analytics. Their work integrates Arduino microcontrollers with gas sensors and wireless modules to transmit data to cloud platforms, showcasing the role of embedded systems and predictive modeling in smart environmental monitoring.

10] **Sendra, S., et al. (2017)** developed a low-cost IoT-based air pollution monitoring system targeted at reducing the economic barriers of environmental sensing. Their model uses cost-effective gas sensors and wireless communication to gather and transmit data. The research demonstrates successful implementation of real-time monitoring and highlights energy efficiency and network reliability as key design considerations.

11] **Wang, L.X., Zhang, Y.Z., and Liu, J.H. (2021)** introduced a smart air pollution monitoring system using IoT and Artificial Intelligence. Their system not only detects air pollutants but also uses AI to analyze patterns and issue alerts. This integration supports intelligent decision-making, particularly in highly polluted regions, and adds value to traditional sensor networks.

12] **Naik, U.U., Salgaokar, S.R., and Jambhale, S. (2023)** implemented an IoT-based air pollution monitoring system with a focus on real-time data visualization and alerting mechanisms. Using Arduino-based sensor nodes, their system transmits pollutant levels to a web interface where users can view pollution trends. The study underscores the significance of user-friendly dashboards and mobile accessibility for increasing public awareness.

13] **Uma, S., Manideepika, A.B.K., Divya, K., Vishnu, P.K.P.S., Jyotsna, G., and Eswaramoorthy, M. (2018)** presented a system for air quality monitoring using IoT that includes sensors for detecting various pollutants. The data is collected and sent to the cloud, enabling authorities to take timely actions. The system demonstrates the power of sensor networks in real-time air monitoring.

14] **Kularatna, N. et al. (2008)** proposed an environmental air pollution monitoring system based on the IEEE 1451 standard. Their model aims to fulfill low-cost requirements while maintaining data accuracy and compatibility. This early work laid the foundation for modern smart air quality systems and emphasized standardization in sensor communication and integration.

CHAPTER 3

STANDALONE AIR POLLUTION MONITORING FOR STONE CRUSHING OPERATION PLANT UNSING STM 32

The **Air Pollution Monitoring System** is designed to monitor and analyze air quality in real time using low-cost sensors and a microcontroller platform (STM32F401RE Nucleo). The system collects data on key air pollutants such as CO, CO_2, NO_2, and particulate matter (PM) using sensors like the MQ-135. Additionally, it gathers environmental data such as temperature, humidity, and light intensity using sensors like DHT22 and LDR. All data is processed locally by the microcontroller and displayed on an USART WINDOW for immediate viewing. The system provides real-time updates and activates visual or audible alerts (e.g., buzzer) if pollution levels exceed predefined safe limits. This standalone, cost-effective, and scalable system can be deployed in both urban and rural areas, making it useful for schools, offices, and public spaces to promote awareness and support local environmental monitoring efforts.

HARDWARE REQURIEMENTS

- **Microcontroller**: stm32F401RE nucleo
- **Gas Sensors**: MQ-135 (for CO_2, NH_3, NOx, benzene, etc.)
- **LM35**
- **PHOTORESISTOR**
- **PCBboard**
- **Power Supply**: USB power or battery module.

BLOCK DIAGRAM:

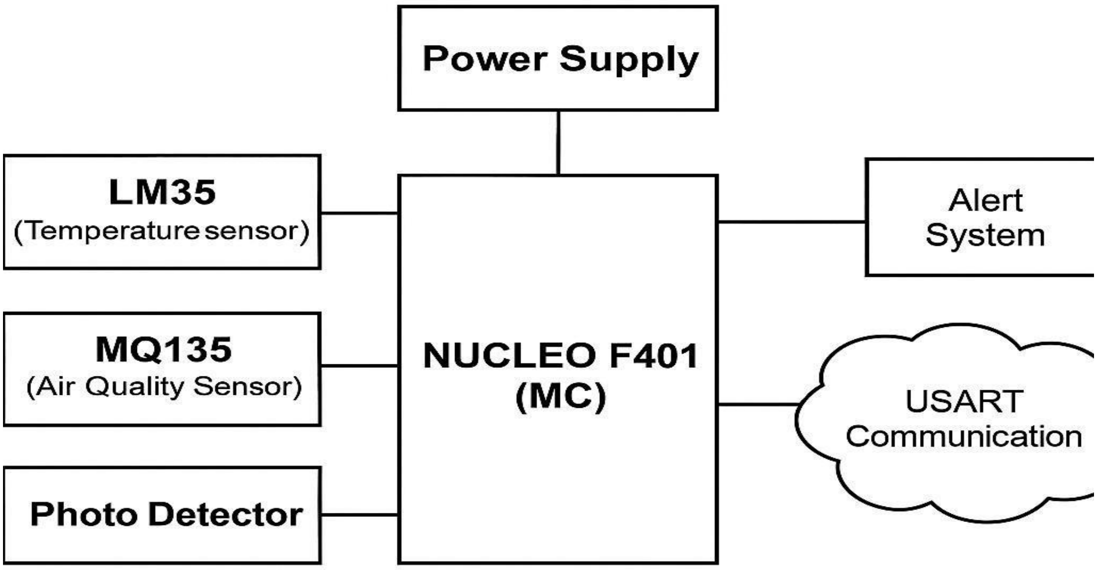

Fig. 3.1. Block Diagram

WORKING PRINCIPLE:

- The STM32F401RE Nucleo board initializes all peripherals including GPIO, ADC, UART, and I2C at startup.
- The MQ-135 gas sensor continuously measures the concentration of harmful gases (like CO_2, NH_3, and benzene) and outputs an analog signal.
- This analog output from MQ-135 is connected to one of the STM32's ADC pins, where it is digitized for interpretation.
- The photoresistor (LDR) measures ambient light intensity and is interfaced with an ADC pin to assess visibility or smog presence.
- The STM32 processes all incoming sensor data in real-time and performs necessary threshold comparisons for air quality assessment.
- Based on the processed values, the system categorizes the air quality as Good, Moderate, or Hazardous.
- If gas levels cross a predefined danger threshold, a buzzer is activated to alert nearby individuals.
- The system operates continuously, refreshing sensor data and display output at regular intervals for real-time monitoring.

3.1 STM32F401RE nucleo Development Board:

- **Overview:**

  The STM32F401RE Nucleo is a 32-bit ARM Cortex-M4 based development board by STMicroelectronics.It offers high performance with low power consumption and operates at up to 84 MHz.It comes with built-in ST-LINK/V2-1 for easy programming and debugging via USB.The board supports Arduino and ST morpho headers, enabling flexible hardware interfacing.

Fig. 3.2. STM32F401RE nucleo Development Board

Usage in Project:

The STM32F401RE reads sensor data from MQ-135 (gas), LM35 (temperature/humidity), and LDR (light).It processes pollutant and environmental data in real-time without cloud or internet use.The data is displayed locally on a USART for monitoring air quality status.It also controls output devices like a buzzer to alert when pollution levels exceed set limits.

Specifications:

- Microcontroller: ARM Cortex-M4 32-bit RISC core
- Clock Speed: Up to 84 MHz
- Flash Memory: 512 KB
- SRAM: 96 KB
- Operating Voltage: 3.0V - 3.6V
- GPIOs: 50+ configurable I/O pins via Arduino and ST morpho headers
- ADC: 12-bit resolution, up to 16 channels
- DAC: Not available (no internal DAC on F401RE)
- Timers: 16-bit and 32-bit general-purpose and advanced-control timers
- Communication Interfaces: USART, SPI, I2C, USB OTG FS, CAN

Parts of STM32F401RE nucleo Development Board:

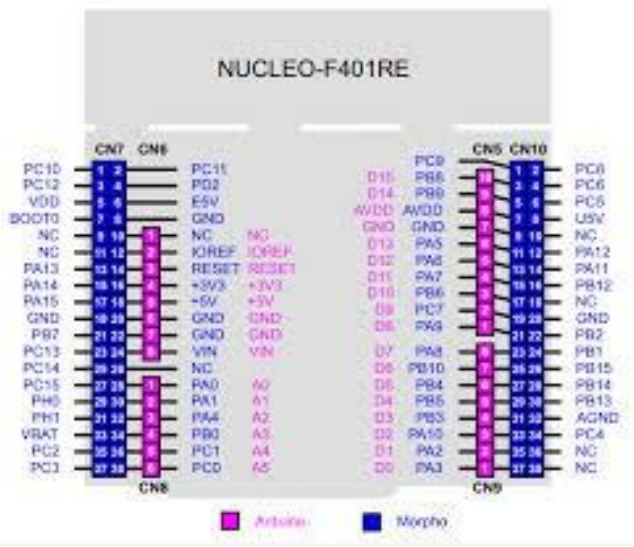

Fig.3.3. Parts of STM32F401RE nucleo Development Board

Explanation of Key Pins:

- PA5 (D13 - Onboard LED Pin): Used to indicate system status (e.g., error, process completion) with LED blinking for visual feedback.
- PA0 (Analog Input - ADC Channel 0): Connected to the MQ135 air quality sensor to read analog voltage levels representing gas concentration.
- PA9 (USART1_TX) and PA10 (USART1_RX): Connected to the Serial Monitor for data logging and debugging through UART communication.
- PB0 (Digital Output): Used to trigger an external buzzer or alarm when pollutant levels exceed safe thresholds.
- PA1 (Analog Input - ADC Channel 1): Optionally used for a second sensor like temperature or humidity to enhance environmental monitoring.

3.2 Peripheral I/O:

In this project, the STM32F401RE Nucleo board uses several GPIO pins for interfacing with external components. The MQ135 air quality sensor is connected to an analog input pin (e.g., PA0) to detect pollutant levels. A buzzer is connected to a digital output pin to trigger alerts when air quality exceeds the threshold. The onboard LED, connected to another digital output, acts as a visual indicator of system status. Push buttons or additional sensors can be connected to other GPIOs based on the project's expansion needs. The flexibility of the GPIO pins enables integration of multiple devices in the system.

3.3 Serial Communication:

Serial communication is used for transmitting air quality data to a computer via the serial monitor. The STM32F401RE supports UART communication through PA9 (TX) and PA10 (RX) pins. This allows developers to debug and observe real-time sensor readings during testing. The USART peripheral can be configured for different baud rates as needed. Data sent via UART helps verify if sensors and peripherals are working correctly. In addition, serial output makes it easier to log data for offline analysis. This communication channel is essential during development and for diagnostic purposes in non-IoT applications.

3.4 MQ-135:

Fig.3.4. MQ-135

The MQ-135 is used in our project to detect harmful gases like CO_2, NH_3, NO_x, and smoke in the air. It continuously senses the air quality and outputs an analog voltage corresponding to the gas concentration. This analog signal is fed into the STM32's ADC pin, where it is converted to a digital value and compared against pollution thresholds. When pollutant levels exceed safe limits, visual and audible alerts are triggered through LEDs and a buzzer. This sensor plays a key role in pollution detection.

3.5. LM35 :

Fig.3.5. LM35

The LM35 is used in our project to monitor the ambient temperature. It provides an analog voltage output that is directly proportional to the temperature in Celsius. The microcontroller reads this voltage and converts it into temperature data. This allows real-time tracking of environmental temperature, which is important for air quality assessment and alerts.

3.6. PHOTORESISTER:

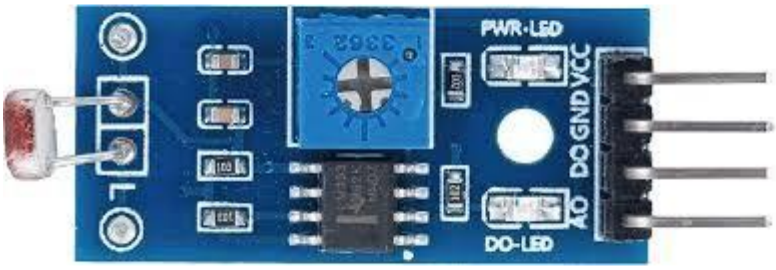

FIG.3.6. PHOTORESISTER

In our project, the photoresistor (LDR - Light Dependent Resistor) is used to measure the intensity of ambient light. It changes its resistance based on the surrounding light level — low resistance in bright light and high resistance in darkness. This helps the system detect whether it is day or night, or monitor visibility levels as part of the environmental conditions.

3.7. PCB board

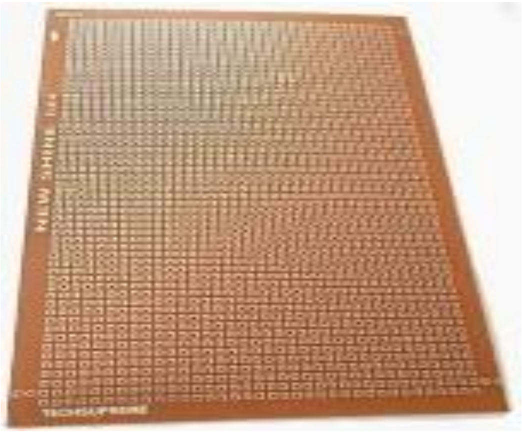

Fig.3.7. PCBboard

The PCB board serves as the physical base for connecting all components in a clean and stable layout. It reduces wiring errors and makes the system more compact and durable. Power lines, sensor connections, and microcontroller interfaces are routed through copper tracks, ensuring consistent performance and easy troubleshooting. It also supports long-term use and field deployment of the project.

3.8 SOFTWARE DESIGN

CODE:

```
#include<stdint.h>
#include<stm32f4xx.h>
#include<string.h>
#include<stdio.h>
#include<string.h>
void LDR_init()  //digital ip based sensor
{
      RCC->AHB1ENR|= (1<<1); //GPIOB clk enable
      GPIOB->MODER&= ~(0xc); //Reset Pb1 00 set as ip mode
      GPIOB->MODER|= (0x00010);   //Set Pb2 op mode
      GPIOB->PUPDR|= (0x8); //Set Pb1 acts as Pull down configuration avoid floating

}
void delay()
{
      for (uint32_t i=0; i<=70000;i++); //Empty loop
}
void MQ135_init() //Analog based sensor
{
       RCC->AHB1ENR|= (1<<0); //GPIOA Peripheral Enable
       RCC->APB2ENR|= (1<<8); //ADC peripheral Enable
       GPIOA->MODER|= (0xc0);//Set as analog mode 1100 = 12 at PA3
       GPIOA->MODER|= (0x3); //set as pA2 temp
       ADC1->CR2|= (1<<0); //ADON enable
       ADC1->SQR3=3; //ADc chnl 3
       ADC1->SQR3=2; //ADc chnl 2  temp
       for(volatile i=0; i<=20000; i++)
       ADC1->CR2|= (1<<30); //Conversion Starts
       ADC1->CR2|= (1<<1); // contineous Conversion
}
void USART_init()
{
      RCC->APB1ENR|= (1<<17); //enable usart clk
      GPIOA->MODER|= (0xA0); //Enable PA2 &A3 1010 -A
      GPIOA->AFR[0]|= (0x700); //tx 0111 pA2 transmit the data
      for(volatile int i=0; i<=20000;i++);
      // Set baud rate to 9600 for 16 MHz clock -> BRR = 16000000 / 9600 = ~1666 = 0x0682
      USART2->BRR =  0x0682;
      USART2->CR1|= (1<<13);  //Usart enable
      USART2->CR1|= (1<<3); //TX enable
}
void USART2_SendString(const char *str)
{
   while (*str)
   {

       while (!(USART2->SR & (1<<7))); // Wait until transmit data register is empty
       USART2->DR = (*str & 0xFF);
```

```
     str++;
   }
}

int main(void)

{
      LDR_init();
      MQ135_init();
      USART_init();

      char buffer[60];
      uint32_t adc_Value, temp;
      float voltage; //MV
      int temperature;
      while(1)
      {
            while(!(ADC1->SR & (1<<1)));  // waiting for the conversion completing
            adc_Value = ADC1->DR;
            delay();
            while(!(ADC1->SR & (1<<1)));  // waiting for the conversion completing
            temp = ADC1->DR;
            voltage = (temp * 3300) / 4095;
            temperature = voltage / 10.0;
            delay();
            if (((GPIOB->IDR & (1 << 1)) != 0) && (adc_Value >= 1100 || temperature > 40))

            {
                  sprintf(buffer,"Unhealthy AIR Move To Safe Zone \r\n");
                  for(volatile int i=0;i<=10000;i++);
                  USART2_SendString(buffer);
        GPIOB->ODR|= (1<<2);
            }
            else
            {
                  GPIOB->ODR&= ~(1<<2);
                  sprintf(buffer,"Fresh AIR \r\n");
                  for(volatile int i=0;i<=10000;i++);
                  USART2_SendString(buffer);
            }
            delay();
}}
```

ESTIMATION

COST OF ESTIMATION:

SI.NO	DESCRIPTION	QUANTITY	RATE	AMOUNT
1	STM32F401RE nucleo	1	2000	2000
2	MQ-135	1	250	250
3	LM35	1	200	200
4	PHOTODETECTOR	1	450	450
5	PCB BOARD	1	120	120
TOTAL AMOUNT:				3020

CHAPTER 4

RESULT ANALYSIS

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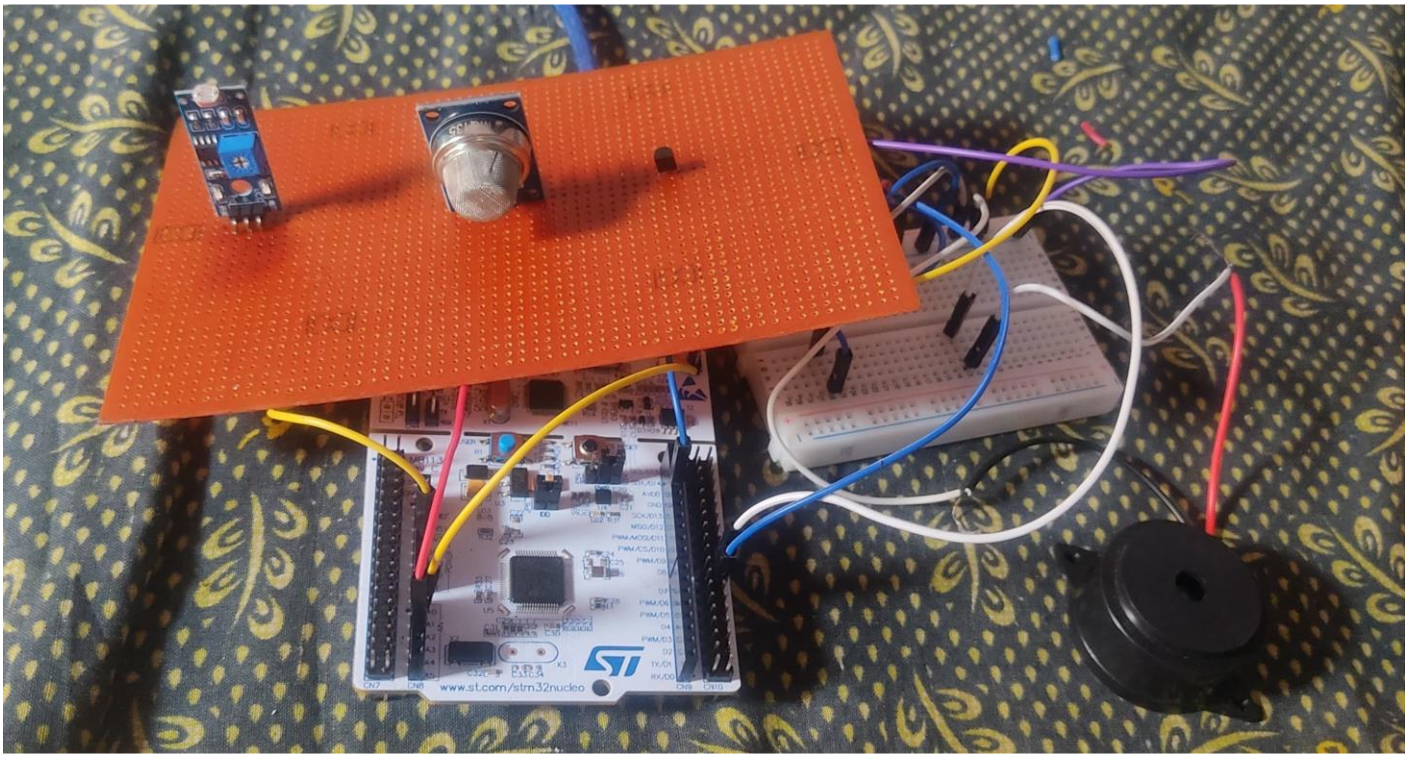

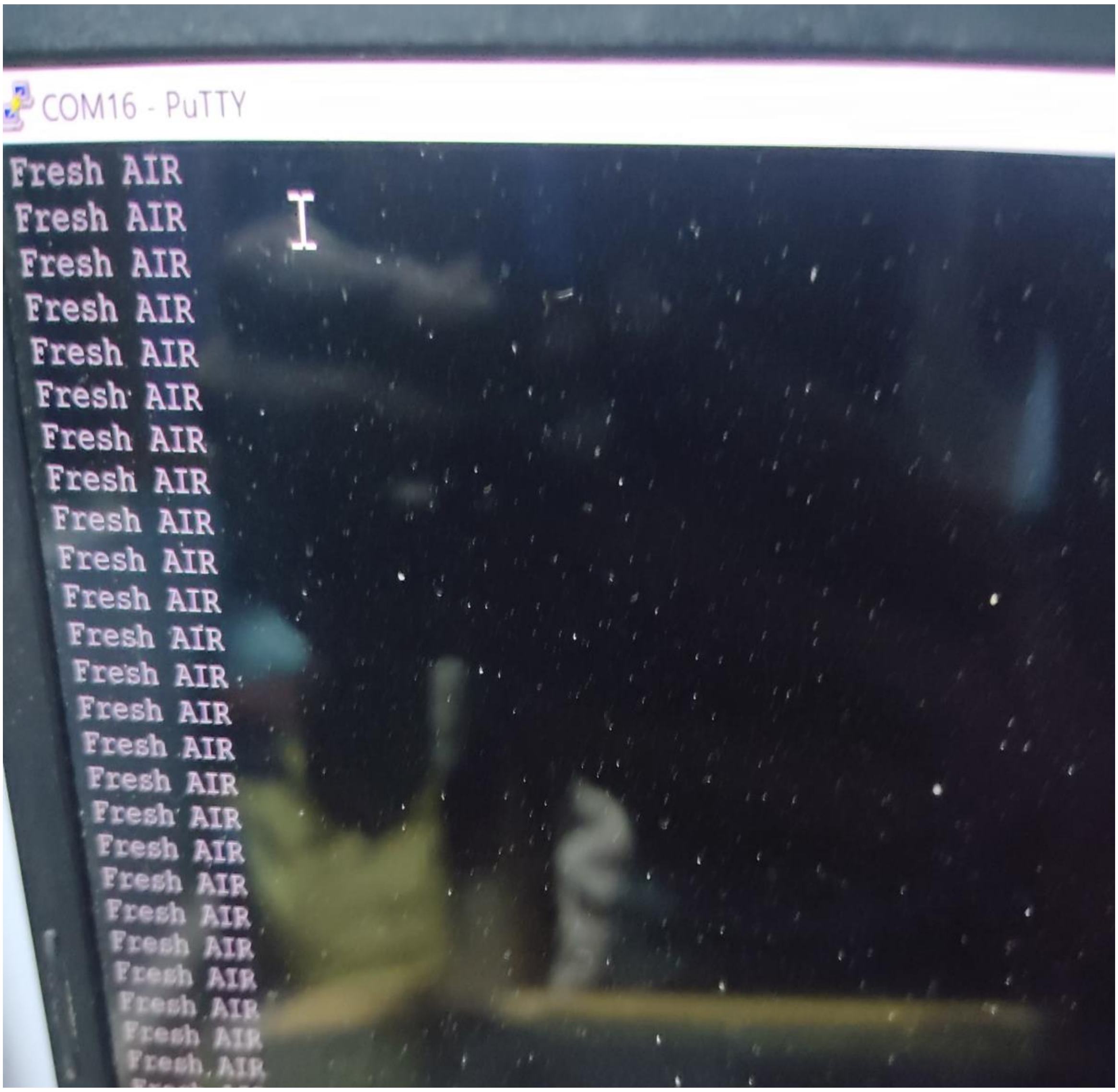
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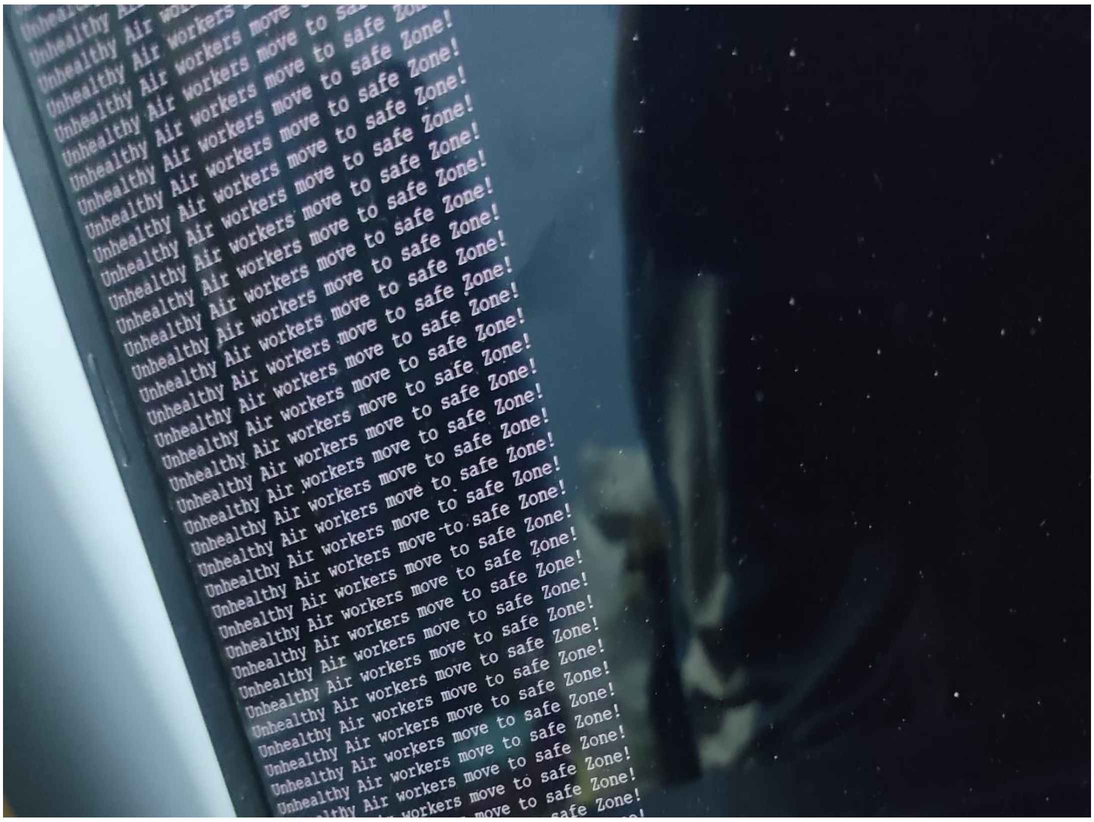
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CHAPTER 5

CONCLUSION

The air pollution monitoring system developed using the STM32F401RE Nucleo board provides a reliable and cost-effective solution for detecting harmful gases in the environment. By integrating the MQ135 sensor and displaying real-time data on an USART, the system effectively monitors key air quality parameters such as CO, CO_2, and NO_2. Visual and audible alerts from LEDs and buzzers help in immediate identification of unsafe pollution levels. This non-IoT implementation ensures local monitoring without reliance on internet connectivity, making it highly suitable for rural or offline areas. The project successfully demonstrates how embedded systems and sensor technology can work together to create practical tools for environmental monitoring. The system is easy to use, scalable, and provides a solid foundation for further development.

CHAPTER 6

FUTURE SCOPE

In the future, this project can be expanded by incorporating additional sensors such as PM2.5 and PM10 for more detailed air quality analysis. The system can be enhanced with data logging capabilities using SD cards to store pollution data over time for later review. For improved user interaction, a graphical display (like an OLED or TFT screen) could be integrated. The system could also include threshold calibration through a user interface to allow adjustable alert levels. While this version does not use IoT, future models may include optional wireless communication such as LoRa or GSM for remote monitoring in low-connectivity areas. Integration with solar power could also make it ideal for deployment in remote or outdoor environments, increasing its real-world applicability.

CHAPTER 7
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