SIDDAGANGA INSTITUTE OF TECHNOLOGY, TUMAKURU-572103

(An Autonomous Institute under Visvesvaraya Technological University, Belagavi)

Mini Project Report on

"Ambient Air Quality Monitoring With Purification By Solar Power"

submitted in partial fulfillment of the requirement for the completion of V semester of

BACHELOR OF ENGINEERING

in

ELECTRONICS & INSTRUEMENTATION ENGINEERING

Submitted by

Amrutha Sharma	(1SI23EI003)
Ankitha G	(1SI23EI004)
Hamsa M	(1SI23EI017)
Meher	(1SI24EI403)

under the guidance of

Mr. Ramesha K S

Assistant Professor

Department of E&IE

SIT, Tumakuru-03

DEPARTMENT OF ELECTRONICS & INSTRUMENTATION ENGINEERING

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DEPARTMENT OF ELECTRONICS & INSTRUMENTATION ENGINEERING

CERTIFICATE

Certified that the miniproject work entitled

"Ambient Air Quality Monitoring With Purification By Solar Power"

is a bonafide work carried out by

Amrutha Sharma V (1SI23EI003)

Ankitha G(1SI23EI004)

Hamsa M (1SI23EI017)

Meher (1SI24EI403)

In partial fulfillment for the completion of V Semester of Bachelor of Engineering in Electronics and Instrumentation Engineering from Siddaganga Institute of Technology, an autonomous institute under Visvesvaraya Technological University, Belagaviduring the academic year 2025–26. It is certified that all corrections and suggestions indicated for internal assessment have been incorporated in the report deposited in the department library. The project report has been approved as it satisfies the academic requirements in respect of project work prescribed for the Bachelor of Engineering degree.

Guide:	Head of the Department
Student Name:	Dept.of Electronics & Instrumentation
USN:	

External Viva Voice:

Names of the Examiners	**Signature with Date**
1.	
2.	

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Amrutha Sharma V	(1SI23EI003)
Ankitha G	(1SI23EI004)
Hamsa M	(1SI23EI017)
Meher	(1SI24EI403)

Abstract

In recent years, the quality of air in both indoor and outdoor environments has drastically deteriorated due to increased pollution, industrial emissions, and urbanization. Exposure to particulate matter such as dust, smoke, and microbes can lead to severe health problems including respiratory diseases and allergies. To mitigate these issues, our project aims to design and develop a smart air purification system using a HEPA filter integrated with sensor-based monitoring and control.

The proposed system utilizes a High-Efficiency Particulate Air (HEPA) filter, capable of trapping up to 99.97 of airborne particles larger than 0.3 microns. A sensor module is used to detect air quality parameters such as dust concentration or gas levels, which are then processed by a microcontroller like Arduino or ESP8266. Depending on the readings, the system automatically adjusts the blower fan speed to maintain optimal air quality inside the enclosure or room.

The implementation focuses on achieving high purification efficiency, low power consumption, and cost-effectiveness. The system design includes a block diagram, circuit connections, and real-time monitoring to validate the performance of the filtration process. The results show that the HEPA filter combined with a controlled airflow mechanism significantly improves air purity levels within a short duration.

This project can be effectively deployed in homes, laboratories, hospitals, and industrial areas where clean air is essential. Furthermore, the design can be enhanced with IoT-based monitoring, mobile app integration, or automatic filter status detection future developments. Thus, this project demonstrates a practical, affordable, and reliable approach to maintaining healthy air standards using advanced filtration and embedded control technology.

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Chapter 1

Introduction

Air pollution has become one of the most critical environmental challenges of the modern world due to rapid urbanization, industrial expansion, and increased vehicular emissions. Pollutants such as carbon monoxide (CO), nitrogen oxides, ammonia, volatile organic compounds (VOCs), and particulate matter significantly degrade the quality of ambient air and pose severe health risks, including respiratory illness, allergies, and cardiovascular problems. Conventional air quality monitoring stations are expensive, stationary, and require a continuous electrical supply, while most purification systems consume high power and are not suitable for outdoor or portable applications. These limitations highlight the need for a sustainable, low-cost, and energy-efficient solution that can both monitor and purify polluted air in real time.

To address this, the project "Ambient Air Quality Monitoring With Purification by Solar Power" integrates renewable energy, sensor technology, and advanced filtration into a single autonomous system. The system uses solar energy as a clean and continuous power source, enabling operation even in remote or off-grid environments. Air quality is monitored using sensors such as MQ135 and PM sensors, which detect harmful gases and particulate matter. Based on the pollution levels, a HEPA filter and DC fan are automatically activated to purify the surrounding air. The system also incorporates microcontroller-based control (ESP8266), enabling real-time data processing, display, and optional IoT-based monitoring.

By combining air quality sensing, filtration, and solar-powered operation, the proposed system offers an environmentally friendly and self-sustaining solution to improve air quality. It is suitable for homes, laboratories, classrooms, outdoor shelters, and industrial areas. This project demonstrates how renewable energy and embedded technology can be integrated to create a smart, efficient, and cost-effective air purification system that contributes to a healthier and cleaner environment.

1.1 Motivation

Rapid industrialization, urban growth, and increased vehicle emissions have led to rising air pollution levels in both cities and rural areas. Traditional air monitoring systems require constant power, high maintenance, and are limited in coverage, while air purifiers consume significant electricity. To address these limitations, this project develops a solar-powered air quality monitoring and purification system that operates independently of the power grid.

The proposed system uses an MQ135 air quality sensor to detect harmful gases such as CO_2 and NH_3, while a HEPA filter cleans the air by removing dust, smoke, and fine solid particles. A DC fan works together with the filtration system to purify the ambient air. The entire system is powered by a solar panel connected to a charge controller and a rechargeable battery, ensuring continuous operation even in the absence of sunlight.

This project aims to create a self-sustaining, eco-friendly, and low-cost solution that promotes clean air and renewable energy utilization. By integrating air quality monitoring, filtration, and solar power, the system contributes to green technology and supports the global mission to achieve a sustainable and pollution-free environment.

1.2 Organisation of the Report

The report is divided into six chapters, which are organized as follows:

Chapter 1: presents an introduction to existing air quality monitoring and purification systems, along with the identification of research gaps that motivate the proposed solar-powered system.

Chapter 2: presents a detailed survey of existing air quality monitoring and purification systems and discusses the research gaps addressed by the proposed solution.

Chapter 3: discusses the system architecture, including the overall block diagram and the methodology adopted for air quality detection and purification.

Chapter 4:describes the hardware components used in the system, such as the MQ135 gas sensor, NodeMCU, HEPA filter, DC fan, solar panel, charge controller, and rechargeable battery.

Chapter 5:explains the working process of the system, testing procedures, experimental results, and performance evaluation under different air quality conditions.

Chapter 6: provides the conclusion of the project, summarizing the successful implementation and outcomes of the system. It highlights the effectiveness of the proposed solution in reducing air pollution and conserving energy and concludes with the references used during the development of the work.

Chapter 2

Literature Survey

2.1 Literature Survey

Muhvu, Kabwe et.al (2025) [1] presented the design and implementation of a compact solar-powered air quality monitoring kit intended for low-power autonomous operation. The system utilizes a SEN55 sensor node along with maximum power point tracking (MPPT), voltage regulation circuitry, and duty-cycling techniques to optimize energy usage. This work serves as a useful reference for photovoltaic panel sizing and battery selection in solar-powered air quality sensing applications. However, the system is limited to monitoring functions only and does not incorporate any air filtration or purification mechanisms.

Garcia, Fernandez et.al (2025) [2] conducted a systematic review of IoT-based air quality monitoring systems integrated with artificial intelligence techniques. The review analyzed over 220 studies, covering sensor technologies, machine learning-based calibration, sensor drift compensation, and edge analytics. The study emphasizes the importance of standardized calibration datasets for reliable air quality assessment. Despite its comprehensive scope, the review highlights the scarcity of long-term deployed solar-powered air purification systems.

Anjan, Pawan et.al (2024) [3] developed a solar-powered weather and air quality monitoring system using an IoT-based multi-sensor architecture. The system integrates environmental sensors with solar panels, telemetry modules, and enclosure designs suitable for outdoor deployment. Energy budgeting considerations were also addressed to ensure continuous operation. However, the system focuses exclusively on sensing and does not include any active air filtration or purification components.

Gololo, Nkosi et.al (2024) [4] presented a detailed review of IoT systems for air quality measurements using LTE/4G and LoRa communication technologies. The study reviewed system architectures, communication protocols, sensor modules, and large-scale deployment strategies. This work is valuable for designing robust telemetry and data communication frameworks. Nevertheless, it does not address photovoltaic and battery integration.

Jose, Thomas et.al (2024) [5] proposed a solar-powered outdoor air purification system incorporating photovoltaic panels, battery storage, DC fans, and multi-stage filtration consisting of pre-filters, HEPA filters, and activated carbon filters. The system was integrated with air quality sensors and IoT-based data transmission and demonstrated particulate matter reduction in semi-enclosed environments such as bus shelters. However, the experimental evaluation was conducted over a short duration, limiting its applicability to confined or semi-open spaces.

Shang and Zhao (2023) [6] investigated intelligent air purifier control strategies to achieve improved trade-offs between energy consumption and indoor air quality. The authors employed deep reinforcement learning techniques to dynamically optimize purifier fan speed and operating schedules. The results showed significant energy savings while maintaining stable air quality levels. This approach is particularly relevant for solar-powered air purifiers, where adaptive control can be synchronized with photovoltaic power availability and battery charge levels.

Pei, Liu et.al(2023) [7] designed a smart filter performance monitoring system aimed at low-cost implementation. The system measures filtration efficiency, differential pressure across the filter, temperature, and humidity to assess filter health and operational status. Although the system provides valuable insights into filter condition monitoring, it was primarily tested in controlled indoor environments and does not consider solar power integration or outdoor applications.

Malleswari, Prasad et.al (2022) [8] reviewed various IoT-based air pollution monitoring systems with an emphasis on Arduino and ESP-based platforms. The study discussed sensor selection, calibration challenges, and communication techniques for data transmission. This review is useful for understanding low-cost air quality monitoring hardware design. However, it does not include recent advancements in solar-powered autonomous systems or machine learning-based calibration methods.

Amitha, Menon et.al (2021) [9] demonstrated the implementation of solar-powered air purifiers integrated with air quality monitoring units. These projects commonly employed HEPA filters, activated carbon filters, DC fans, and microcontroller-based control systems. They provide practical insights into photovoltaic sizing and bill of materials preparation.

However, these works are not peer-reviewed and are limited by short-term testing and insufficient sensor calibration.

Wei and Chen (2019) [10] developed a solar-powered air quality monitoring system intended for long-term operation under subtropical climatic conditions. The system demonstrated autonomous functionality through optimized solar-battery management and calibrated gas sensors. While the study successfully addresses sustainable air quality monitoring, it does not include any air filtration or purification components and is geographically limited to subtropical regions.

2.2 Summary of Literature Survey

The literature survey reveals substantial progress in the development of solar-powered air quality monitoring systems, particularly those integrating Internet of Things (IoT) platforms, low-power sensor nodes, and efficient energy management techniques. Several studies focus on photovoltaic panel sizing, battery selection, maximum power point tracking (MPPT), and duty-cycling strategies to enable long-term autonomous operation in outdoor environments. Additionally, various review papers emphasize sensor calibration, data reliability, and robust communication technologies such as LTE, 4G, and LoRa for large-scale air quality monitoring deployments.

Despite these advancements, most existing systems are limited to air quality sensing and monitoring and do not incorporate active air filtration or purification mechanisms. A few recent works have proposed solar-powered air purification systems using multi-stage filtration techniques, including HEPA and activated carbon filters. However, these systems are often evaluated over short durations, confined to semi-enclosed environments, or lack comprehensive long-term performance analysis.

2.3 Objective of the Project

The main objective of this project is to design and develop a solar-powered ambient air quality monitoring and purification system capable of operating autonomously in outdoor environments.

2.4 Scope of the Project

- Design and implementation of a solar-powered ambient air quality monitoring and purification system for autonomous outdoor operation.
- Integration of air quality sensing, air purification, and renewable energy harvesting into a single functional unit.
- Monitoring of ambient air quality parameters such as particulate matter, temperature, and humidity using low-power sensors.
- Implementation of a basic air purification mechanism using multi-stage filtration to reduce airborne pollutants.
- Utilization of photovoltaic panels, battery storage, and power regulation circuits to ensure continuous system operation.
- Development of an IoT-based data communication framework for real-time monitoring and data logging.
- Limitation of the system to small-scale applications and prototype-level deployment.
- Exclusion of advanced artificial intelligence-based control, large-scale deployment, and long-term field validation from the present work.

Chapter 3

System Block Diagram and Methodology

This chapter presents the overall architecture and working principle of the Ambient Air Quality Monitoring System using Solar and Filtering. The system is designed to monitor air pollutants, filter impure air, and operate entirely on solar energy for sustainable and continuous operation.

3.1 System Block Diagram

The complete block diagram of the system is shown in Figure 3.1

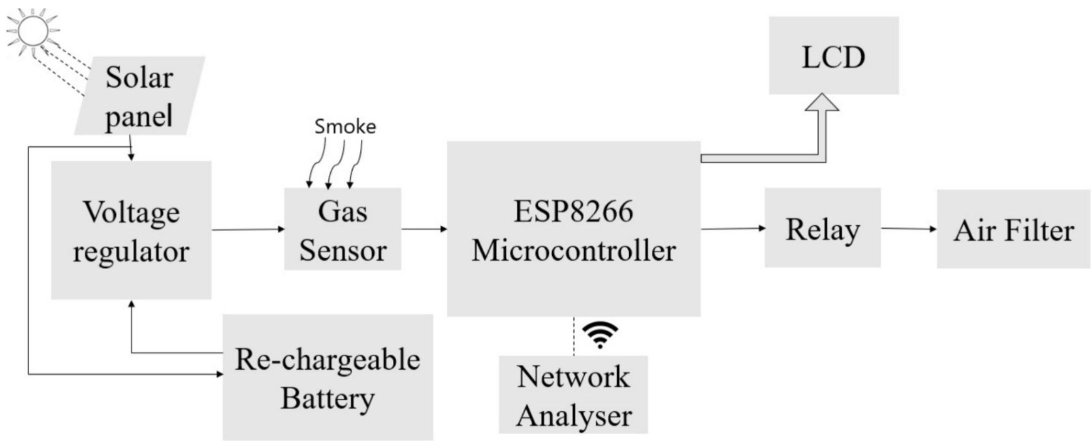

Figure 3.1: Block Diagram

3.2 System Components

The proposed system consists of the following major components:

- **Solar Power Supply Unit:** Converts solar energy into electrical power to operate the sensors, microcontroller, and fan-filter units. A rechargeable battery stores energy to ensure continuous operation during night-time or low sunlight conditions.

- **Air Quality Sensing Unit:** Comprises sensors such as the MQ135 sensor for detecting CO_2, NH_3, and volatile organic compounds (VOCs), an MQ7 sensor for carbon monoxide (CO) detection, a PMS5003 sensor for PM2.5 and PM10 particulate matter measurement. These sensors continuously monitor environmental parameters and transmit the collected data to the controller.

- **Microcontroller Unit (ESP8266):** Processes the sensor data, controls the operation of the purification fan, and transmits real-time air quality data to an IoT dashboard or mobile application via wireless communication.

- **Filtering Unit:** Consists of a HEPA filter and an activated carbon filter mounted within an air chamber. A 12 V DC fan draws polluted air through the filters to remove particulate matter and gaseous pollutants. The fan speed and filtration process can be controlled based on the measured pollutant levels.

- **IoT / Display Unit:** Displays air quality index (AQI) values and sensor readings on an LCD screen or a web-based dashboard for user monitoring and analysis.

3.3 Methodology

The methodology adopted for the proposed system is summarized as follows:

- **Solar Energy Harvesting and Storage:** The solar panel captures sunlight and converts it into electrical energy. A solar charge controller regulates the charging of the rechargeable battery and provides a stable 5 V / 12 V DC supply to the entire system.

- **Air Quality Monitoring:** Air quality sensors such as the MQ135 detect harmful gases and pollutants present in the ambient air. The sensor outputs are interfaced with the ESP8266 microcontroller through its analog-to-digital conversion capability.

- **Data Processing and AQI Calculation:** The ESP8266 processes the sensor readings and converts them into concentration values expressed in parts per million (ppm) or micrograms per cubic meter (μg/m^3). Based on standard environmental guidelines, the Air Quality Index (AQI) is calculated.

- **Decision and Control Action:** When the measured pollutant concentration exceeds a predefined threshold, the microcontroller initiates appropriate control actions such as activating the filtration unit fan, adjusting the fan speed proportionally to pollutant levels, and storing or transmitting data wirelessly using Wi-Fi.

filtration system consisting of:

- HEPA filter to remove particulate matter such as PM2.5, PM10, dust, and pollen.
- Activated carbon filter to reduce odors and harmful gaseous pollutants.

Chapter 4

System Hardware

This chapter presents the detailed description of all the hardware components used in the implementation of the Ambient Air Quality Monitoring System using Solar and Filtering. The system consists of three major sections — Power Supply Unit, Monitoring Unit, and Filtration Unit. Each hardware component plays a specific role in ensuring the system functions reliably and efficiently under solar power.

4.1 Solar Power Supply Unit

The solar power unit forms the backbone of the entire system by providing continuous, renewable energy for all electronic components.

A Fig 4.1 shows the photograph of solar panel is a 12V, 10W polycrystalline solar panel is used to convert solar energy into electrical energy. It generates direct current (DC) power sufficient to charge the battery and operate the sensors and microcontroller during daylight hours. The output voltage typically ranges from 12V–18V depending on sunlight intensity.

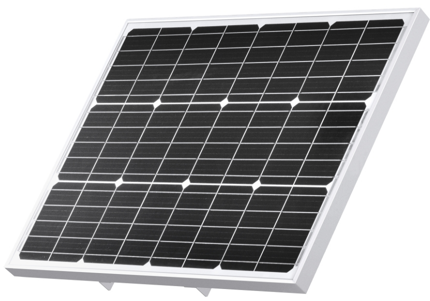

Figure 4.1: Photograph of Solar Panel

Fig 4.2 shows the Photograph of MQ-135 Gas Sensor is a widely used air-quality sensor designed for detecting a variety of harmful gases present in the environment. It is especially suitable for measuring general indoor and outdoor air pollution

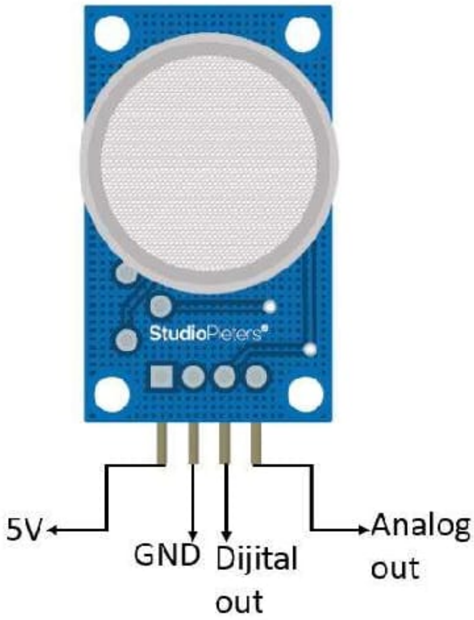

Figure 4.2: Photograph of Gas sensor

Fig 4.3 shows the Photograph of Relay module acts as a switch that allows the micro-controller (ESP8266) to control high-power devices like the DC fan. Since the ESP8266 cannot directly power the fan, the relay safely turns the fan ON or OFF based on the air-quality readings. When pollution is high, the relay activates the fan for purification; when air quality improves, it turns the fan off.

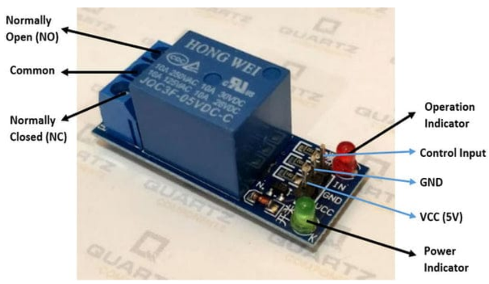

Figure 4.3: Photograph of Relay Module

Fig 4.4 shows the Photograph ofBuck Converter reduces the 12V output from the solar panel or battery to a stable 5V supply required for powering the ESP8266 microcontroller and sensors. Since the ESP8266 and gas sensors cannot operate on 12V, the buck converter ensures safe, regulated, and efficient voltage conversion, allowing all electronic components to run reliably without damage.

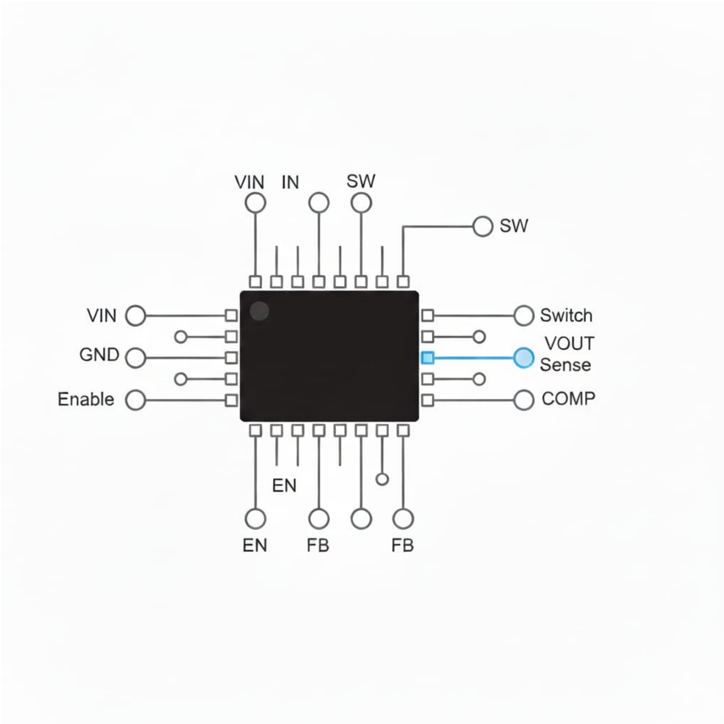

Figure 4.4: Photograph of Buck Converter

Fig 4.5 shows the Photograph of LCD displays real-time air quality readings and system status.It shows the values detected by the sensors such as gas levels (from MQ135), temperature,humidity, and the Air Quality Index (AQI). It also indicates whether the purification system is ON or OFF, helping users know when pollution is high. Overall, the LCD provides immediate visual feedback about the current air quality and the working state of the purifier.

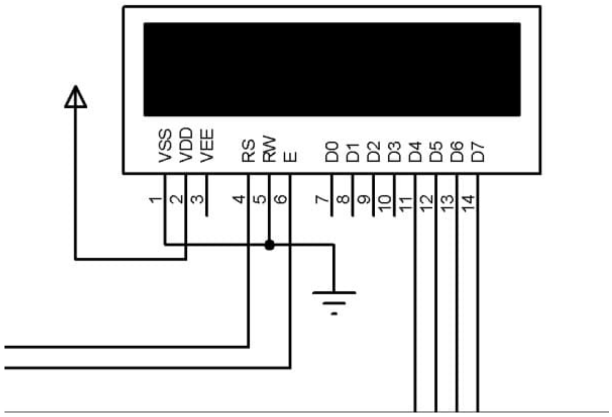

Figure 4.5: Photograph of LCD

4.2 Monitoring Unit

This unit includes all sensing and control components that detect and analyze air quality in real time.

- **ESP8266 Microcontroller:** The ESP8266 microcontroller serves as the brain of the system. It processes sensor signals, computes air quality indices, controls the filtration fan, and transmits data wirelessly to an IoT dashboard. Its built-in Wi-Fi module enables remote monitoring and cloud data storage. Alternatively, an Arduino UNO can be used in basic configurations without Wi-Fi capability. Key features of the ESP8266 include a dual-core 32-bit processor, ADC (Analog-to-Digital Converter) channels, PWM outputs for fan control, and integrated Wi-Fi and Bluetooth.

- **Air Quality Sensors:** The following sensors are integrated to monitor various environmental parameters. MQ135 is used to detect gases such as CO, NH_3, benzene, and VOCs in the range of 10–1000 ppm. MQ7 is used for Carbon Monoxide (CO) detection in the range of 10–2000 ppm. PMS5003 or SDS011 sensors are used to detect particulate matter PM2.5 and PM10 in the range of 0–1000 $\mu g/m^3$. The DHT11 sensor measures temperature and humidity in the range of 0–50°C and 20–90% respectively. These sensors generate analog or digital signals proportional to pollutant concentration, which are read by the ESP8266, converted into meaningful AQI values, and displayed or transmitted.

- **LCD Module:** A 16×2 LCD or OLED display is used to show real-time values of temperature, humidity, gas levels, and the Air Quality Index (AQI). It provides local feedback to users without requiring an internet connection.

- **IoT Dashboard:** Using the ESP8266's Wi-Fi feature, data is transmitted to cloud platforms such as ThingSpeak, Blynk, or Adafruit IO. This enables remote access to air quality information through a smartphone or computer.

4.3 Filtration Unit

This section purifies the ambient air when the system detects high pollutant levels.

- **DC Fan:** A 12V DC fan draws polluted air through the filters. Fan speed is automatically controlled by the ESP8266 based on measured AQI values. When air quality is poor, fan speed increases for effective purification. The fan is powered directly from the solar-battery circuit through a transistor driver stage.

- **HEPA Filter:** The High-Efficiency Particulate Air (HEPA) filter removes dust, smoke, pollen, and fine particulate matter (PM2.5 and PM10). It captures 99.97% of particles larger than 0.3 microns, ensuring significant reduction in suspended pollutants.

4.4 Signal Conditioning and Driver Circuit

To ensure proper interfacing and performance: Voltage Regulators : Provide stable 5V for sensors and ESP8266. Transistor Driver Circuit: Used to switch the fan based on control signals from the ESP8266. Relay Module : For controlling high-current devices such as fans or pumps.

4.5 Working Principle

- The solar panel charges the rechargeable battery through a charge controller, ensuring regulated and safe power supply.
- The ESP8266 microcontroller continuously reads air quality data from the connected gas and particulate sensors.
- When the detected pollutant levels are within safe limits, the system operates in monitoring mode without activating the purifier.
- If pollution levels exceed the predefined threshold values (e.g., CO above 200 ppm or PM2.5 above 100 $\mu g/m^3$), the ESP8266 activates the fan motor.
- Polluted air is drawn into the purifier and passed through the HEPA filter and activated carbon filter for effective purification.
- The filtered air is released back into the environment, while real-time AQI values are displayed on the LCD and uploaded to the IoT cloud platform.

4.6 Summary

The hardware architecture demonstrates the integration of renewable energy, sensor technology, and filtration mechanisms into a single system. The combination of solar panels, ESP8266 controller, air sensors, and dual-stage filters ensures both real-time air quality monitoring and active air purification. This design achieves energy-efficient, low-cost, and sustainable air quality management suitable for smart city and environmental applications.

Chapter 5

System Software

The software requirements for the Solar-Powered Air Purification System include all the programs and tools necessary for monitoring, control, and data analysis of the system. The system uses microcontroller-based automation, where sensors measure air quality parameters such as dust concentration, carbon dioxide , and temperature. The software ensures that data from these sensors are processed efficiently to control fans, filters, and solar power utilization.

5.1 About Software Requirements

The software requirements for the implementation are as follows:

Microcontroller Programming Environment: (e.g. ESP8266 platform) for
developing the control logic.

Data Monitoring Interface: Software or cloud platform to display real-time data such as air quality index (AQI), solar panel voltage, and battery charge status.

Data Logging Software:To record and analyze sensor data over time for performance evaluation.

Communication Protocols: If IoT integration is used, Wi-Fi modules require firmware and networking software.

Power Management Algorithms:Implemented in software to switch between solar and stored energy based on real-time power availability.

About Software design overview

5.2 Monitoring Mode

In this mode, the microcontroller (ESP8266) continuously reads data from various environmental sensors such as the MQ-135 air quality sensor and voltage sensors for solar panel and battery levels. The acquired analog data is converted into digital values using the built-in ADC of the microcontroller. These readings are processed and displayed on an LCD screen, showing the Air Quality Index (AQI), temperature, humidity, and power source status (solar or battery).

If IoT integration is enabled, the same data is transmitted wirelessly to a cloud dashboard or mobile app for remote monitoring.

5.3 Purification Control Mode:

In this mode, the software automatically controls the air purification unit based on real-time air quality readings. When the AQI exceeds a pre-defined pollution threshold, the program triggers the relay or motor driver circuit to activate the fan and air filter. The system remains active until the air quality returns to a safe level, at which point the software turns the purifier OFF or switches it to low-power standby mode. This logic ensures that the system maintains optimal air quality while conserving electrical energy. LED indicators or display messages inform the user about the purifier's operational state.

5.4 Power Management Mode:

The power management logic ensures efficient utilization of solar energy and battery backup. The software constantly monitors the voltage levels of the solar panel and battery. If sufficient sunlight is available, the system runs directly on solar power while simultaneously charging the battery through a charge controller. When solar power drops below a set voltage threshold (e.g., during night-time or cloudy weather), the software automatically switches to battery mode to maintain continuous operation. This seamless transition between power sources is handled by the software-controlled relay logic, ensuring reliability without manual intervention.

Additional Functionalities:

Data Logging: Sensor data such as AQI, temperature, and voltage readings can be logged in ESP8266 or sent to an SD card for long-term analysis.

System Alerts: The program can generate alerts LED indicators in cases of poor air quality, low battery, or sensor failure.

5.5 About Algorithm

The algorithm defines the logical steps that the system follows to purify air using solar power efficiently. It controls how the system responds to varying air quality and power conditions.

General Algorithm for the System:

Start the system when power is available (solar or battery).

Initialize all sensors (air quality, voltage sensors).

Read real-time sensor values at regular intervals.

Analyze air quality:

If air quality is below the safe threshold (poor AQI), activate the purification system fan and filter.

If air quality is good, keep the system in standby or low-power mode.

Monitor solar input:

If solar power is sufficient, run the system directly on solar energy.

If not, switch to battery backup automatically.

Display sensor data on an LCD screen or IoT dashboard.

Repeat the process continuously while the system is active.

This algorithm ensures optimal air purification while minimizing power consumption by prioritizing solar energy usage.

5.6 About Flowchart

Figure 5.1 shows the flowchart of the System also highlights the initialization phase of the system, where the microcontroller configures the sensors, communication modules, and power management units before entering normal operation. This ensures that all system components are properly synchronized and ready for data acquisition.

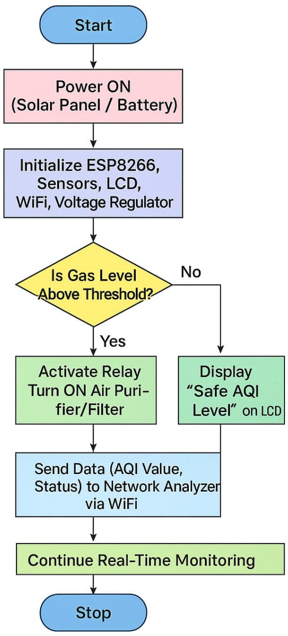

Figure 5.1: Flow Chart of the System

5.7 Summary

The Figure 5.1: Flow Chart of the system provides a visual representation of the algorithm, showing the logical sequence of operations in the system. It helps in understanding how the control flow proceeds from one stage to another.

The software developed for the Solar-Powered Air Purification System efficiently integrates real-time sensing, decision-making, and energy management. It utilizes the flexibility of the ESP8266 microcontroller to acquire sensor data, execute intelligent purification control, and optimize solar energy usage.

The implementation demonstrates that: Automated air purification can be achieved based on sensor feedback. Solar energy can reliably sustain continuous system operation. The software ensures minimal power consumption and efficient data processing. Overall, the designed software workflow validates the effectiveness of the system as a smart, sustainable, and autonomous air purification solution for eco-friendly environments. the flowchart demonstrates the interaction between sensing, control logic, and IoT communication, where processed data is transmitted to the cloud for logging and remote monitoring. This structured workflow ensures reliability, scalability, and ease of future upgrades.

Chapter 6

Test and Results

This chapter explains the testing procedure and results of the proposed Ambient Air Quality Monitoring with Purification by Solar Powersystem. Various test cases were conducted to verify sensor accuracy, AQI threshold detection, IoT communication, and automatic purification control.

6.1 Test Cases

Table 6.1: Test Cases for Air Quality Monitoring System

Test ID	Test Condition	Input AQI	Expected Output
TC1	Normal air condition	AQI < 200	Fan OFF, Data displayed on Blynk
TC2	Moderate pollution	AQI $= 100$–200	Fan ON, Alert displayed on Blynk
TC3	High pollution	AQI > 200	Fan ON, Continuous filtration
TC4	Wi-Fi connected	Sensor data	Data transmitted to Blynk app
TC5	Solar powered mode	Normal operation	System operates without interruption

6.2 Results

The proposed system continuously monitored ambient air quality and generated real-time AQI values. The AQI increased in the presence of smoke, dust, and harmful gases, confirming accurate pollution detection. When the AQI value exceeded the predefined threshold (AQI > 100), the system correctly identified polluted air conditions and automatically activated the DC fan through the relay module for air purification. The fan remained ON until the AQI returned to safe levels and then switched OFF automatically.

Sensor data and AQI values were successfully transmitted to the Blynk IoT platform using Wi-Fi, where real-time readings and fan status were displayed with minimal delay. The system operated efficiently using solar power with low energy consumption and achieved continuous, reliable performance without system failure, making it suitable for sustainable air quality monitoring applications.

6.3 Software Design Overview

The software is designed to handle four main functions:

- Initialization and Setup: Configures GPIO pins, initializes sensors and the LCD, and establishes a Wi-Fi connection.
- Data Acquisition: Continuously collects real-time data from the air quality sensor (MQ135).
- Data Processing and Decision Logic: Processes sensor readings, calculates the Air Quality Index (AQI), and determines whether pollution levels exceed predefined safe limits.
- Control and Display: Activates the fan and filtration system when poor air quality is detected. Displays real-time values on the LCD and uploads the same data to the IoT cloud dashboard.

6.4 Algorithm

The following algorithm summarizes the working procedure of the system:

- Start the program.
- Initialize all input/output pins, sensors, and LCD module.
- Connect the ESP8266 to the Wi-Fi network for cloud communication.
- Read analog values from gas sensors (MQ135) and digital values from ESP8266.
- Convert sensor readings into concentration levels (ppm).
- Compute the Air Quality Index (AQI) using the standard AQI conversion formula.
- Display the measured values and AQI on the LCD.
- Check if AQI $>$ threshold (e.g., AQI $>$ 200):
  - If true, activate DC fan for air filtration.

  - If false, keep fan off (monitoring mode only).

- Transmit the collected data to the IoT platform (Blynk).
- Repeat the entire process continuously.

6.5 Program Workflow Description

The ESP32 starts by initializing all sensors and the LCD . It establishes a Wi-Fi connection and authenticates with the selected IoT platform. Sensor values for CO_2, and CO are acquired at fixed time intervals (e.g., every 5 seconds). The microcontroller computes the AQI, updates the LCD and simultaneously uploads the readings to the cloud. When AQI exceeds the safe limit, a control signal is sent to activate the fan, drawing air through the HEPA and carbon filters. As the air quality improves, the system automatically turns the fan off to conserve power. The cycle repeats continuously for real-time monitoring and purification.

6.6 Summary

The software efficiently integrates data collection, analysis, filtration control, and cloud communication into a single embedded system. Using the ESP8266 microcontroller with Arduino IDE, it ensures low-power, real-time operation supported by solar energy. The logical structure allows automatic response to environmental changes, making the system a smart, adaptive, and sustainable air quality management solution.

The software efficiently integrates sensor data acquisition, real-time analysis, filtration control, and cloud communication into a single embedded framework. Gas concentration data collected from the MQ135 sensor is continuously processed by the ESP8266 microcontroller, where raw analog values are converted into meaningful pollutant concentration levels expressed in parts per million (ppm). Based on these values, the Air Quality Index (AQI) is calculated using standard AQI conversion formulas to provide a clear indication of air pollution levels.

Chapter 7

Conclusion and Future Scope

7.1 Conclusion

This project presents a solar-powered air quality monitoring and purification system that integrates sensing, embedded processing, intelligent control, and IoT-based cloud communication into a single platform. Using the ESP8266 microcontroller and MQ135 sensor, the system continuously monitors air quality, computes the Air Quality Index (AQI), and displays real-time values while transmitting data to the cloud. A threshold-based control logic automatically activates the air filtration unit when pollution levels exceed safe limits and deactivates it once conditions normalize, ensuring efficient energy usage. The use of solar energy enables sustainable and long-term autonomous operation. IoT integration through the Blynk platform allows remote monitoring and data visualization. Overall, the system provides a smart, low-power, adaptive, and environmentally sustainable air quality management solution.

7.2 Future Scope

The system can be enhanced by integrating additional sensors such as PM2.5, PM10, CO, NO_2, and SO_2 for comprehensive air quality monitoring. Machine learning techniques may be applied for pollution prediction and early warning generation. Communication technologies like GSM, LoRaWAN, or NB-IoT can be incorporated for large-scale deployment. Further improvements include advanced power management, higher-capacity solar modules, and multi-stage air filtration using HEPA and activated carbon filters. Deployment of multiple sensor nodes can enable distributed air quality monitoring for smart city and industrial applications.

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Course Outcomes

After successful completion of the mini project, graduates will be able to:

CO1: Identify a problem through literature survey and knowledge of contemporary engineering technology.

CO2: Consolidate the literature search to identify issues/gaps and formulate the engineering problem.

CO3: Prepare a project schedule for the identified design methodology, engage in budget analysis, and share responsibility among team members.

CO4: Provide sustainable engineering solutions considering health, safety, legal, cultural issues and demonstrate concern for the environment.

CO5: Identify and apply mathematical, scientific, engineering, and management concepts necessary to implement the identified engineering problem.

CO6: Select appropriate engineering tools and components required to implement the proposed solution.

CO7: Analyze, design, and implement an optimal design solution, interpret experimental results, and draw valid conclusions.

CO8: Demonstrate effective written communication through the project report, one-page poster presentation, project video, and preparation of a four-page IEEE/Springer format paper.

CO9: Engage in effective oral communication through PowerPoint presentation and project demonstration.

CO10: Demonstrate compliance with prescribed standards and safety norms and abide by professional ethical norms.

CO11: Perform effectively as a team member, contribute to team objectives, and mentor or lead the team when required.

Program Outcomes

PO1: Engineering Knowledge Apply knowledge of mathematics, natural science, computing, engineering fundamentals, and an engineering specialization to develop solutions for complex engineering problems.
PO2: Problem Analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions with consideration for sustainable development.
PO3: Design / Development of Solutions: Design creative solutions for complex engineering problems and develop systems, components, or processes to meet identified needs with consideration for public health and safety, whole-life cost, net zero carbon, culture, society, and environment.
PO4: Conduct Investigations of Complex Problems: Conduct investigations of complex engineering problems using research-based knowledge including design of experiments, modeling, analysis, and interpretation of data to provide valid conclusions.
PO5: Engineering Tool Usage: Create, select, and apply appropriate techniques, resources, and modern engineering IT tools, including prediction and modeling, recognizing their limitations to solve complex engineering problems.

PO6: The Engineer and the World: Analyze and evaluate societal and environmental aspects while solving complex engineering problems for their impact on sustainability with reference to economy, health, safety, legal framework, culture, and environment.

PO7: Ethics: Apply ethical principles and commit to professional ethics, human values, diversity and inclusion, and adhere to national and international laws.

PO8: Individual and Collaborative Team Work: Function effectively as an individual and as a member or leader in diverse and multi-disciplinary teams.

PO9: Communication: Communicate effectively and inclusively within the engineering community and society at large, such as being able to comprehend and write effective reports and design documentation, and make effective presentations considering cultural, language, and learning differences.

PO10: Project Management and Finance: Apply knowledge and understanding of engineering management principles and economic decision-making and apply these to one's own work, as a member and leader in a team, and to manage projects in multidisciplinary environments.

PO11: Life-Long Learning: Recognize the need for, and have the preparation and ability for independent and life-long learning, adaptability to new and emerging technologies, and critical thinking in the broadest context of technological change.

Program specific Outcomes

Student will be able to

PSO1: Apply the technical knowledge of measurement techniques, instrumentation, control, communications and the state- of- the art technologies in process, healthcare and related domains.

PSO2: Apply the knowledge of Signal Processing, Electronic Circuits and Programming Skills to design embedded systems for real time application

CO-PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2
CO-1											3		3
CO-2		3										3	
CO-3										3			3
CO-4						3						3	
CO-5	3	3										2	3
CO-6					3						3		3
CO-7			3	3								2	
CO-8										3		3	2
CO-9										3		3	
CO-10								3				2	3
CO-11									3			3	
Average	3	3	3	3	3	3	3	3	3	3	3	3	3

Attainment level: - 1: Slight (low) 2: Moderate (medium) 3: Substantial (high)

Appendices

Appendix A
Code Implementation

```
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
#define MQ135_PIN A0
#define RELAY_PIN D5
LiquidCrystal_I2C lcd(0x27, 16, 2);
int airValue = 0;
int threshold = 300;
void setup()
{
    pinMode(MQ135_PIN, INPUT);
    pinMode(RELAY_PIN, OUTPUT);
    digitalWrite(RELAY_PIN, LOW);
    lcd.init();
    lcd.backlight();
    lcd.setCursor(0,0);
    lcd.print("Air Quality");
    lcd.setCursor(0,1);
    lcd.print("Monitoring");
    delay(2000);
    lcd.clear();
}
void loop()
{
    airValue = analogRead(MQ135_PIN);

    lcd.setCursor(0,0);
    lcd.print("MQ135: ");
    lcd.print(airValue);
```

```
    if (airValue > threshold)
    {
        digitalWrite(RELAY_PIN, HIGH);   // Fan ON
        lcd.setCursor(0,1);
        lcd.print("Air: POOR ");
    }
    else
    {
        digitalWrite(RELAY_PIN, LOW);    // Fan OFF
        lcd.setCursor(0,1);
        lcd.print("Air: GOOD ");
    }

    delay(2000);
}
```

Microcontroller

```
#include <ESP8266WiFi.h> const char* ssid = "ROBOCAR";
const char* password = "12345678";
void setup()
{
WiFi.begin(ssid, password);
while (WiFi.status() != WL_CONNECTED)
{
delay(500);
}
}
```

Table 7.1: Table A: Plan of Action

Activity	Sept 2025	Oct 2025	Nov 2025	Dec 2025
Literature survey for problem identification	gray!30			
Defining objectives and system specification		gray!30		
Literature survey for methods to address the problem		gray!30		
Component Selection		gray!30		
System Design		gray!30		
Calibration of Loadcell			gray!30	
Hardware Implementation			gray!30	
Software Development and Integration			gray!30	
Testing and Interpretation of Results			gray!30	
Documentation and Report Preparation				gray!30

Budget Analysis

Table B: Cost of the Components

Components	**Quantity**	**Cost (in Rupees)**
Air Filter	1	972
DC Fan	1	105
Node MCU ESP8266	1	165
Solar Panel	1	588
Others	1	1170
Total Cost	–	**3000/-**

Self Assessment of Project

Table C: Self Assessment of Project

No.	PO / PSO	Contribution from the Project	Level
1	PO1 – Engineering Knowledge	Applied knowledge of mathematics, engineering fundamentals, electronics, and air filtration concepts to design and implement a solar-powered air purifier system.	2
2	PO2 – Problem Analysis	Identified and analyzed air pollution problems through literature review and evaluation of air quality parameters, and formulated a sustainable solar-based purification solution.	2
3	PO3 – Design / Development of Solutions	Designed and developed a low-cost solar-powered air purifier considering public health, safety, energy efficiency, and environmental sustainability.	3
4	PO4 – Conduct Investigations of Complex Problems	Conducted experiments and analyzed sensor data to evaluate air quality and assess the performance of the air purification system.	2
5	PO5 – Modern Tool Usage	Used modern engineering tools such as microcontrollers, sensors, programming platforms, and testing tools to develop and validate the system.	3

No.	PO / PSO	Contribution from the Project	Level
6	PO6 – The Engineer and the World	Analyzed societal and environmental impacts of air pollution and developed a sustainable solution that promotes clean air and renewable energy usage.	3
7	PO7 – Ethics	Followed professional and ethical practices by designing a safe, eco-friendly system that benefits society and minimizes environmental impact.	2
8	PO8 – Individual and Team Work	Worked effectively as an individual and as a team member by sharing responsibilities and collaborating to complete the project successfully.	3
9	PO9 – Communication	Communicated technical ideas, design methodology, and project results effectively through reports, presentations, and discussions.	3
10	PO10 – Project Management and Finance	Applied project management and financial planning principles by estimating costs, selecting economical components, and completing the project within budget.	2
11	PO11 – Life-long Learning	Demonstrated independent learning by exploring new concepts in air quality monitoring, solar energy, and sensor technologies beyond the curriculum.	3

No.	**PO / PSO**	**Contribution from the Project**	**Level**
12	PSO1 – Measurement, Instrumentation and Control Systems	Applied knowledge of measurement techniques and instrumentation to monitor air quality parameters and control the purification process.	3
13	PSO2 – Signal Processing, Electronics and Programming	Applied knowledge of electronics, signal processing, and programming to process sensor data and control system operation efficiently.	3

Level	Poor	Average	Good	Very Good	Excellent
Grade	1	2	3	4	5

Sustainable Development Goals

Table D: Sustainable Development Goals

SDG	**Level (1: Poor, 2: Good, 3: Excellent)**
No Poverty	–
Zero Hunger	–
Good Health and Well-being	–
Quality Education	–
Gender Equality	–
Clean Water and Sanitation	–
Affordable and Clean Energy	2
Decent Work and Economic Growth	2
Industry, Innovation, and Infrastructure	3
Reduced Inequalities	–
Sustainable Cities and Communities	–
Responsible Consumption and Production	–
Climate Action	–
Life Below Water	–