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IoT Based Outdoor Manhole Monitoring System

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Abstract

The *IoT-Based Outdoor Manhole Monitoring System* aims to enhance the safety and efficiency of municipal infrastructure maintenance through real-time monitoring. Traditional manual inspections are labour-intensive, time-consuming, and prone to errors, which can lead to accidents and costly repairs. This system integrates IoT technology, using sensors and a microcontroller to monitor key parameters such as gas concentration, water level, temperature, in areas like manholes, landfills, and farm ponds. Data is processed and transmitted via cloud platforms or mobile applications, enabling timely alerts and responses. By reducing the need for manual checks, the system minimizes risks to workers and the public. Its scalable design allows for easy integration with smart city systems, promoting environmental sustainability and public safety.

1. Introduction

Manholes serve as critical access points for underground utility maintenance in urban infrastructure, including water, telecommunications, electrical, and sewage systems. However, inadequate monitoring of these facilities poses significant safety risks, including flooding during heavy rainfall, hazardous gas accumulation, fire incidents, and accidents from damaged covers [1]. Traditional visual inspection methods are becoming increasingly impractical and unsafe as urban infrastructure expands and ages. [2]

This paper presents an IoT-based manhole detection and monitoring system that addresses these challenges through continuous automated surveillance [3]. The system employs an ESP32 microcontroller integrated with temperature, gas, and ultrasonic water level sensors to monitor environmental conditions in real-time. Data transmission occurs wirelessly to mobile applications and cloud-based platforms, enabling remote monitoring and immediate alert notifications to maintenance personnel and authorities [4].

The proposed solution offers several advantages: reduced operational costs, enhanced emergency response times, elimination of hazardous manual inspections, and improved public safety through accident prevention [5]. By implementing this cost-effective IoT approach, cities can advance toward smarter, more sustainable urban infrastructure management while maintaining critical utility system reliability[6].

1.0 Materials and Methods

1.1 Materials

The IoT-based Manhole Detection and Monitoring System was developed to track water level, gas concentration, temperature, and lid movement in real time. Sensors were connected to an ESP32 microcontroller, sending data to a cloud platform and smartphone app (e.g. Blynk) for 24/7 monitoring and alerts. A block diagram and flowchart were used to plan the system, and circuit simulation was done using Cirkit before testing on a breadboard. Sensors were calibrated for accuracy, and the system was programmed using Arduino IDE. This method ensured the system was reliable, energy-efficient, and scalable for improving urban safety and early hazard detection.

1.2 Project Block Diagram

The IoT-based Manhole Monitoring System is centered around the ESP32 microcontroller, which connects to key sensors including the DHT22 for temperature, HC-SR04 for water level detection, and MQ-2 for harmful gas detection. These components are arranged on a breadboard for easy setup and power distribution. Sensor data is collected by ESP32 and displayed on a 0.96-inch OLED screen, providing on-site real-time readings for maintenance workers. Using its built-in Wi-Fi, the ESP32 also sends data to the Blynk IoT platform via a mobile hotspot, enabling remote monitoring and instant alerts through smartphones or PCs. This setup allows early detection of hazardous conditions like gas leaks, flooding, or overheating, reducing the need for manual inspections and enhancing safety in urban environments.

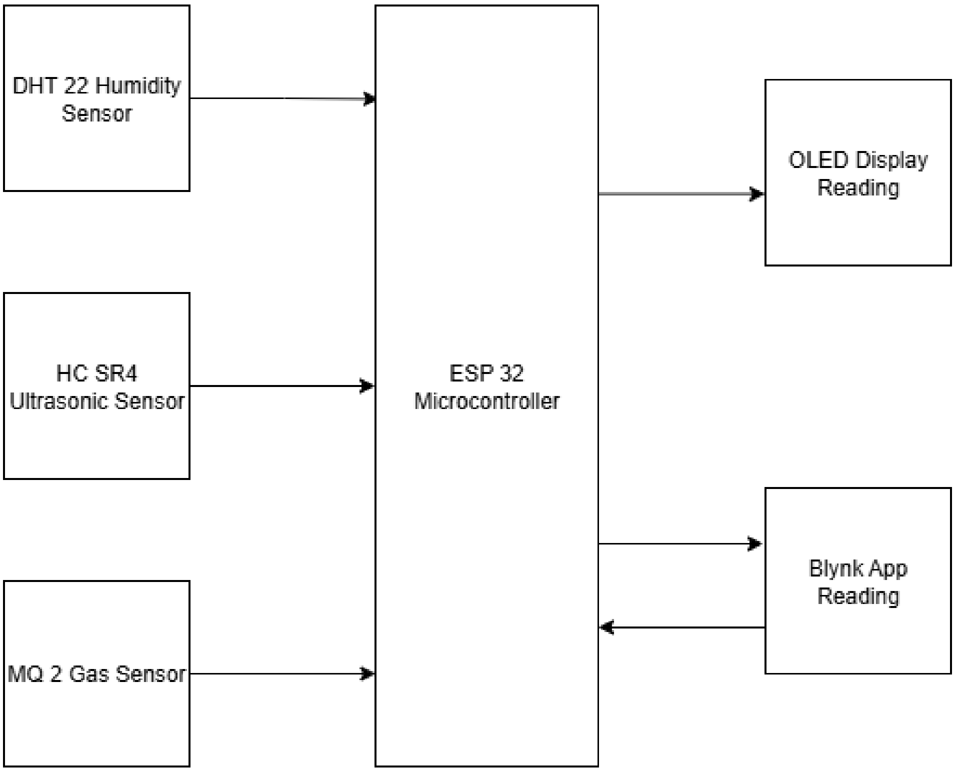

Fig. 1 *Project Block Diagram*

2.3 System Flowchart

The system flow of the IoT-based Manhole Detection and Monitoring System begins with the ESP32 microcontroller booting up and establishing a Wi-Fi connection. Once connected, the ESP32 initializes and collects data from three main sensors: DHT22 (temperature), HC-SR04 (water level), and MQ-2 (gas or smoke).

If no Wi-Fi is found, the system enters a retry loop until a stable connection is established. The sensor readings are compared against predefined thresholds to detect abnormal or hazardous conditions such as flooding or gas leaks. When such conditions are identified, alerts are triggered. Simultaneously, real-time data is displayed on a local OLED screen for field monitoring and sent to the Blynk mobile app for remote access. This process ensures continuous, accurate, and scalable monitoring of manhole conditions, enhancing safety and reducing reliance on manual inspection.

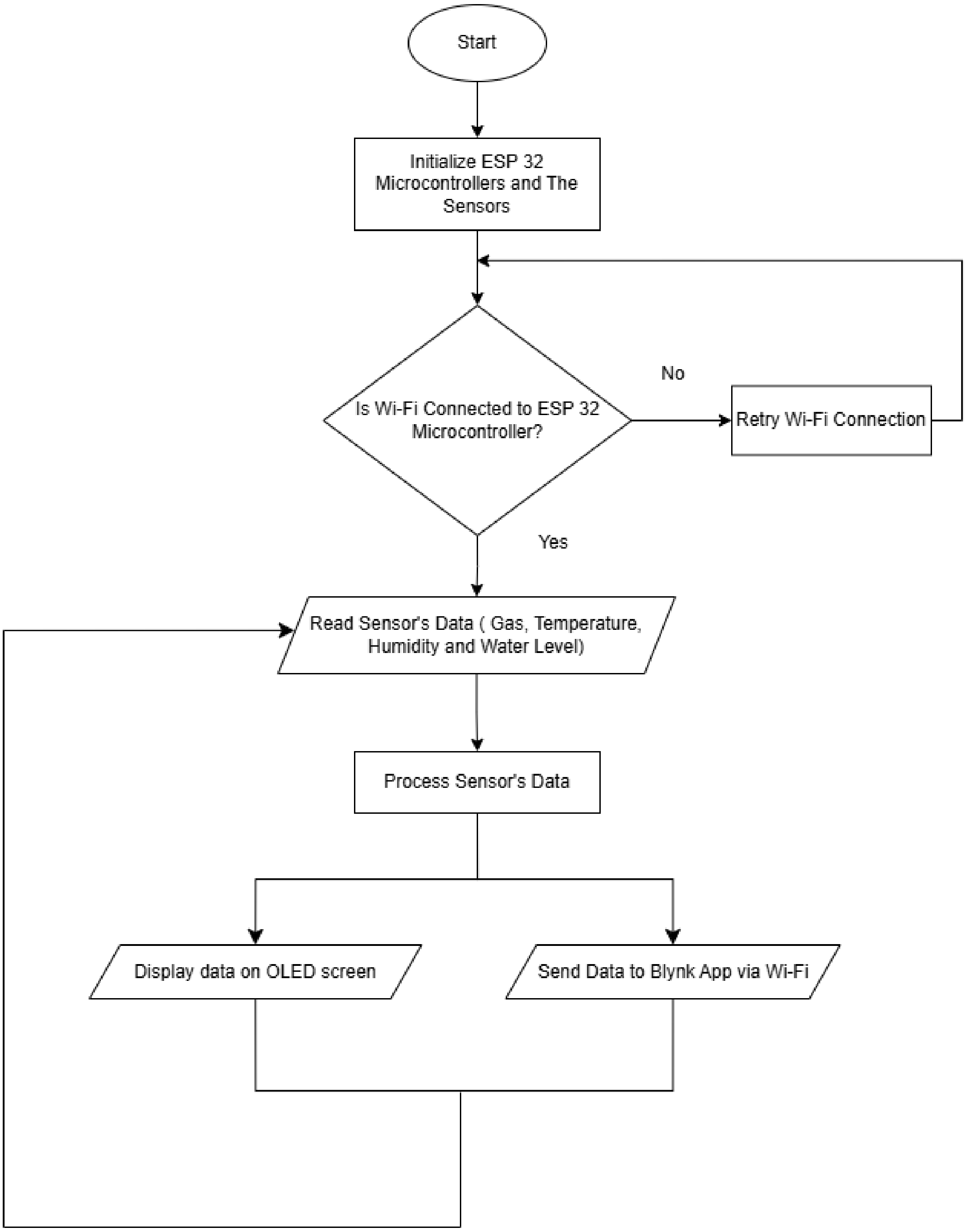

Fig. 2 *System Flowchart*

2.4 Project Schematic Diagram

The IoT-based manhole monitoring system was first designed and tested using the Cirkit Simulator, a web-based platform that allows circuit simulation and Arduino code testing without physical hardware. The main components included an ESP32 microcontroller, DHT22 sensor for temperature and MQ-2 gas sensor, HC-SR04 ultrasonic sensor for water level, and a 0.96" OLED display for real-time data output. Each component was connected to the ESP32 using appropriate protocols such as digital I/O and I2C. The simulator enabled testing of sensor input, data processing, and OLED output, including converting distance to water level percentage and filtering gas readings. Real-time simulation helped optimize code, verify functionality, and debug without hardware damage risk. This virtual prototyping approach saved time and cost while increasing confidence in the system's performance before physical implementation.

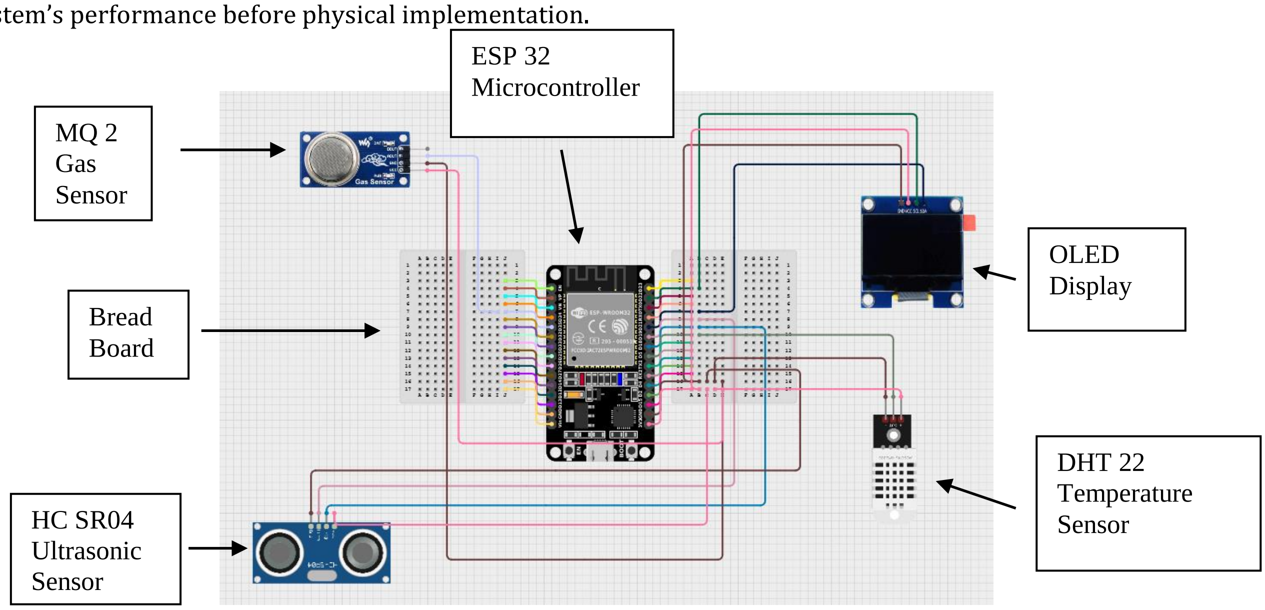

Fig. 3 *Schematic Diagram*

3.0 Result and Discussion

The IoT-based Manhole Detection and Monitoring System was tested using a prototype built with a cylindrical polystyrene enclosure to simulate real conditions. Sensors including the DHT11 for temperature, MQ-2 for gas detection, and HC-SR04 for water level were installed under the lid, connected to an ESP32 microcontroller on a breadboard. A 0.96" OLED display provided real-time readings, while data was also sent to the Blynk app via mobile hotspot for remote monitoring. The system was evaluated by simulating various conditions: paper smoke to test the gas sensor, gradual water addition for water level detection, and heat exposure for temperature response. The sensors performed accurately, with real-time data successfully displayed and transmitted, confirming the system's reliability for detecting hazardous manhole conditions and supporting safe, practical deployment.

3.1 Prototype Design

The project design of IOT devices-based manhole detection and monitoring system employs a cylindrical polystyrene case with removed cover. An OLED screen is set in the edge to be used to display real-time data and a breadboard with an ESP32 microcontroller, and associated electronics sits on the lid as seen in a top-down view. The front and side views show the system's overall alignment, the OLED display's location, and its compact cylindrical structure. Three holes are cut under the lid to securely attach the ultrasonic, gas, and DHT 22 sensors, which all point downward into the cylinder to sense the water level, gas concentration, and environmental conditions. Inside the cylinder, there is still a hollow space that looks like a manhole chamber where testing conditions like flame, gas, or water are injected. From the bottom view, the flat base of the cylinder is visible, ensuring that the device stays stable and upright while in operation.

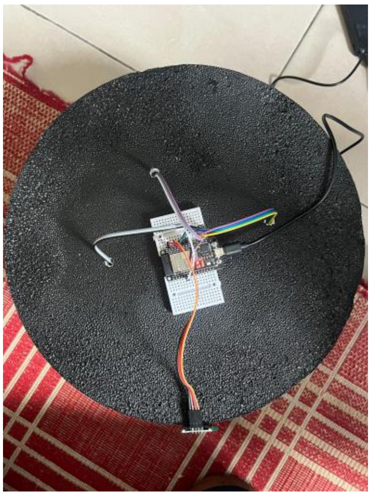

Fig. 4 *Top View of the Project*

Fig. 5 *Front View of the project*

Fig. 6 *Under the Lid of Project*

3.2 Sensor Data Readings and Analysis

During the testing phase, each sensor demonstrated reliable and accurate performance under simulated manhole conditions. The MQ-2 gas sensor detected smoke from burning paper and triggered alerts when gas levels exceeded safety thresholds, confirming its sensitivity to flammable gases like methane or LPG. The HC-SR04 ultrasonic sensor accurately measured water levels by detecting the decreasing distance between the sensor and rising water in a container, showing a consistent inverse relationship. The DHT22 sensor responded effectively to applied heat, indicating clear changes in both temperature levels. Real-time data from all sensors was displayed on an OLED screen and transmitted through Wi-Fi to the Blynk mobile app using the ESP32 microcontroller, ensuring seamless local and remote monitoring. These results confirm the system's reliability and practicality as a low-cost, real-time IoT solution for smart manhole detection and urban infrastructure safety. The sensors also showed fast response times, with readings updating within seconds of environmental changes, which is crucial for emergency alerts. The consistent communication between the hardware and mobile platform validated the stability of the Wi-Fi connection throughout testing. No sensor failures or data loss occurred during trials, proving the system's robustness.

3.2.1 OLED Display and Blynk App Interface

In this project, the Blynk mobile application plays a vital role in enabling real-time remote monitoring of environmental data collected by the sensors. The ESP32 microcontroller connects to the internet via a mobile hotspot and transmits sensor data—such as gas levels (from the MQ-2 sensor), water level (from the HC-SR04 sensor), and temperature (from the DHT22 sensor)—to the Blynk platform. Through the Blynk app, users can view updated readings on their smartphones and receive instant alerts if any parameter exceeds predefined safety thresholds. This ensures that maintenance teams or authorities can take timely action even when not physically present at the site.

Simultaneously, a 0.96-inch OLED display is mounted on the manhole prototype to provide on-site, real-time visual feedback. It continuously displays sensor values in a clear, readable format, allowing technicians or field personnel to observe changes instantly. The dual-display system—OLED for local monitoring and Blynk for remote access—enhances the reliability and usability of the system. This combination ensures continuous visibility and rapid response, making the solution practical and effective for urban infrastructure safety.

Fig. 7 *Blynk App Interface Reading*

Fig. 8 *OLED Display Reading*

Table 1: OLED display and Blynk app reading of HC SR4 Ultrasonic sensor

Height (cm)	OLED Display and Blynk App Interface Reading
0	0
1	7
2	20
3	34
4	40
5	47

Table 2: OLED display and Blynk app reading of DHT22 sensor

Time (s)	OLED Display and Blynk App Interface Reading
0	Temperature: 29
10	Temperature: 31
20	Temperature: 33
30	Temperature: 35
40	Temperature: 37
50	Temperature: 39

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Table 3: OLED display and Blynk app reading of MQ 2 gas sensor

Time (s)	OLED Display and Blynk App Interface Reading
0	2
20	3
40	4
60	5
80	6
100	7

3.3 Graphical Analysis of Sensor Readings

3.3.1 Water Level Detection Using HC-SR04 Sensor

The HC-SR04 ultrasonic sensor was thoroughly tested for its effectiveness in water level detection by positioning it above a half-filled plastic bottle and gradually increasing the water height from 1 cm to 10 cm, one step at a time. As the water level rose, the sensor recorded decreasing distances between its surface and the water, showing a reliable inverse relationship between water height and sensor readings—from 87 cm down to 7 cm. This confirmed the sensor's high precision and consistent accuracy in detecting minor water level variations. Such performance is crucial for IoT-based manhole monitoring, where early detection of rising water could indicate flooding or blockage. The sensor's measurements were displayed in real time on a 0.96-inch OLED screen and also transmitted to the Blynk mobile application via the ESP32 microcontroller. The consistency of values on both platforms verified the system's data integrity and seamless connectivity.

Moreover, the HC-SR04 responded with minimal latency, making it ideal for time-sensitive applications where rapid changes in conditions require immediate alerts. Its sensing range, from 2 cm to 400 cm, allows for both shallow and deep manhole installations, ensuring flexibility across various urban drainage setups. This wide detection capability ensures that even slight water level changes are recognized early, giving authorities enough time to take preventive or corrective action. The sensor's low cost, low power consumption, and ease of integration into microcontroller systems further support its suitability for scalable and sustainable smart city infrastructure.

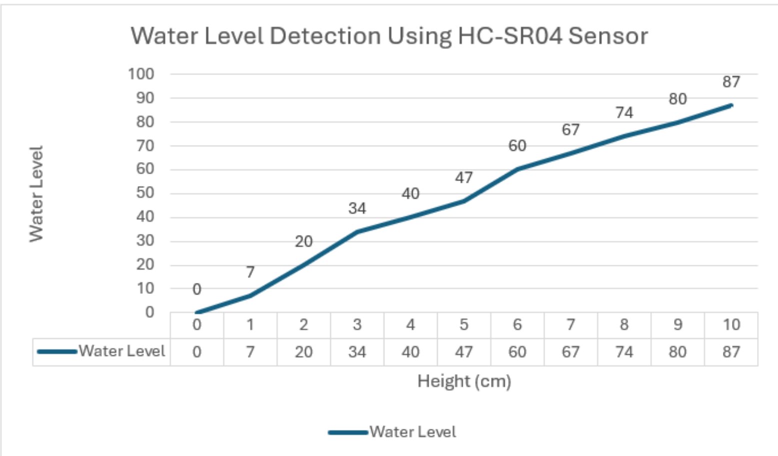

Fig. 9 *Line Graph based on Water Level detection reading*

Penerbit UTHM

3.3.2 Temperature detection using DHT 22 sensor

The DHT22 temperature sensor was tested using a controlled flame to simulate gradual heat buildup, with results plotted on a line graph showing temperature (°C) over time (seconds). The temperature increased steadily by approximately 1°C every 5 seconds, confirming the sensor's responsiveness and accuracy. Readings were displayed in real-time on both the OLED screen and Blynk mobile app, enabling remote monitoring. The test was limited to 50°C to avoid damaging the prototype, which was built from polystyrene with a deformation threshold of 80°C. The sensor's fast response and precise decimal readings demonstrated its suitability for detecting early signs of overheating or fire hazards in IoT-based manhole monitoring systems.

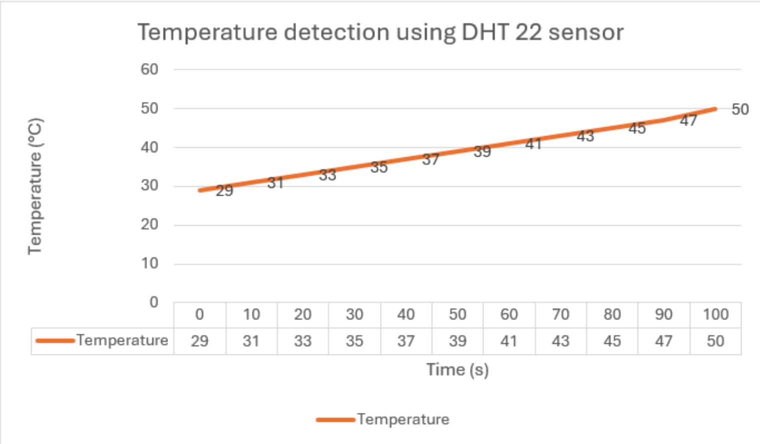

Fig. 10 *Line Graph based on Temperature detection reading*

3.3.3 Concentration gas level LPG using MQ 2 sensor

A line graph was used to show the MQ-2 gas sensor's response to LPG concentration (in PPM) during a paper smoke test, simulating gas leakage in manholes. The LPG levels increased steadily from a baseline of 2 PPM to a peak of 9 PPM over 140 seconds, indicating a direct correlation between smoke density and sensor response. The readings stabilized after 120 seconds, showing the sensor's consistency under saturated conditions. Real-time data was clearly displayed on both the OLED screen and Blynk app, confirming reliable system operation. These results validate the MQ-2 sensor's effectiveness in detecting hazardous gases for timely alerts in IoT-based manhole monitoring.

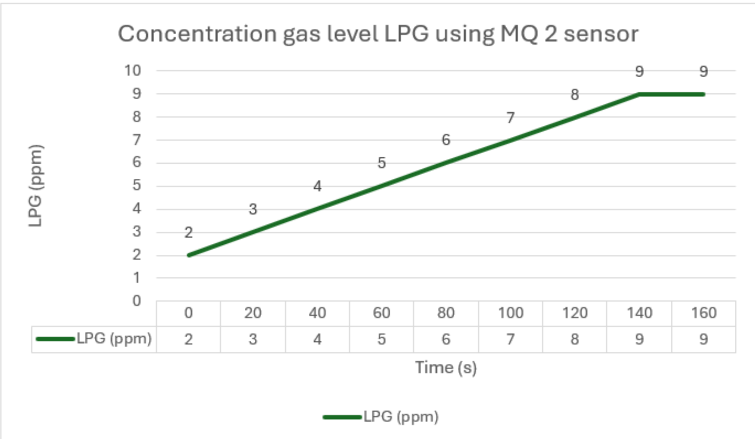

Fig. 12 *Line Graph based on MQ 2 (LPG) reading*

4. Conclusion

The proposed IoT-Based Manhole Detection and Monitoring System offers an efficient solution to improve urban safety by detecting hazards such as water overflow, toxic gas buildup, and abnormal temperature changes. Using the ESP32 microcontroller with HC-SR04, DHT22, and MQ-2 sensors, the system enables real-time monitoring and accurate data transmission. Information is displayed locally via an OLED screen and remotely through the Blynk mobile app, allowing for immediate alerts and quick response.

Test results confirmed the system's reliability in detecting environmental changes and alerting users promptly. Its dual-display and wireless connectivity make it a practical early-warning tool for public infrastructure management. While improvements are needed in network stability and hardware durability, the system presents a scalable, low-cost solution for smart city integration. With further development, this technology has strong potential to enhance the safety and efficiency of urban infrastructure.

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