# An Internet of Things (IoT) Based Smart Waste Bin for Enhancing Waste Management

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***Abstract***

*The growing global challenge of waste management, particularly in urban settings, necessitates innovative solutions to mitigate environmental pollution, health hazards, and operational inefficiencies in traditional waste collection methods. This paper presents the design and implementation of an IoT-based smart trash bin system aimed at optimizing waste management processes through real-time monitoring of waste levels and the detection of hazardous gases. The system integrates laser diode sensors for waste level detection and gas sensors including TGS2611 and MQ135, for monitoring methane and ammonia emission. These sensors, combined with the ATMEGA128p microcontroller and SIM808 GSM module, allow for seamless data transmission to the ThingSpeak cloud platform for analysis and timely decision-making. The system was tested under various conditions, demonstrating high accuracy in fill-level monitoring and gas detection, with response times averaging 5.6 seconds. By providing real-time insights into waste accumulation and environmental conditions, this smart trash bin system offers an efficient, cost-effective, and scalable solution for municipalities and waste management authorities. The integration of IoT technology into waste management enhances operational efficiency, reduces environmental hazards, and promotes sustainable urban development. Future work will focus on improving system scalability and minimizing reliance on internet connectivity, making the solution viable for broader applications in both urban and rural settings.*

***Keywords:*** *IoT-based waste management, smart trash bin, ultrasonic sensors, real-time monitoring, ThingSpeak platform, hydrogen sulfide monitoring, ATMEGA128p microcontroller, SIM808 GSM module.*

## 1.0 INTRODUCTION

Waste generation has been a constant byproduct of human activity since ancient times, with the advent of urbanization, industrialization, and growing populations exacerbating this challenge. Managing waste has become an urgent concern, particularly in urban settings whereby the traditional methods of waste management such as landfill dumping and incineration, which are inefficient waste disposal practices, have led to environmental degradation, health risks, and economic burdens. Traditional waste management systems in Nigeria, and globally, have often failed to effectively handle increasing volumes of waste, resulting in overflowing bins, irregular waste collection, exposure to harmful gases, and poor recycling efforts. These issues call for an intelligent approach to waste management by proposing a solution through the design and implementation of an IoT-based smart trash bin for waste management systems.

The Internet of Things (IoT), which refers to the interconnection of devices through the internet, presents a revolutionary approach to enhancing waste management practices. IoT enables the integration of sensors, communication networks, and data analytics to create intelligent systems that monitor, analyze, and optimize various operations in real-time. In the context of waste management, IoT technology can be leveraged to create smart trash bins capable of monitoring fill levels, detecting the emission of hazardous gases, and providing real-time data to waste management authorities for timely interventions. By equipping waste bins with sensors to monitor fill levels and hazardous gas emissions, IoT can optimize waste collection, prevent environmental hazards, and enable real-time data-driven decision-making for municipalities and waste management authorities.

This paper presents the design and implementation of an IoT-based smart trash bin system that not only monitors the fill level of the bin but also detects the presence of harmful gases such as methane, ammonia, and hydrogen sulfide. The integration of MQ4, MQ135, and TGS2611 sensors allows for monitoring gases such as ammonia, methane, and hydrogen sulfide, which are dangerous pollutants. This system represents a shift from traditional, inefficient methods to a more technologically advanced approach, contributing to cleaner urban environments and improved public health, thus, optimizing waste collection, reducing operational costs, and allowing for timely waste collection and gas monitoring.

## 2.0 SUMMARY OF RELATED LITERATURE REVIEW

In recent years, several studies have explored the use of IoT in waste management, each aiming to address specific inefficiencies in traditional waste collection and disposal systems. Mahajan et al. (2017) implemented a smart waste management system using IoT sensors to monitor the fill levels of waste bins. However, this system lacked the capability to detect harmful gases produced by decomposing waste, which are a critical aspect of urban waste management. Similarly, Nkolika et al. (2019) developed a smart waste bin system using a microcontroller and infrared sensors but did not incorporate gas detection technology, leaving a significant gap in ensuring environmental safety.

Ogunwolu *et al*. (2022) took a step further by integrating gas sensors, particularly the MQ136 for ammonia detection as well as the MQ4 for fill level detection, into their IoT-based waste management system. While this improved the system's ability to monitor harmful emissions, it still did not cover all critical gases like hydrogen sulfide and methane, which limits its utility in areas where this gas is prevalent. Chandra and Tawani (2020) emphasized the importance of community engagement with smart waste management systems but did not address the technical complexities of incorporating multiple gas sensors for comprehensive environmental protection.

Juwariyah *et al*. (2021) designed an IoT-based smart bin system that utilized ultrasonic sensors and DHT22 sensors for monitoring waste fill levels and environmental conditions such as temperature and humidity. Their work focused on user engagement through the Blynk application but did not incorporate gas sensing capabilities.

The proposed system in this work goes beyond the limitations of these previous studies by integrating comprehensive gas detection capabilities using MQ136 for ammonia, MQ137 for hydrogen sulfide, and TGS2611 for methane, thus providing a more comprehensive solution. This system not only monitors fill levels and gas concentrations but also transmits real-time data to a cloud-based platform (ThingSpeak) for analysis and decision-making. By addressing gaps in previous designs, this multi-gas monitoring approach ensures a more holistic and safer waste management process, which inadvertently improves both environmental safety and operational efficiency in waste management.

## 3.0 METHODOLOGY

The design of the IoT-based smart trash bin system focuses on three core components: waste level monitoring, gas detection and data communication by integrating sensors, microcontrollers, and communication modules to monitor waste levels and gas concentrations in real-time.

### 3.1 System Components

(i) **Combinations of Laser diode sensors with LDR:** These sensors measure the light intensity from Light dependent resistor (LDR) mounted by the inner structure of the device to monitor the fill level of the wastes height of the waste inside the bin. When the trash reaches a certain threshold, the system alerts the waste management authority.

(ii) **Gas Sensors (MQ136, MQ137):** These sensors monitor the concentration of hazardous gases such as ammonia and methane gas. MQ136 is responsible for ammonia detection and MQ137 for methane gas detection.

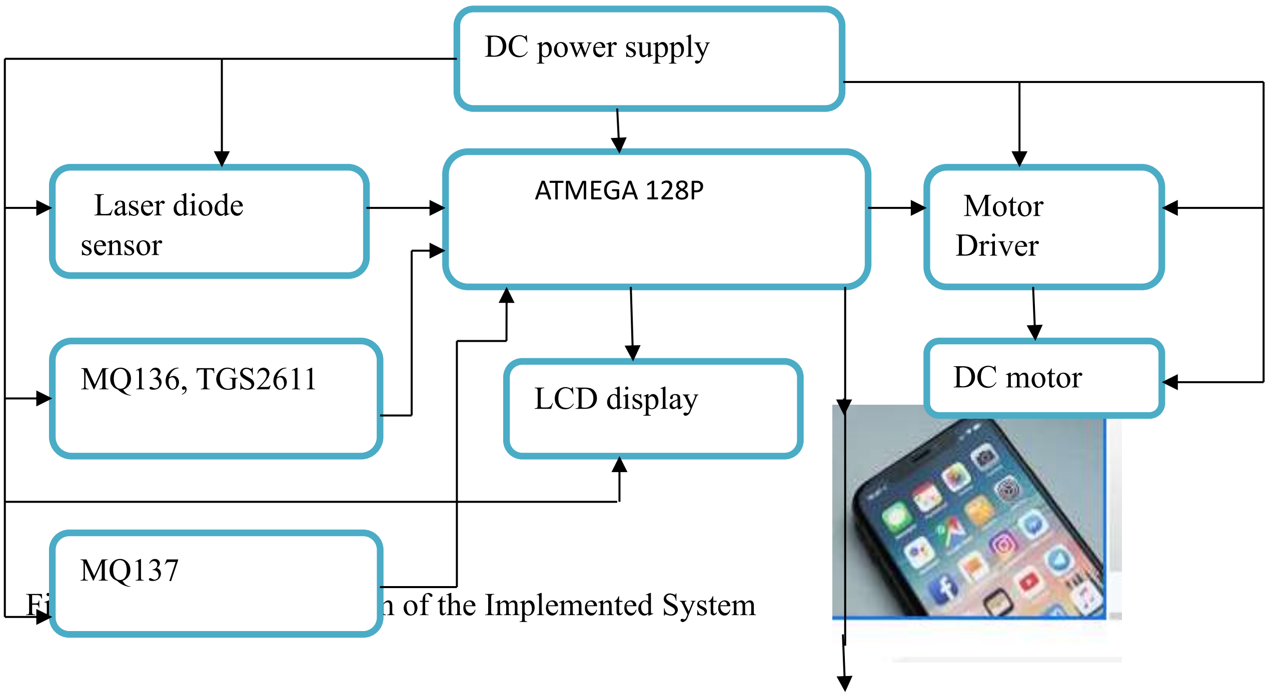
(iii) **GSM Module (SIM808):** This module enables real-time data transmission to the ThingSpeak IoT platform, allowing for remote monitoring and analysis of the bin's status.

(iv) **Arduino ATMEGA128p Microcontroller:** This microcontroller serves as the system's central processing unit, integrating inputs from all sensors and managing data flow**.**

(v) **Servo Motors and Electromechanical Components:** These are used for automatic lid control based on waste level and gas detection data.

(vi) **LM358:** is a two in one comparator that compares the inputs from the light dependent resistor through which the output is transmitted to the arduino nano digital input for decision making.

The system's operation begins with the sensors continuously monitoring the waste level and gas concentrations. The combination of laser diode and Light dependent resistor sensor track the waste's height, while the gas sensors monitor the levels of ammonia, methane, and hydrogen sulfide. Once certain thresholds are reached, the system either sends alerts for waste collection or closes the bin to prevent exposure to harmful gases. Data from the sensors is transmitted via the GSM module to the ThingSpeak platform, where it is analyzed and visualized**.** Figure 3.1 shows the block diagram of the system while figure 3.2 shows the complete circuit diagram of the system.




Fi... n of the Implemented System

### 3.2 The System Circuit Diagram

The circuit diagram shown in figure 3.2 is the line to line connection of integrated components used in the system. From the diagram, the heart of the system is the Atmega 128 controller which serves as the host for all others used components in the circuit. 5voltsDC power source is used to power the developed system. All the components are controlled appropriately where necessary with the use of resistors, LM358, 12VoltsDC relays for smooth running of the system. The Liquid Crystal Display (LCD 16x2) displays current happenings within the system.

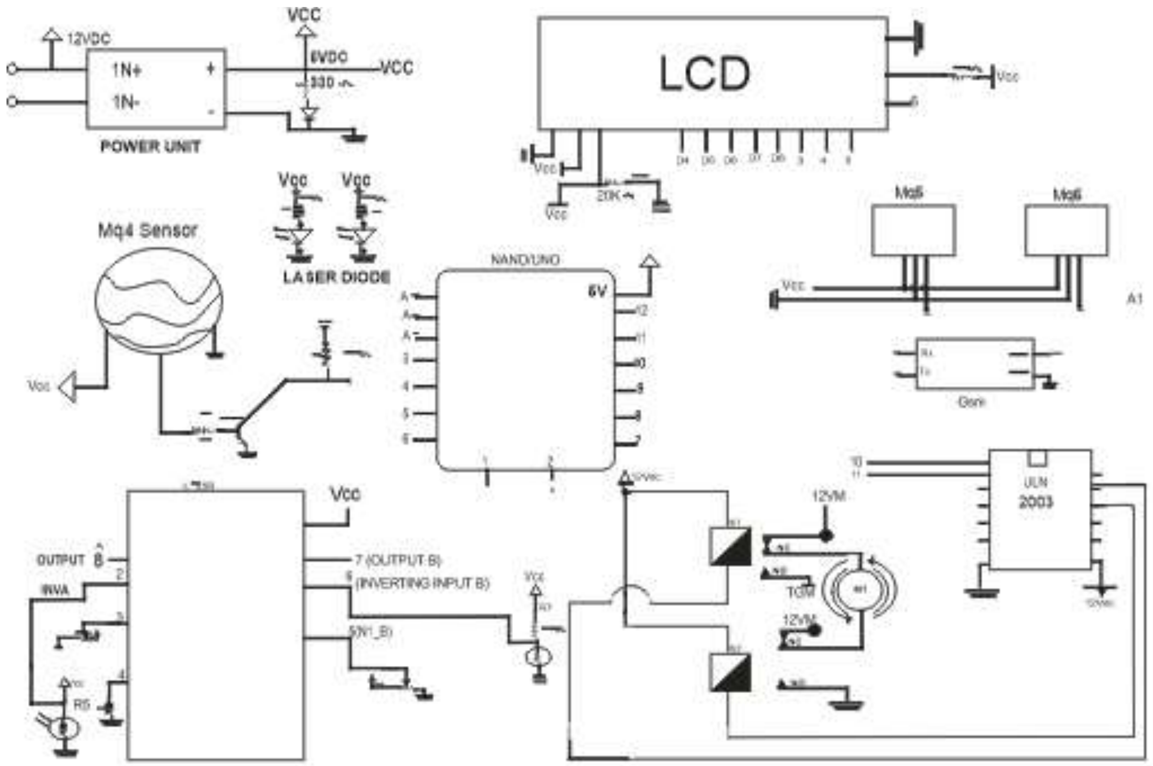



Figure 3.2 The complete circuit diagram of the system

### 3.2.1 System Implementation

The schematic diagram from the circuit diagram of the developed system is shown in figure 3.3. in the schematic diagram, each components are selected as visualize from the circuit diagram using Cadsoft Eagles professional V6.1.0. The Printed Circuit Board (PCB) was developed using from the schematic diagram.

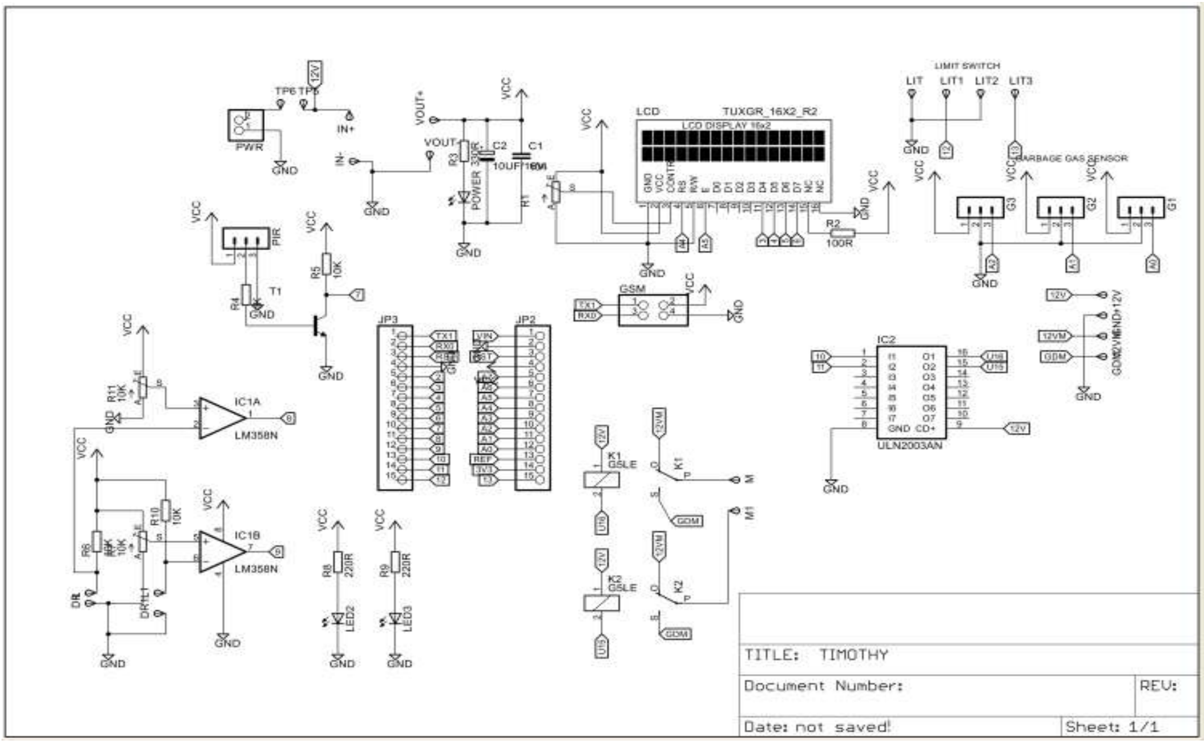



Figure 3.3 The schematic diagram of the developed system

The schematic diagram shows the layout of each component and how it will appear on the board

### 3.2.2 The Trash Bin Printed Circuit Board

In figure 3.4, the printed circuit board of the system is shown. Electronics components are positioned and soldered on the board.

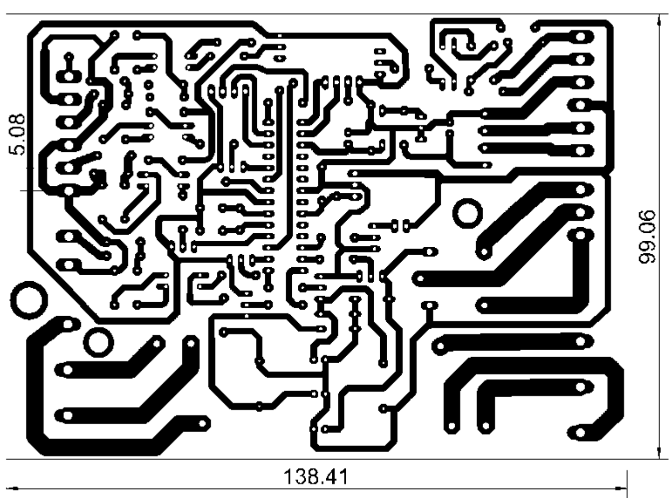



Figure 3.4 The System’s printed circuit board

**The systems flow chart**

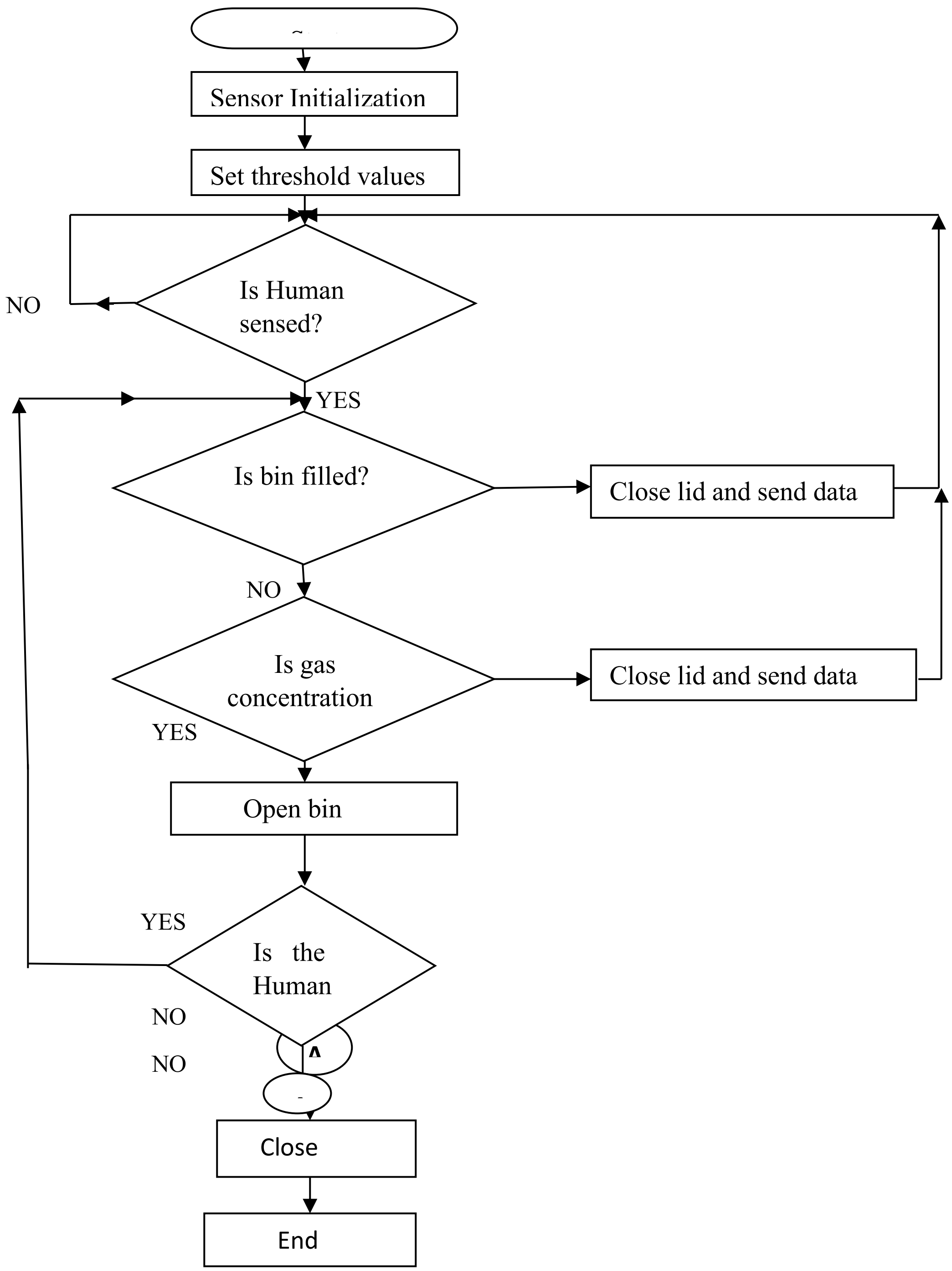



Figure 3.5 The system's flow chart

## 4.0 RESULT AND DISCUSSION

The system was assembled and tested under varying conditions to ascertain its effectiveness and availability. Figure 4.1 and figure 4.2 show the image of the system's electronic circuit and the final packaging of the product.

Figure 4.1: Image of the System's electronic circuit

Figure 4.2: Image of the Implemented System

### 4.1 Performance Evaluation of the System

The performance of the smart waste bin system was evaluated under various conditions, including tests with bio degradable and non-biodegradable waste materials using the developed prototype in figure 4.2. The following factors were taken into consideration:

1. **Fill-Level Accuracy**: The laser diode fill level sensors demonstrated high accuracy in measuring the bin's fill level. This was demonstrated from the thingSpeak result in figure 4.5
2. **Gas Concentration Detection**: The gas sensors accurately detected the concentration of ammonia gas in the system. Table 4.1 provides the gas concentration readings at different stages of waste decomposition while figure 4.6 shows the ThingSpeak communication of the gas detection.
3. **Data Transmission and Response Time**: The system successfully transmitted data to the ThingSpeak platform with an average response time of 5.6 seconds. This is well within the acceptable range for real-time monitoring systems. Figure 4.5 shows the **ThingSpeak** generated result when the smart trash bin is full while figure 4.6 shows the Thinspeak result for gas level. The waste management authority will make use of this result for the purpose of decision making.

The system was tested in both controlled environments (laboratory) and real-world scenarios. In the controlled environment, artificial biogas mixtures were used to test the sensitivity of the MQ135 ammonia gas sensor and the result shown in table 4.1. Similarly, the graph of its sensitivity was plotted in figure 4.3.

Table 4.1 shows the result of Ammonia gas concentration against analog voltage obtained from the laboratory testing.

**Table 4.1: Result showing the concentration of Ammonia gas sensor against analog voltage**

| S/N | **Part per million (ppm ranges)** | **Analog voltage readings(Volts)** | **Time intervals(seconds)** |
|---|---|---|---|
| 1. | 10 | 1.2 | 10 |
| 2. | 50 | 1.3 | 10 |
| 3. | 100 | 1.4 | 10 |
| 4. | 200 | 1.9 | 10 |
| 5. | 500 | 2.7 | 10 |
| 6. | 1000 | 3.9 | 10 |
| | | | |

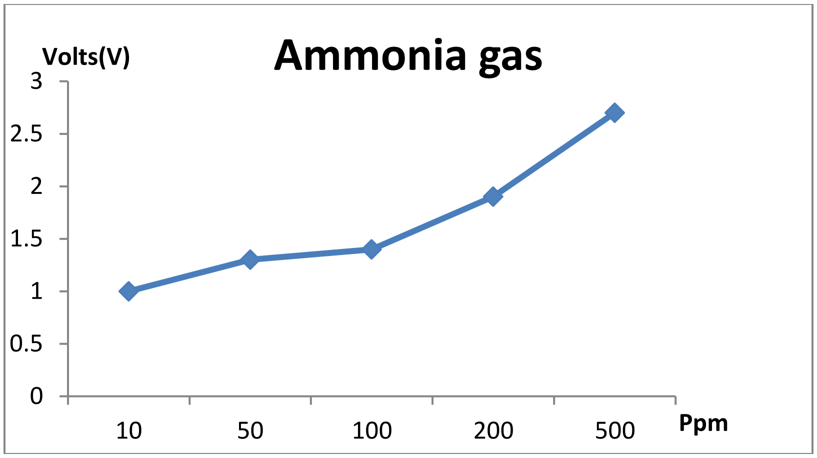



Figure 4.3: Ammonia gas plot of analog voltage against known concentration

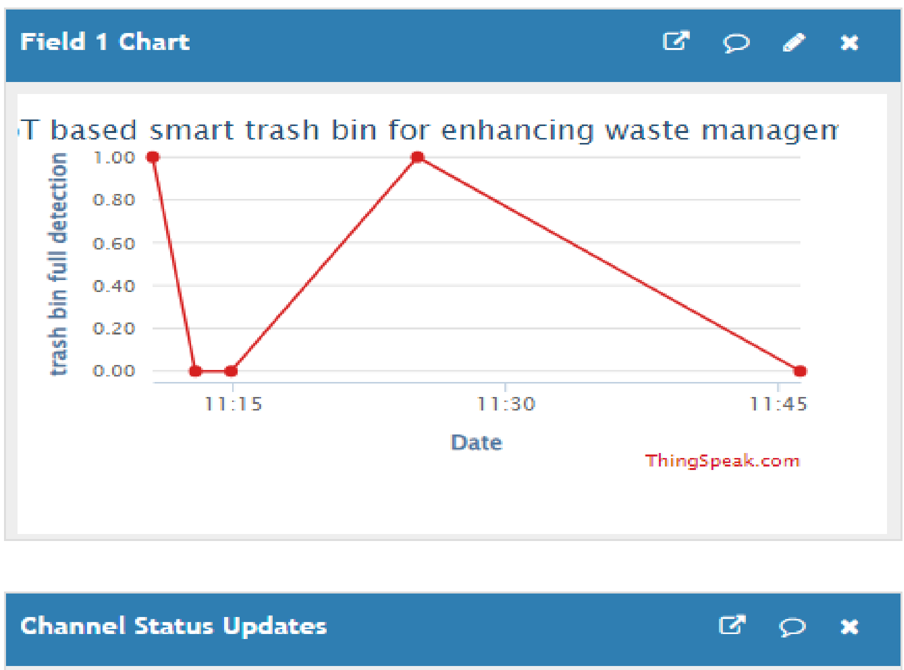



Figure 4.4: ThingSpeak result showing the fill level detection

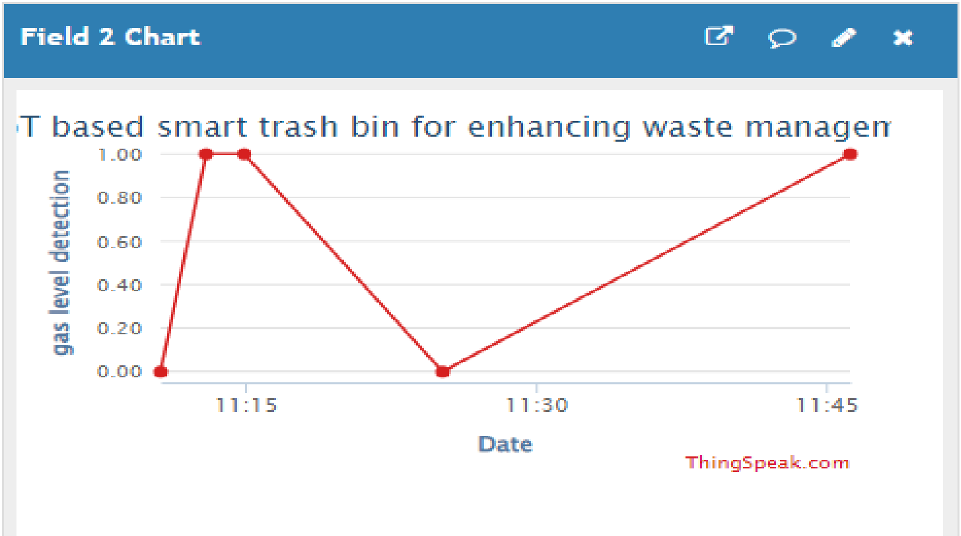



Figure 4.5: ThingSpeak result of the gas level detection

## 4.2 DISCUSSION

As seen in figure 4.5 and figure 4.3, the two variables, namely the waste fill level and gas detection can be monitored at the same time between HIGH and LOW depending on the sensor configuration. The waste management authority can make an informed decision base on the thingspeak information in the graph.

The implementation of the IoT-based smart trash bin system demonstrates significant improvements over traditional waste management practices. By incorporating real-time data collection and automated decision-making processes, the system optimizes waste collection schedules, minimizes human intervention, and ensures that hazardous gases are detected before they can pose a risk to human health or the environment. The integration of multiple gas sensors sets this system apart from previous designs, providing a more comprehensive approach to managing both waste levels and environmental safety.

However, challenges such as the system's reliance on consistent internet connectivity, especially in remote or underdeveloped areas, need to be addressed. The initial cost of deployment for smart waste bins may also be a barrier for widespread adoption, particularly in developing regions. Nevertheless, the long-term cost savings from optimized waste collection routes and reduced environmental impact justify the investment.

## 5.0 CONCLUSION

This paper presents the design and implementation of an IoT-based smart trash bin for waste management systems. The system combines waste fill-level monitoring with hazardous gas detection, providing a comprehensive solution for modern waste management challenges. By leveraging IoT technology, the system enhances operational efficiency, reduces costs, and promotes environmental sustainability. Future work will focus on improving the system's scalability and reducing dependency on internet connectivity to ensure that it can be deployed in a wider range of environments.

## REFERENCES

Abidemi, O., Olamide, F., Adeyinka, A. and Alashiri, O. (2022) 'Design and development of a smart waste bin for effective waste collection', *Future Trends in Networks and Computing Technology*, pp. 363–372. doi: 10.1007/978-981-19-50-37-726.

Chandra, R. and Tawani, T. (2020) 'Design of Smart Trash Bin', *IOP Conference Series: Materials Science and Engineering*, Vol 879, pp. 112–121.

Juwariyah, T., Krisnawati, T. and Sulasminingsih, S. (2021) 'Design of IoT-based Smart Bins monitoring System using Blynk', *IOP Conference Series: Materials Science and Engineering*. doi: 10.1088/1757-899x/1125/1/012078.

Li-Fen, T., Peng, Q.and Rongpan, D.(2022). "Design and Implementation of Intelligent Control Garbage Bin". Journal of Electrical and Computer Engineering, Volume 2022, Article ID 7306548. School of Physics and Electronic Information Engineering, Hubei, China

Lopez, F., Da Silver, D.S., & Cardoso, J.(2018). A survey of internet of Things platforms for smart cities**"**. Journal of King Saud University-Computer and Information Sciences

Mahajan, S.A., Akshay, S.K., Apoorva, S., Mrunaya, S. and Shivani, I. (2017) 'Smart waste management system using IoT', *International Journal of Advanced Engineering Research and Science (IJAERS)*, 4(4), pp. 21–39. (9) Madakam, S., & Ramachandran, R.(2015). "Barcelona Smart City: The Heaven on Earth". (Internet of Things: Technological God). *ZTE Communications* 13(4): 3-9

Nkolika, O., Nafiu, I. and Olanrewaju, K. (2019) 'Development of a smart, automated waste management system', *European Journal of Engineering and Technology*, 7(2), pp. 56–75.

Ogunwolu, F., Mbonu, H., Raji, A. and Omiyale, A. (2022) 'Design and implementation of an IoT-based smart bin for fill level and biodegradability monitoring', *Journal of Engineering Research*, 25(3), pp. 84–89.