DEVELOPMENT OF IOT-BASED HAZARDOUS GAS MONITORING AND NOTIFICATION SYSTEM

MBM - GazAlert

Proponents

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What is a Hazardous Gas?

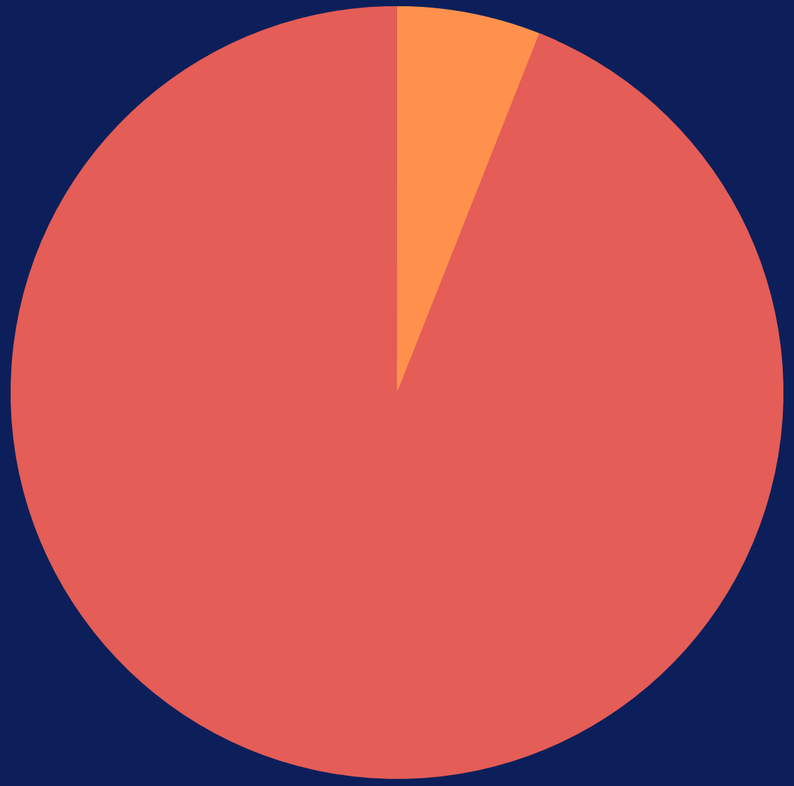
A **hazardous gas** is a colorless gas less dense than air and has an odor smell that can serve as a warning.

- corrosive
- explosion
- flammable
- dangerously reactive

Source: ehrs.upenn.edu

INTRODUCTION

6% Ammonia, and other various other gases



94% Methane

Source: health.ny.gov

Origins of Methane and Ammonia

Emission of Methane is produced by organic wastes

- food scraps
- yard waste
- biodegradable materials

Source: www.npr.org/

Emission of Ammonia is produced by waste materials

- demolition debris (drywalls)
- decomposition of organic waste
- animal and human waste
- nitrogen fixation processes

Source: www.health.ny.gov

INTRODUCTION

Prolonged exposure to **hazardous gas**

- illness
- lung damage (asphyxiation)
- kidney, liver damage
- death

Source: ec.europa.eu

Acceptable PPM limit for Methane And Ammonia

NIOSH is the government agency that makes recommendations to OSHA. NIOSH reviews the available science to figure out a safe exposure limit for most workers over the course of a working lifetime. The NIOSH Recommended Exposure Limit (REL) for ammonia is 25 ppm averaged over an eight-hour work day.

Working Exposure Limits of Methane

Currently, there are no specified occupational exposure limits for methane gas. The National Institute for Occupational Safety and Health's (NIOSH) in the United States recommends a maximum of 1000 ppm (0.1%) during an eight-hour work period.

1000ppm

TWA concentration can result in irritation to workers.

Occupational Exposure Standards

	Exposure level
NIOSH 8-hours TLV*	1000 ppm
Potentially explosive	50,000 to 150,000 ppm
Asphyxiation	500,000 ppm

Sources: https://minearc.com/wp-content/uploads/2021/04/risks-and-safety-hazards-of-methane-infographic-final.pdf
https://www.osha.gov/sites/default/files/2019-03/fs4-howmuch2.pdf

Long-Term Exposure of landfill gases

- Eye, throat, Lung Irritation
- Nausea, nasal blockage, asthma
- Headache, chest pain, weight loss

Source: health.ny.gov

General Issues of Landfills

- Poor Waste management
- Long term Health Issues
- Lack of proper equipment

BACKGROUND

233 Open Landfills

48 Open Landfills in Western Visayas

189 Establised Landfills

300 More Future Sanitary Landfills

According to the denr.gov.ph

- Landfill gas (LFG) is produced by the **decomposition of organic materials** in landfills

- These gasses have detrimental effects on the environment and the people when not monitored and controlled

INTRODUCTION

One of the challenging problems that hasn't been resolved is the Calajunan dumping site

260 metric tons each day

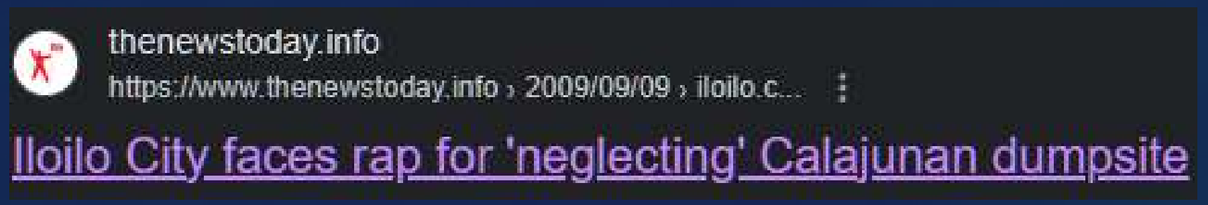
EXISTING PROBLEM

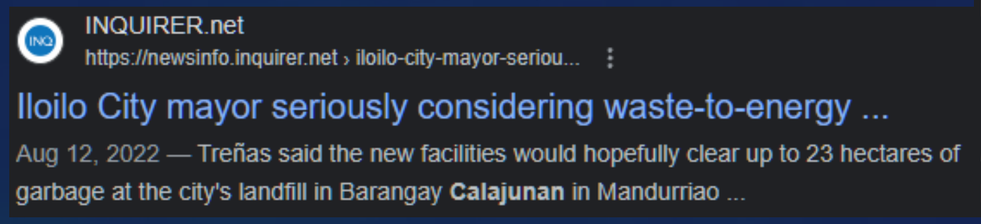
- Never ending garbage remains **untreated,** shaping as a mountain

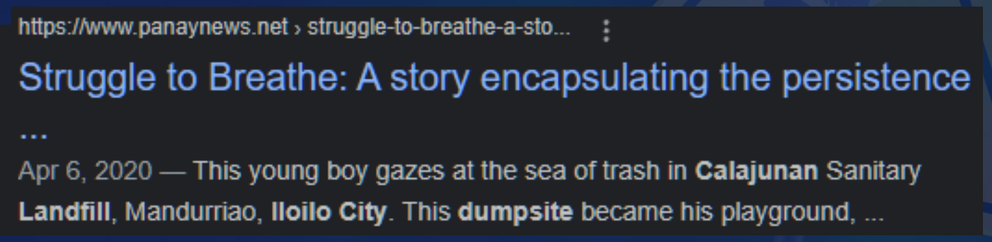
- Complaint and experience of disgusting smell

caused by Volatile organic compounds which are hazardous to a human body

EXISTING PROBLEM (Continued)







jezza in current events February 29, 2012 468 Words

‘Close Calajunan dumpsite’

BY JEZZA NEPOMOCENO

ILOILO City – The “poorly managed” open dumpsite of the city in Brgy. Calajunan, Mandurriao district must be closed for posing danger to public health and safety, said a group of concerned city residents.

They are proposing the establishment of a “metro Iloilo dumpsite and sanitary landfill” far away from population centers.

RATIONALE

- Methane causes **30% of global warming**
- Methane effects: mood changes, slurred speech, vision problems, memory loss, nausea, vomiting and facial flushing
- High levels of ammonia can cause **coughing**, **irritation** of the **eyes**, **nose**, and **throat**, **headache**, **nausea**, and **breathing difficulties**
- The project is essential in helping workers and residents near the landfill areas to make well-informed decisions about their health
- Data gathered can be used by government agencies for policymaking

OBJECTIVES OF THE STUDY

General Objective

To develop an IOT-based hazardous gas monitoring and notification system

Specific Objective

- **to build** a prototype that detects methane and ammonia levels as well as temperature and humidity, display real-time data via LCD and ThinkSpeak IoT platform, and alert user via email

- **to determine** the functionality and reliability of the system

PROPOSED SOLUTION

To Build a portable gas Monitoring Device

alert system

real-time Monitoring

portability

COMPARISON CHART

Features	Gazalert	Literature Study 1	Literature Study 2	Literature Study 3
MQ-4	✓	-	✓	MQ-2
MQ-137	✓	✓	-	-
DHT22	✓	-	✓	-
ESP32	✓	ESP8266	Arduino Uno	Arduino Uno
20x4 display	✓	-	16xx2 display	Commercial Display
Buzzer	✓	-	-	-
Led lights	✓	-	-	-

SUMMARY

- Only our device uses ThinkSpeak used for IOT platform notification and ESP32 as the device's microcontroller.
- Our device uses ESP32 which is more powerful than the ESP8266 and Arduino Uno board
- DHT 22, Led lights and buzzer is a feature not implemented with other devices

SIGNIFICANCE OF THE STUDY

Residence
Give residence near waste yards information on their current situation

Workers
Benefit the health of people who work in close proximity to wasteyards.

Local authorities
Inform
local authorities the negative consequences of improperly managed waste yards.

Researchers
Help researchers for conducting their future studies related to this research

TARGET BENEFICIARIES

Materials Recovery Facilities

Waste management services

Local Government Units

STUDIO SHODWE

Standards and Legal Bases

RA. 9003 or Ecological Act of 2001

Implements systematic, comprehensive and ecological solid waste management

It ensures:

- public health and environmental conversation
- proper solid waste segregation, processing, handling management and disposal

Source: Mother Earth Foundation PH - Posts | Facebook

STUDIO SHODWE

Standards and Legal Bases

Source: RA 6969 by Maureen Malazo (prezi.com)

RA. 6969 or Toxic Substances, Hazardous and Nuclear Waste Control

It ensures:

- penalties for violation thereof, and for other purposes
- control, manage importation, manufacture, processing, distribution, transport treatment and disposal of toxic substance, hazardous and nuclear wastes

SYSTEM DESIGN REQUIREMENTS

Conceptual Framework - IPO Diagram

Input

- Hardware Specifications
- Software Specifications
- IoT Requirements
- Framework

Process

- Literature Review
- Prototyping Method
- Experiment set-up (Testing)
- Evaluaiton of Functionality and reliability

Output

Development of Hazardous Gas Monitoring and Alert System

Feedback

System Refinement

THEORETICAL FRAMEWORK

Based on Andrew Whitmore (2015) and Bandyopadhyay & Sen (2011), the definition and analysis of IoT are relevant to the aims of this study. The unconstrained growth of IoT will not only provide efficiency but encourage practical uses while promoting unforeseen challenges for its negative uses.

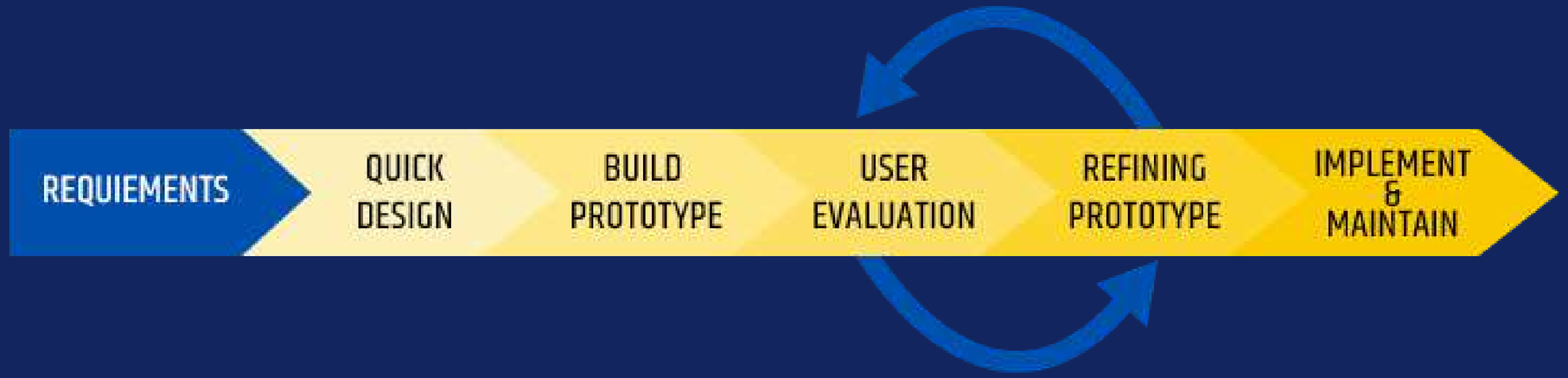
SCOPE AND DELIMITATIONS

- Development is strictly for Methane and Ammonia for gas monitoring
- Testing conducted at Calajunan Mandurriao dumping site in Iloilo.
- Research only limited to waste yards within Iloilo City
- Mainly Focused on Methane and Ammonia; other hazardous gasses not explored in wasteyards

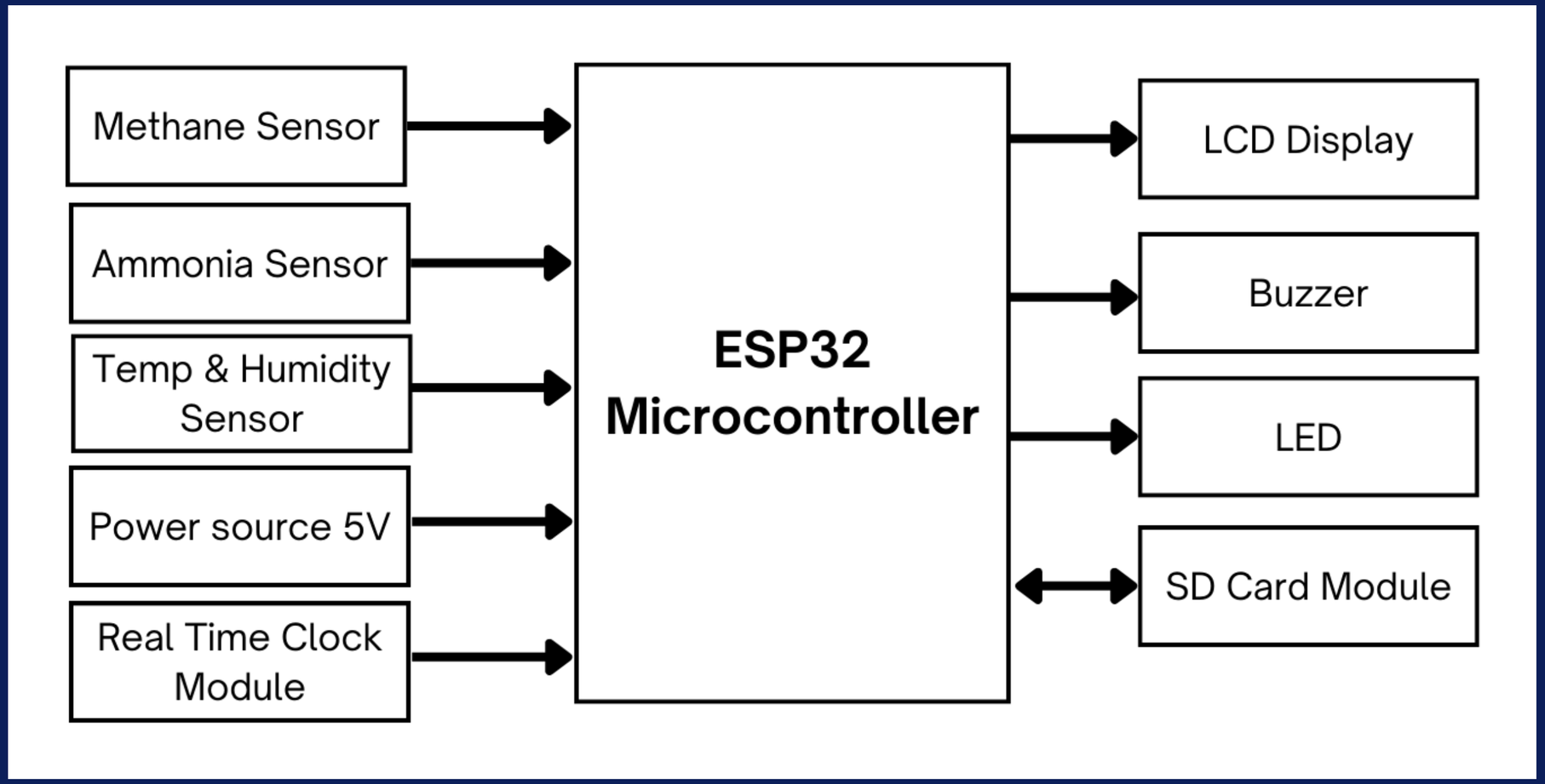
METHOD

Evolutionary Prototype

1. Prototyping model for system development
2. Experimental Setup for testing and evaluation
3. Descriptive statistics for data analysis



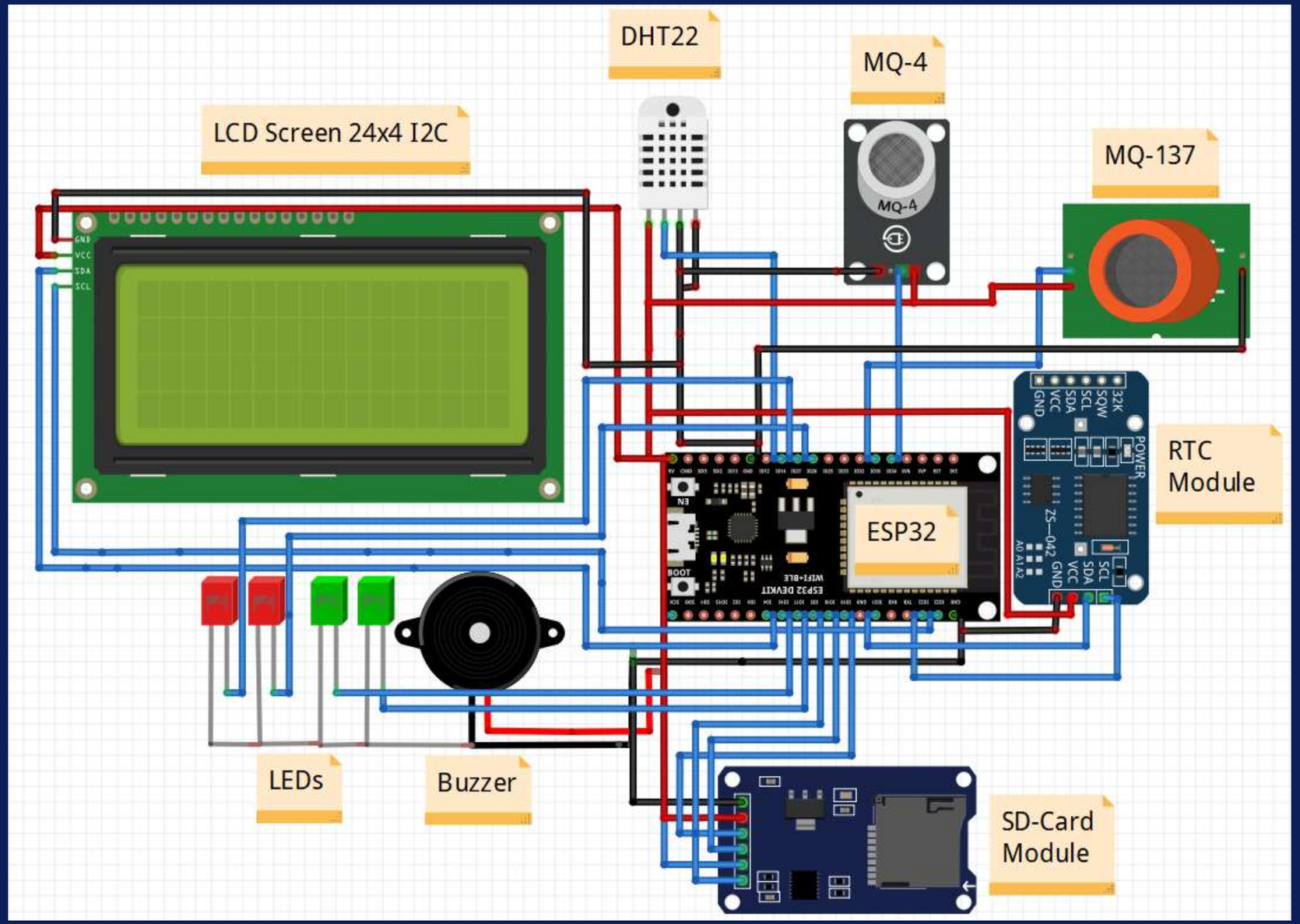
SYSTEM ARCHITECTURE AND MATERIALS



Wi-Fi Modem

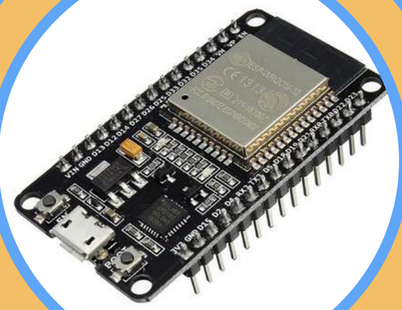
ThingSpeak™
IoT Platform

CIRCUIT DIAGRAM



Materials/Design Requirements

HARDWARE



Operating Voltage: 3.3V
Digital I/O Pins: 32
Analog Input Pins: 1
Clock Speed: 80MHz/240MHz

ESP32

Size: 35mm x 22mm x 23mm
voltage: DC 5 V
Detection range: 10～1000ppm

MQ-137

32 Mm X 22 Mm X 27 Mm
voltage: 5v
Detection range:300～10000ppm

MQ-4

voltage range: 3V to 24V DC.
frequency range : 3,300Hz.
supply current : below 15mA
sound pressure level : 85dBA or 10cm.

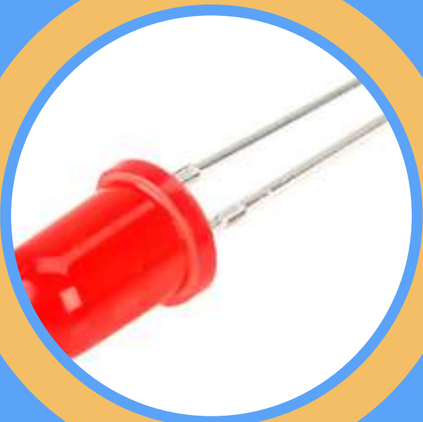
Buzzer

Materials/Design Requirements

HARDWARE

Temperature Range: -40°C to 80°C
Temperature Accuracy: ±0.5°C
Humidity Range: 0 to 100% RH
Humidity Accuracy: ±2% RH

DHT22

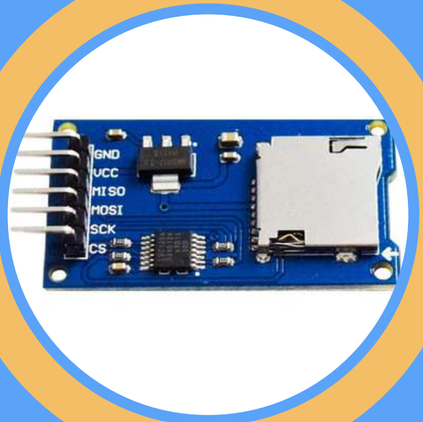


Size: 35mm x 22mm x 23mm
voltage: DC 5 V
Detection range: 10～1000ppm

LED Light

Length: 240mm x 4
Material: Plastic

JumperWire

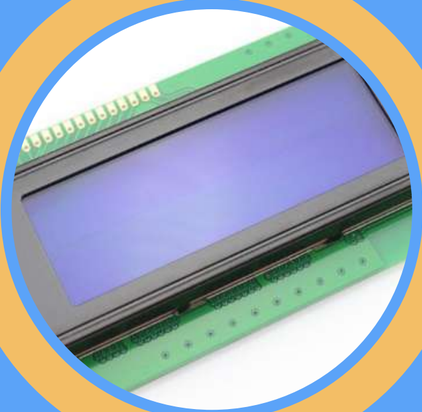


Power supply: 4.5V – 5.5V, 3.3V
Size: 45 x 28mm.

SD Card Module

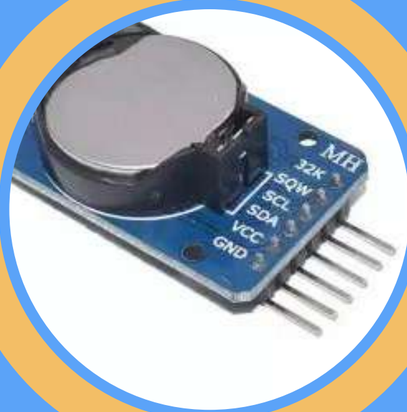
Materials/Design Requirements

HARDWARE



Supply voltage: 5V, 3.3V
View direction: Wide viewing angle
Size: 98x60x24mm

20x4 LCD screen



Operating voltage of DS3231 MODULE: 2.3V – 5.5V
Can operate on LOW voltages
Consumes 500nA on battery backup
Maximum voltage at SDA , SCL : VCC + 0.3V

RTC Module

Materials/Design Requirements

SOFTWARE

SketchUp

Developer: Trimble

Platform: cloud-based 3D modeling

OS: Windows 11,10, 8.1

Version: Pro 2022

Fusion 360

fritzing

Developer: Interaction Design Lab Potsdam

Platform: electronics design

OS: Windows, Mac, Linux

Version: 0.9.10

Fritzing

ARDUINO

Developer: David Mellis

Platform: cross-platform application

OS: Windows, Mac, Linux

Version: 2.0

Arduino IDE

ThingSpeak

Developer: ThingSpeak.

Platform: IoT Analytics

OS:Windows 11,10,8.1

ThingSpeak

Materials/Design Requirements

Formula for Ammonia Sensor

10 ^ ((log10(ratio) - b) / m)

The PPM value is calculated using a logarithmic formula based on the calibration values obtained from the website

by

Aswinth Raj

(https://circuitdigest.com/microcontroller-projects/arduino-mq137-ammonia-sensor).

Materials/Design Requirements

Formula for Ammonia Sensor

10 ^ ((log10(ratio) - b) / m)

- determine the ratio between the sensor resistance (Rs) and the resistance in fresh air (Ro)
- Taking the logarithm (base 10) of this ratio helps us analyze the relationship between the two resistances
- adjust the calculation by subtracting an intercept value (b) obtained during calibration, as suggested by Aswinth Raj

Materials/Design Requirements

Formula for Ammonia Sensor

10 ^ ((log10(ratio) - b) / m)

- divide the adjusted value by a slope value (m) obtained during calibration. This division helps account for the sensitivity of the sensor, as indicated by Aswinth Raj's calibration findings

- raise 10 to the power of the adjusted result, effectively reversing the logarithm calculation and providing us with the PPM value

Materials/Design Requirements

Formula for Methane Sensor

$$PPM = a * ratio^b$$

The calibration constants 'a' and 'b' used in the gas concentration calculation formula for the MQ4 gas sensor were obtained through the MQUnifiedsensor library.

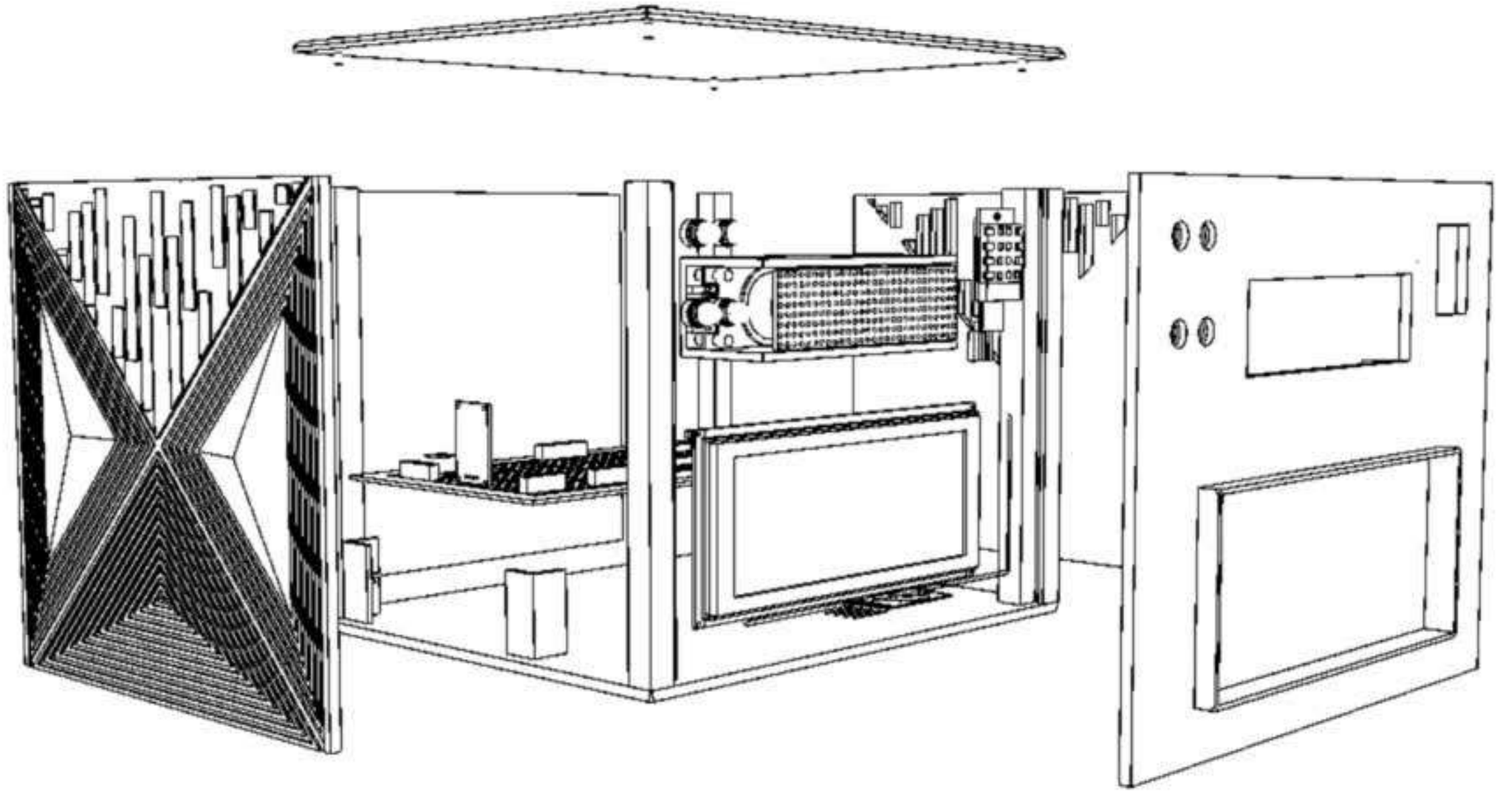
The MQUnifiedsensor library, developed by Miguel5612 and available on GitHub, provides the necessary functions and algorithms for reading gas sensor data and calculating gas concentrations.

Materials/Design Requirements

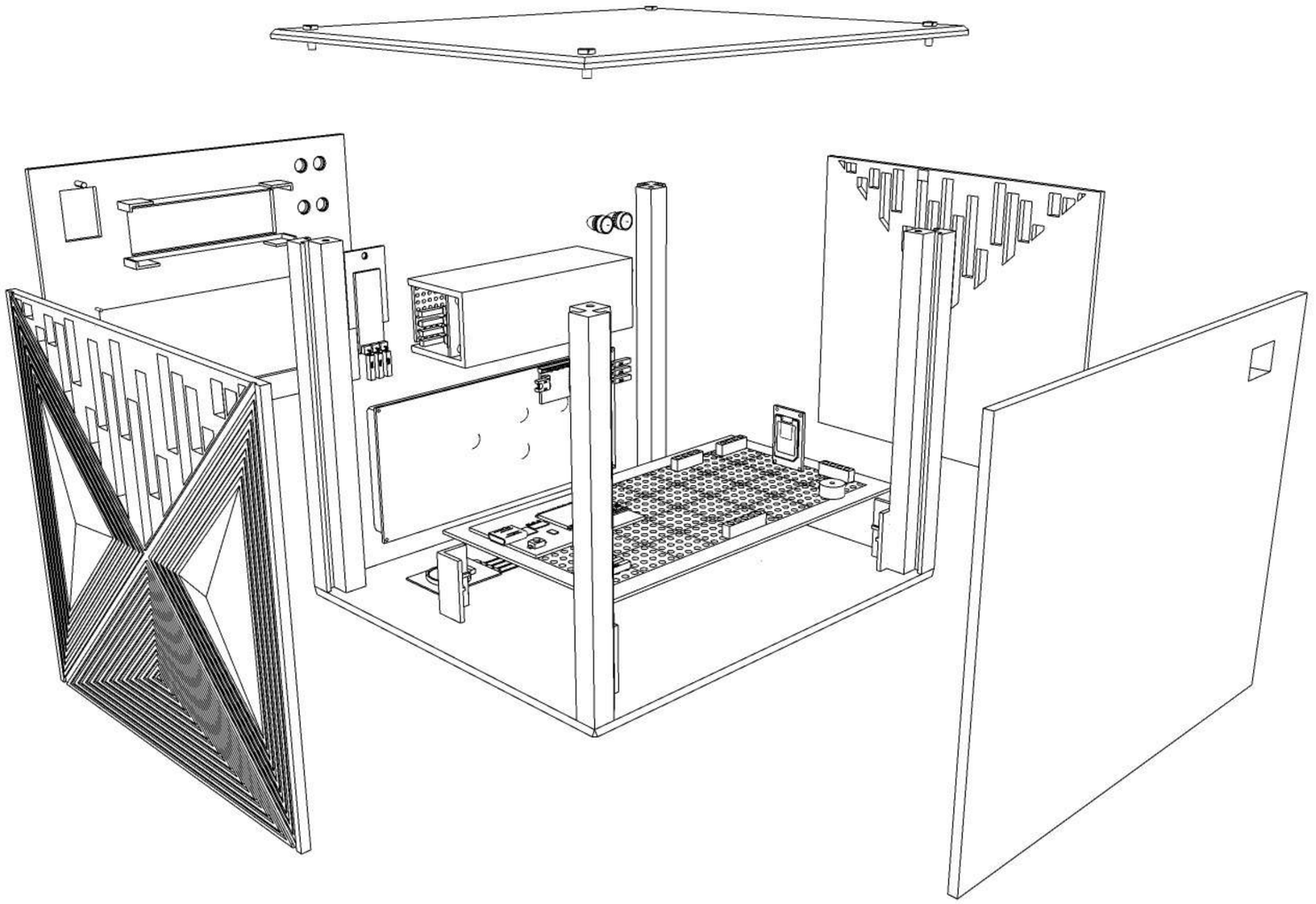
Formula for Methane Sensor

$$PPM = a * ratio^b$$

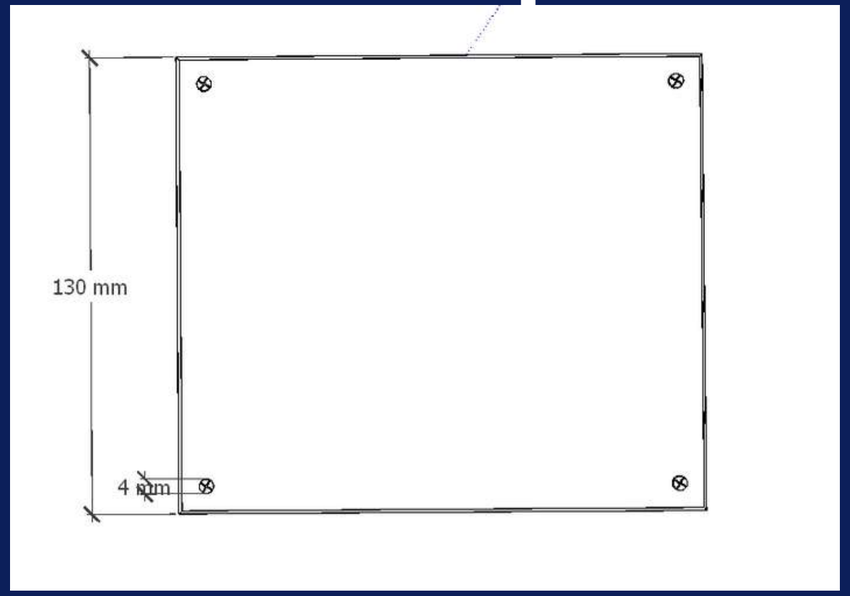
- PPM represents the gas concentration in parts per million.
- 'a' and 'b' are constants specific to the gas being detected.
- 'ratio' is the ratio of the sensor resistance (RS) to the R0 resistance in clean air.

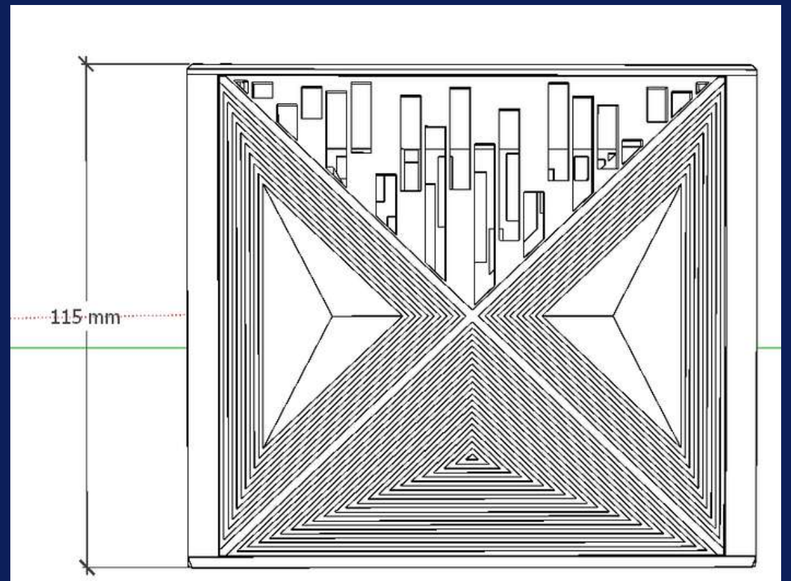


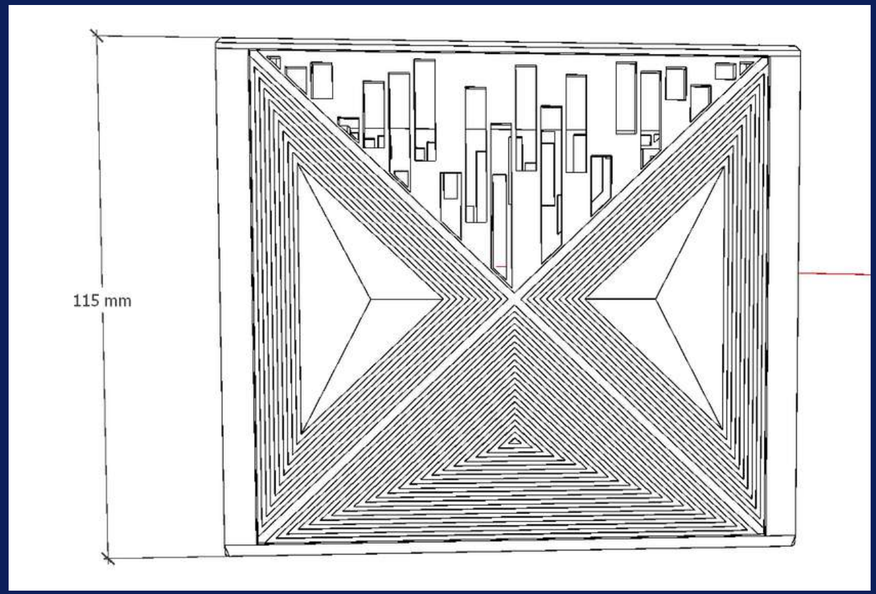
Proposed Packaging Design

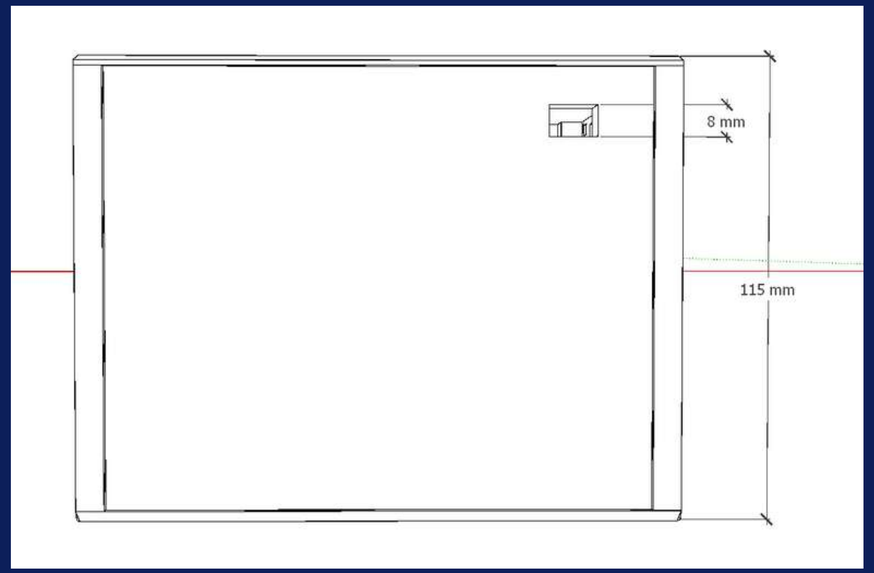


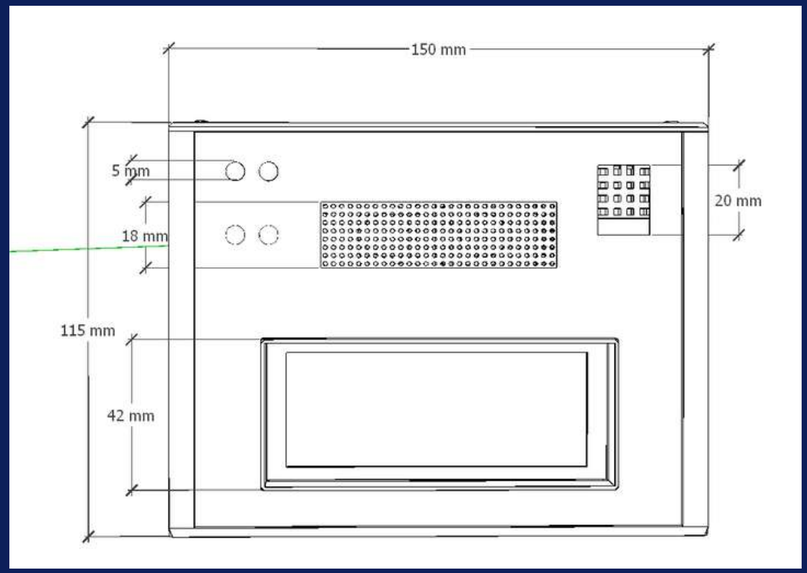
Proposed Dimension of the Device











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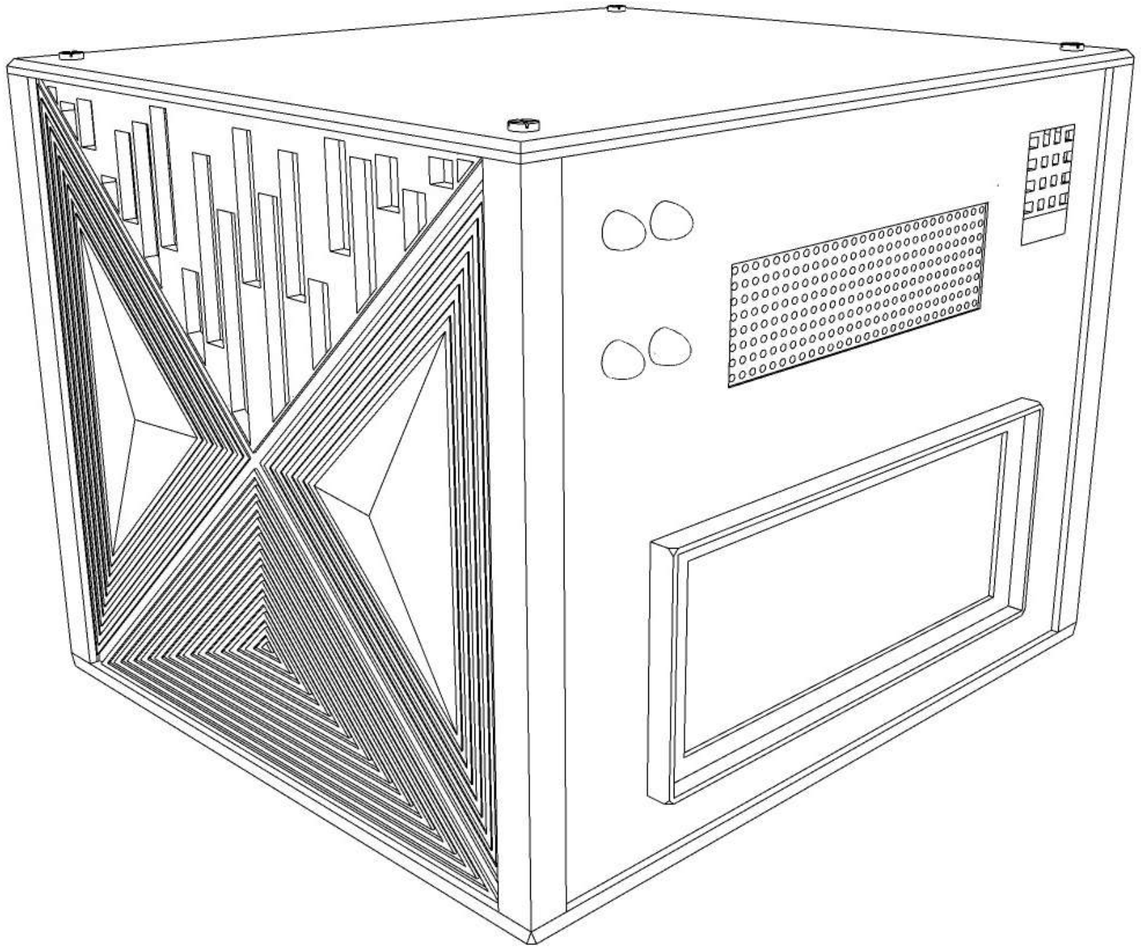
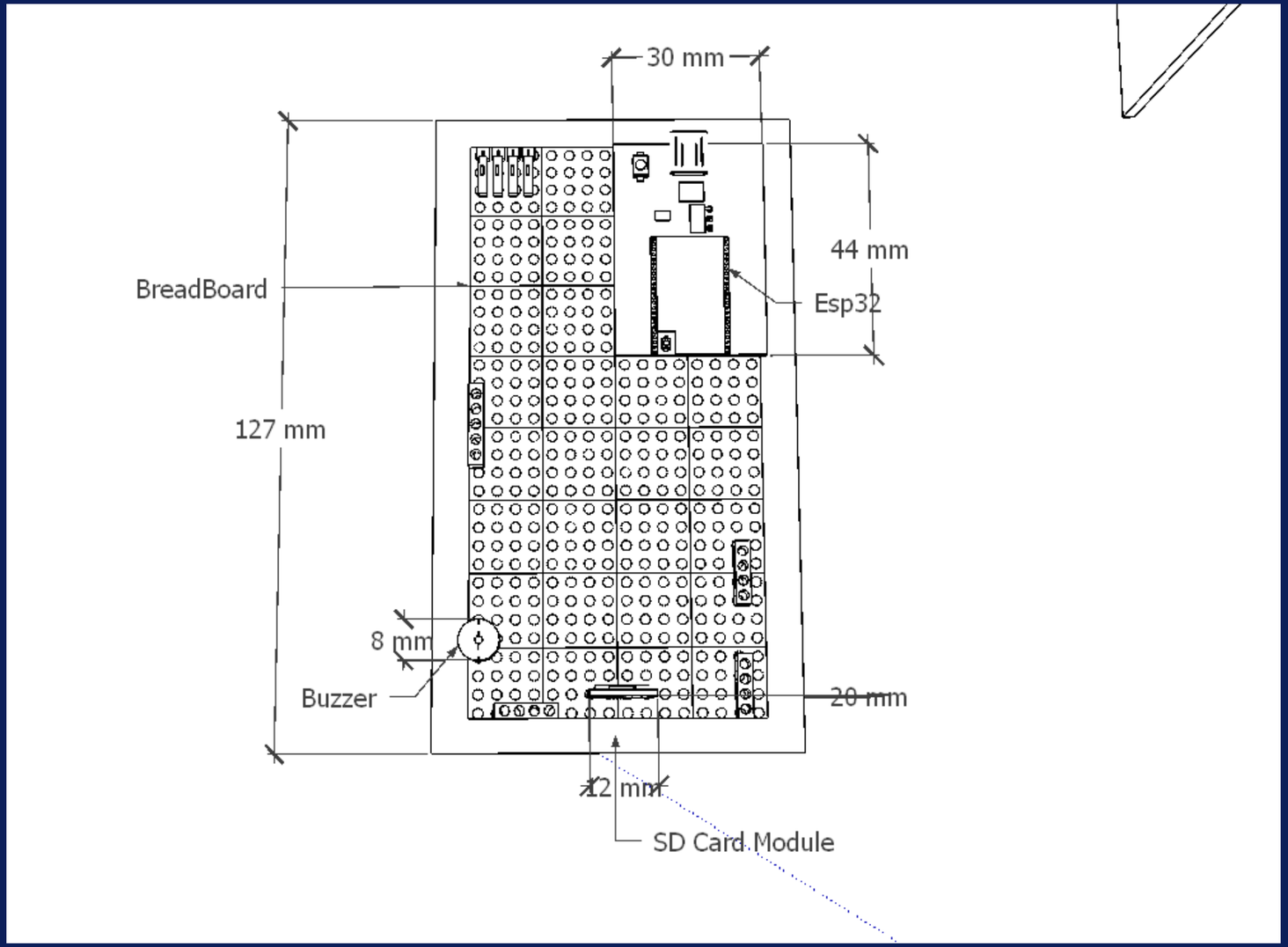
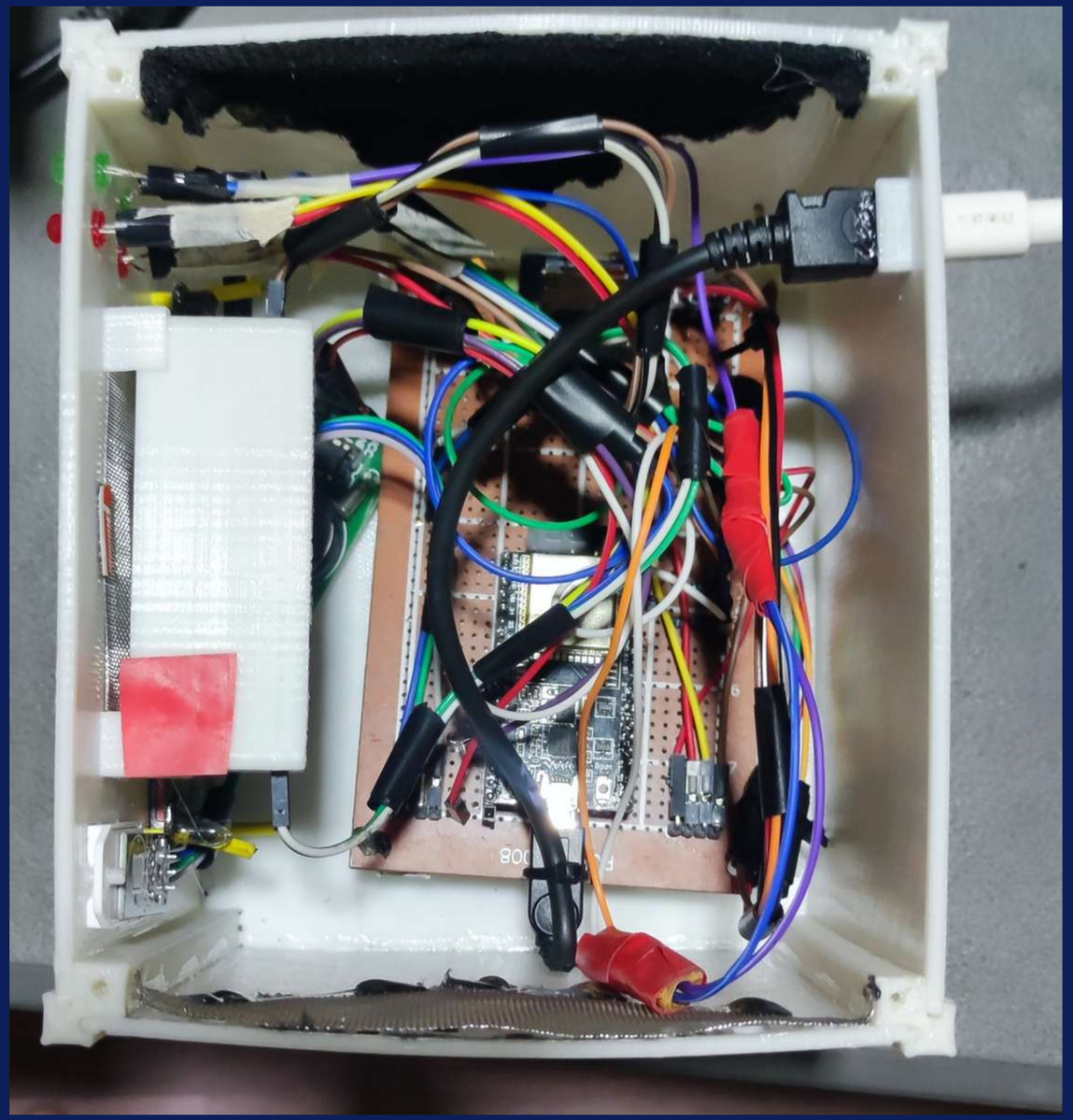


Proposed Packaging Design



FINAL PROTOTYPE

Circuit of the Prototype

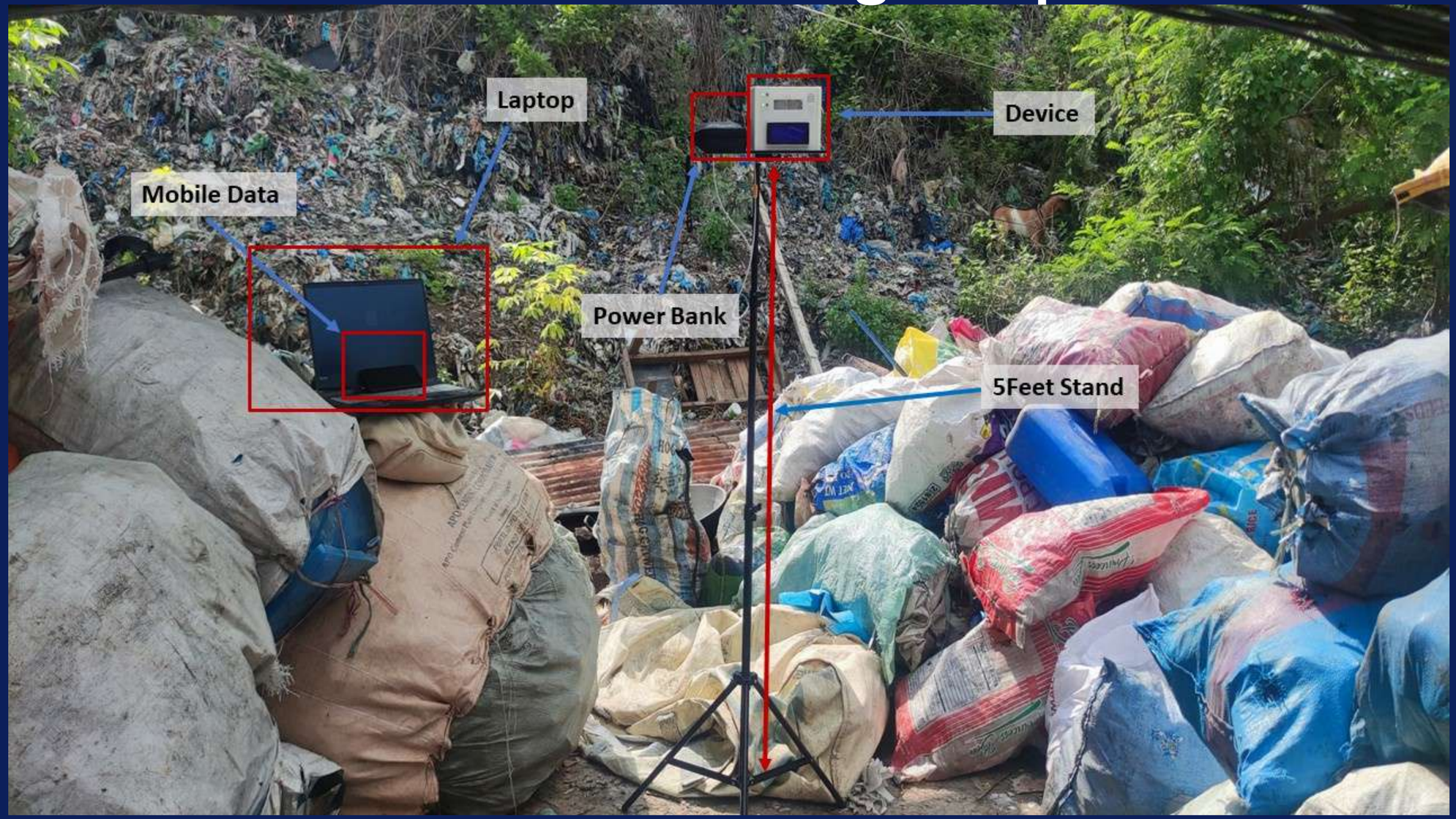


Actual picture of residential area - 4/6/2023

Actual picture of landfill hill - 4/6/2023

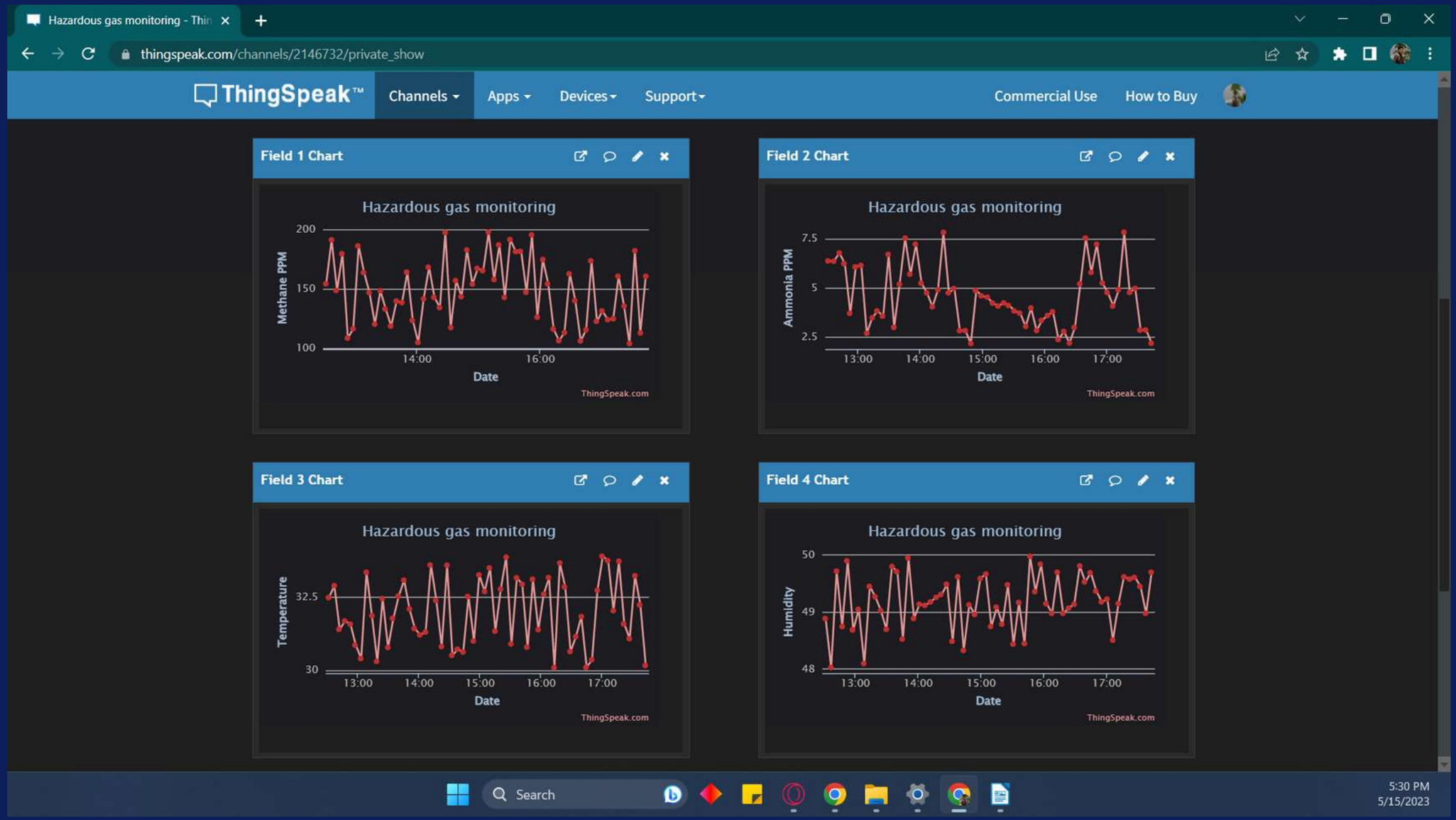
RESULTS

Data Gathering Setup



RESULTS

Desktop View

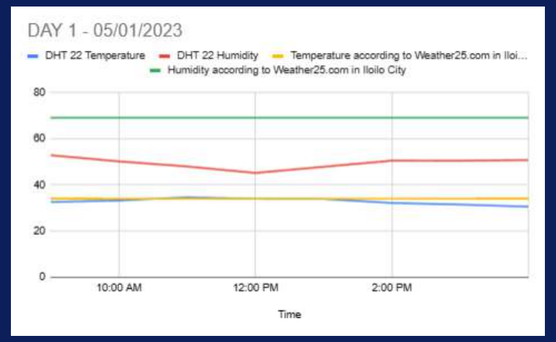


Video Demo Presentation

The prototype will produce a *buzzer sound*, and 4 LEDs will light up when it turns on.

UNIT TESTING RESULTS

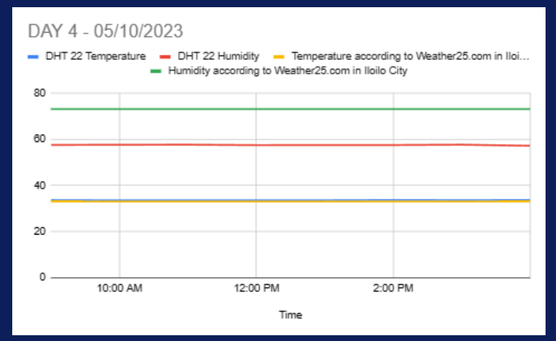
Data from Calajunan Dumpsite



Day 1

Average: 33.60°C
Standard deviation: 0.25°C.
Maximum: 33.99°C
Minimum: 33.05°C

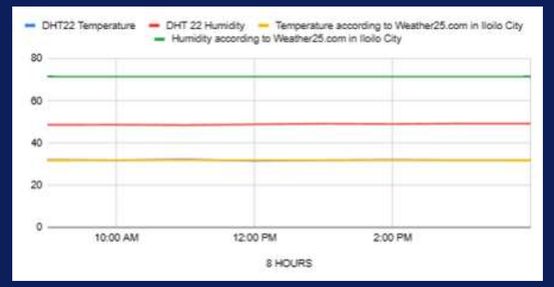
Average: 57.47%
Standard deviation: 0.58%.
Maximum: 59%
Minimum: 54.12%



Day 4

Average: 33.60°C
Standard deviation: 0.25°C.
Maximum: 33.99C
Minimum: 33.05°C

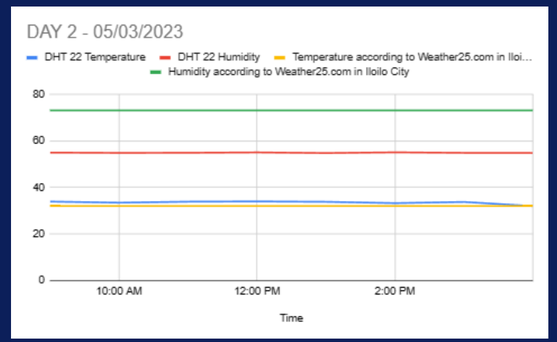
Average: 57.47%
Standard deviation: 0.58%.
Maximum: 59%
Minimum: 54.12%



Day 7

Average: 32.08°C
Standard deviation: 1.15°C.
Maximum: 33.91°C
Minimum: 30.8°C

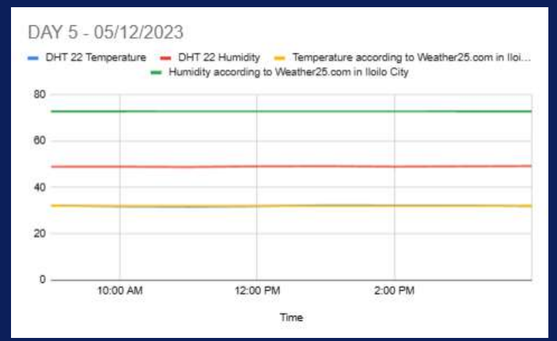
Average: 49.00%
Standard deviation: 0.55%.
Maximum: 49.97%
Minimum: 48.02%



Day 2

Average: 33.50°C
Standard deviation: 1.10°C.
Maximum: 35°C
Minimum: 29.12°C

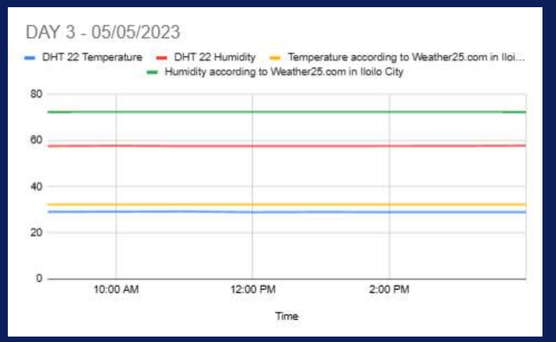
Average: 54.86%
Standard deviation: 0.53%.
Maximum: 56%
Minimum: 54%



Day 5

Average: 32.01°C
Standard deviation: 1.07°C.
Maximum: 33.92°C
Minimum: 30.06°C

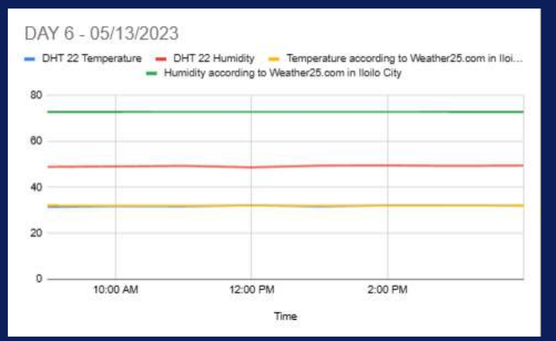
Average: 48.96%
Standard deviation: 0.58%.
Maximum: 49.98%
Minimum: 48.02%



Day 3

Average: 29.03°C
Standard deviation: 0.50°C.
Maximum: 29.97°C
Minimum: 28.11°C

Average: 57.55%
Standard deviation: 0.25%.
Maximum: 58%
Minimum: 57.06%



Day 6

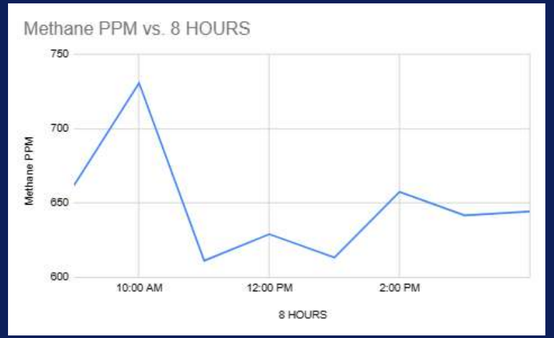
Average: 31.85°C
Standard deviation: 1.07°C.
Maximum: 33.92°C
Minimum: 30.06°C

Average: 49.15%
Standard deviation: 0.53%.
Maximum: 50%
Minimum: 54.12%

Data gathered from Day 1 to Day 7 for Temperature and Humidity

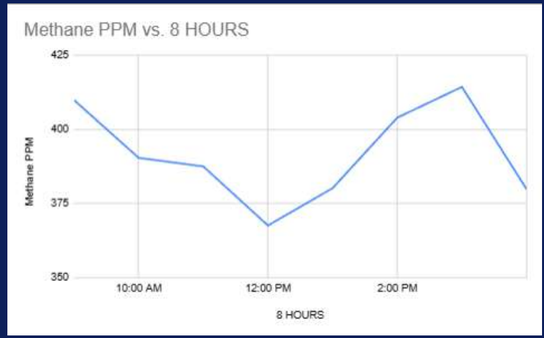
Day 1

Average: 391.08
Standard deviation: 156.25.
Maximum: 606.43
Minimum: 191.19



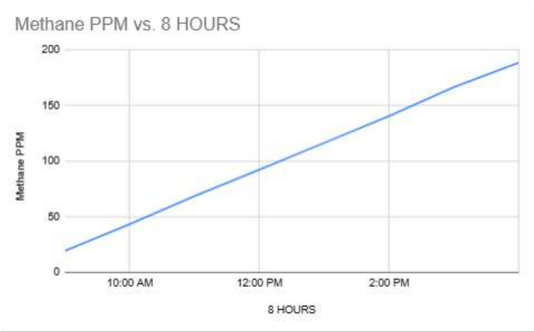
Day 2

Average: 648.85
Standard deviation: 37.99
Maximum: 730.91
Minimum: 611.33



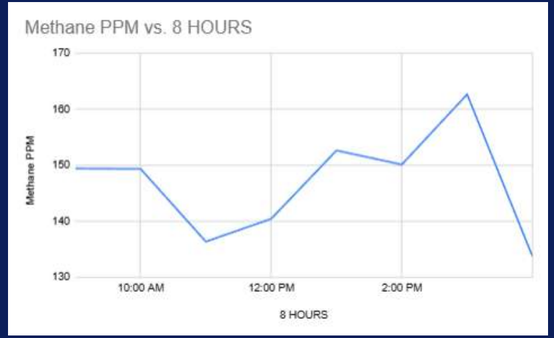
Day 3

Average: 391.78
Standard deviation: 16.35
Maximum: 414.41
Minimum: 367.63



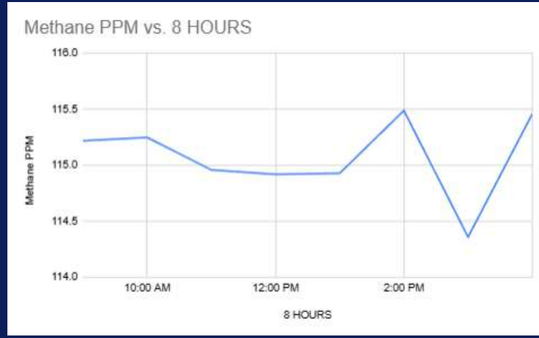
Day 4

Average: 104.60
Standard deviation: 59.52
Maximum: 188.66
Minimum: 19.39



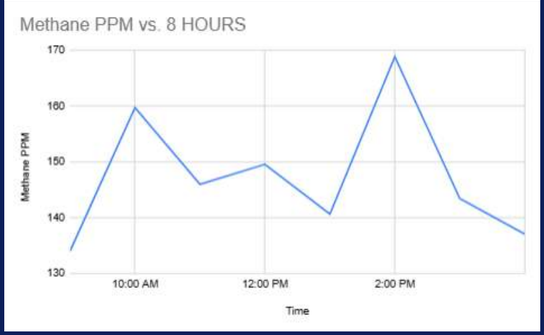
Day 5

Average: 146.87
Standard deviation: 9.49
Maximum: 162.70
Minimum: 133.76



Day 6

Average:115.07
Standard deviation: 0.37
Maximum: 115.49
Minimum: 114.36



Day 7

Average: 147.44
Standard deviation:11.76
Maximum: 168.91
Minimum: 134.04

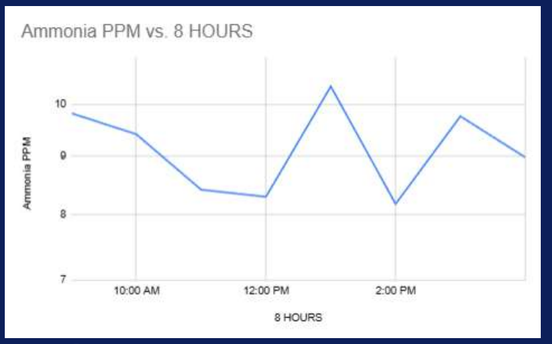
Data gathered from Day 1 to Day 7 for Methane

Day 1

Average: 3.23
Standard deviation: 2.25.
Maximum: 6.66
Minimum: 0.59

Day 2

Average: 12.02
Standard deviation: 0.87
Maximum: 13.05
Minimum: 10.14



Day 3

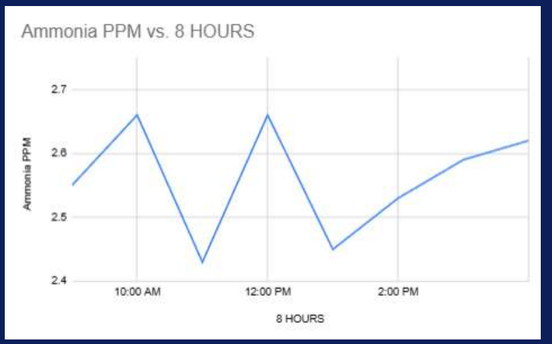
Average: 9.15
Standard deviation: 0.82
Maximum: 10.37
Minimum: 8.17

Day 4

Average: 5.07
Standard deviation: 2.03
Maximum: 6.55
Minimum: 0.55

Day 5

Average: 5.30
Standard deviation: 0.46
Maximum: 5.77
Minimum: 4.41



Day 6

Average: 2.56
Standard deviation: 0.09
Maximum: 2.66
Minimum: 2.43

Day 7

Average: 5.01
Standard deviation: 0.89
Maximum: 6.17
Minimum: 3.62

Data gathered from Day 1 to Day 7 for Ammonia

Analysis

Landfill Activity:

- Fluctuations in methane levels
  - Day 1 and Day 2: Higher methane levels
    - Potential methane release due to waste deposition or gas migration
  - Day 4: Spikes in methane levels
    - Increased methane production from decomposition processes or changes in waste management practices

- Ammonia release during decomposition of nitrogen-containing waste materials
  - Day 2: Higher readings
    - Associated with increased waste deposition or specific waste types being disposed

- Fluctuations in subsequent days
  - Indicate changes in waste composition or management practices.

Analysis

Atmospheric Conditions:

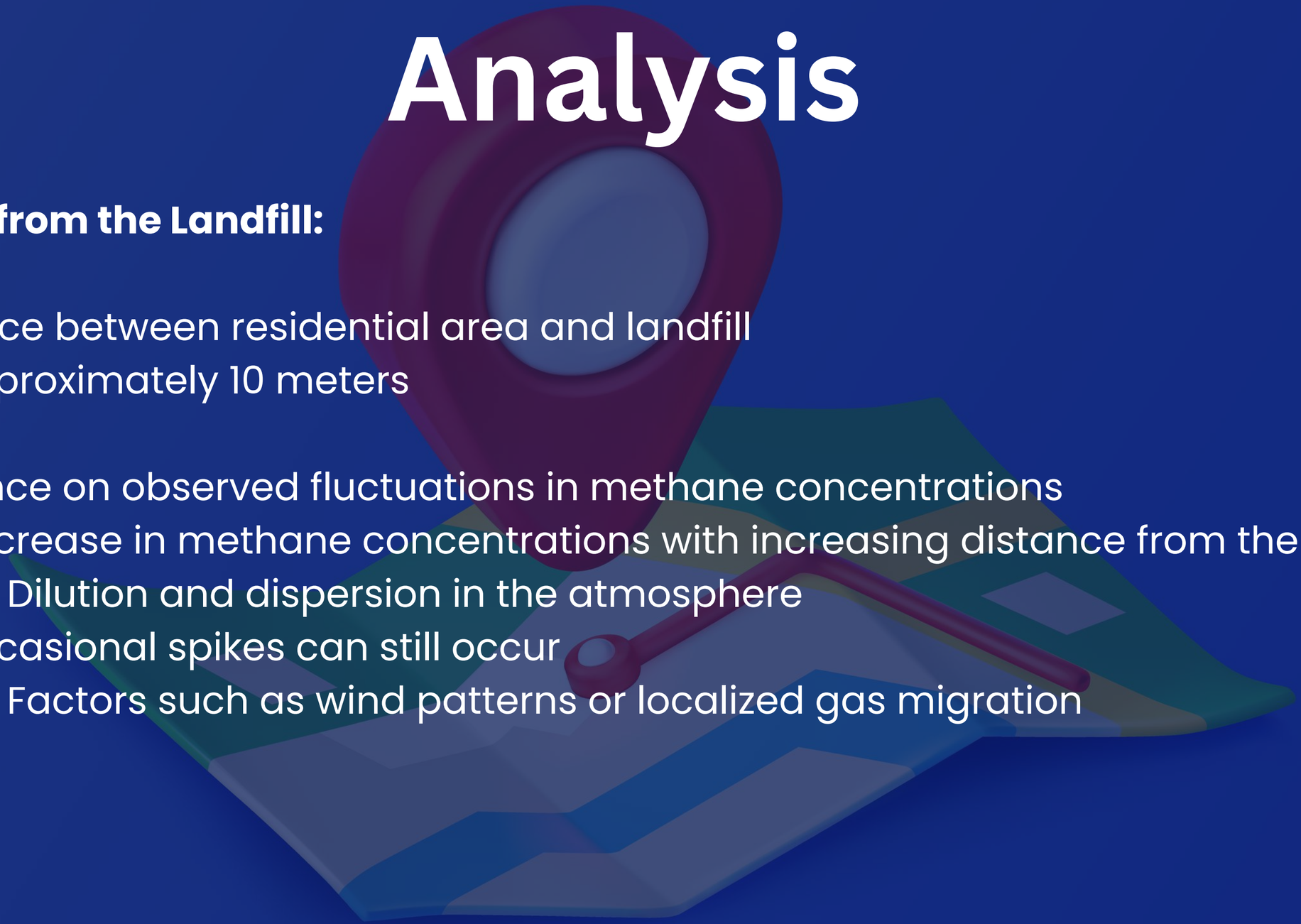
- Atmospheric conditions affecting methane dispersion and concentration
  - Changes in temperature and wind direction
- Day 3 and Day 7: Relatively lower methane levels
  - Favorable atmospheric conditions facilitated better dispersion of methane
  - Lower readings at the residential area
- Wind patterns carrying landfill emissions towards the residential area
  - Resulting in higher ammonia readings
- Changes in wind patterns or favorable atmospheric conditions
  - Can lead to lower readings
  - Improved dispersion of methane

Analysis

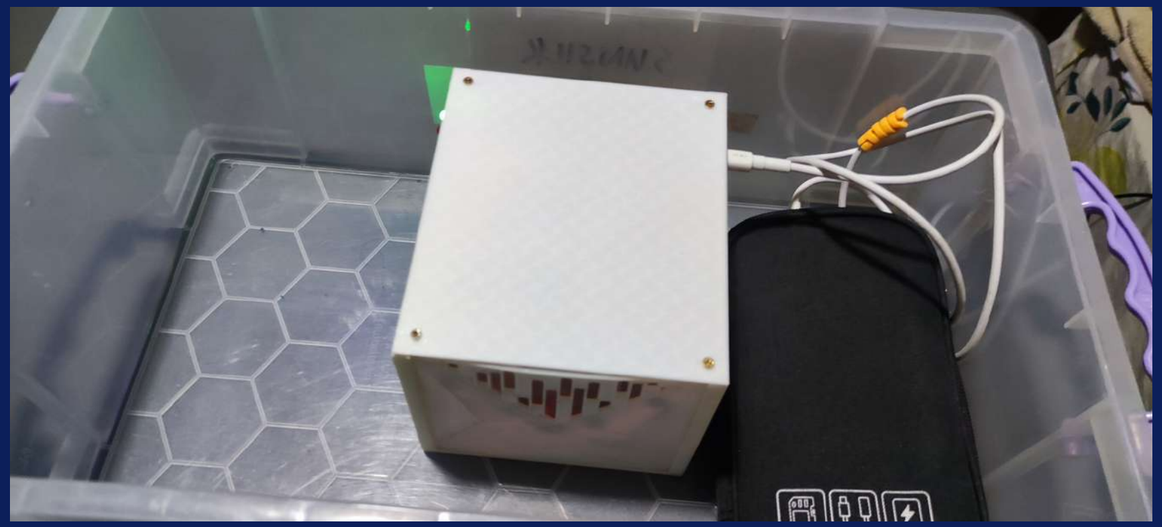
Distance from the Landfill:

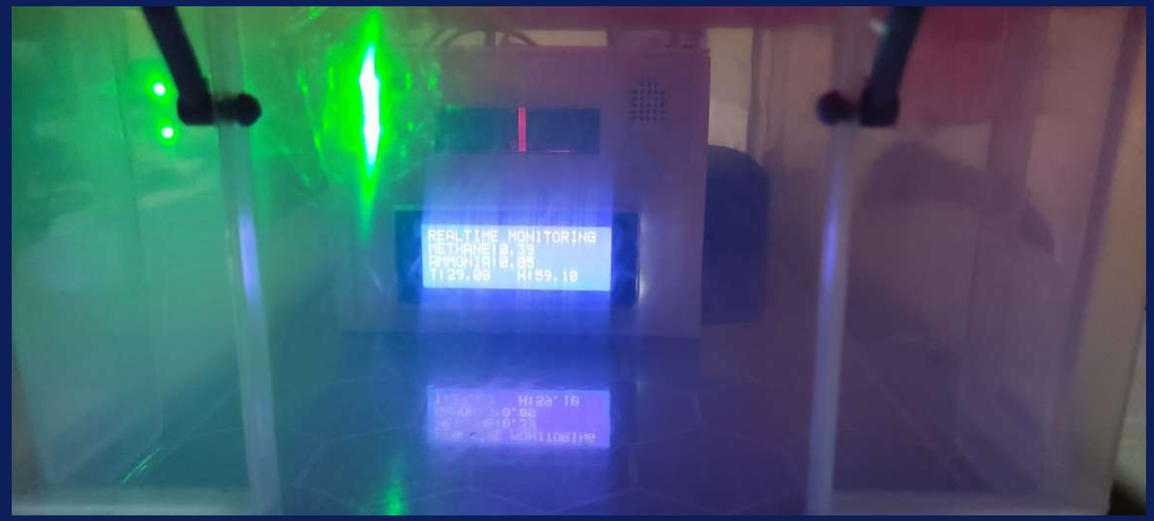
- Distance between residential area and landfill
  - Approximately 10 meters

- Influence on observed fluctuations in methane concentrations
  - Decrease in methane concentrations with increasing distance from the landfill
    - Dilution and dispersion in the atmosphere
  - Occasional spikes can still occur
    - Factors such as wind patterns or localized gas migration



UNIT TESTING RESULTS





Data from closed space area

Day 1

Average: 4.95
Standard deviation: 1.076.
Maximum: 6.75
Minimum: 3.14

Day 2

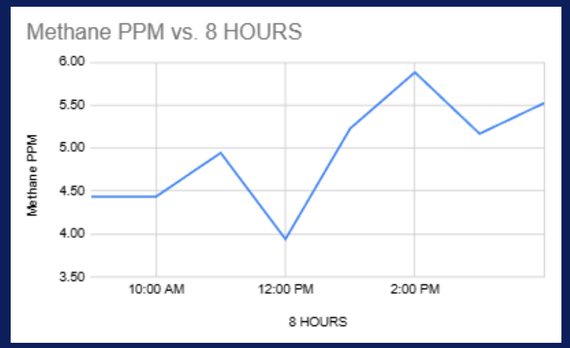
Average: 9.98
Standard deviation: 3.72
Maximum: 20.62
Minimum: 5.01

Day 3

Average: 4.09
Standard deviation: 3.26
Maximum: 9.94
Minimum: 0.17

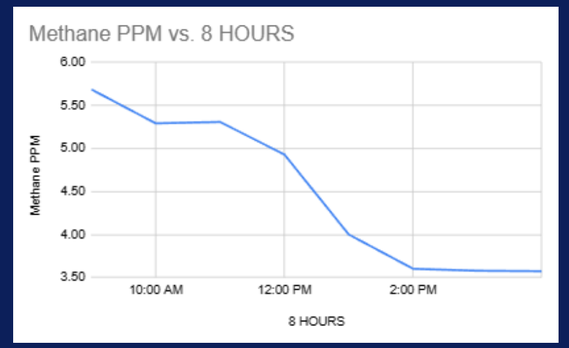
Day 4

Average: 3.98
Standard deviation: 0.89
Maximum: 5.95
Minimum: 2.21



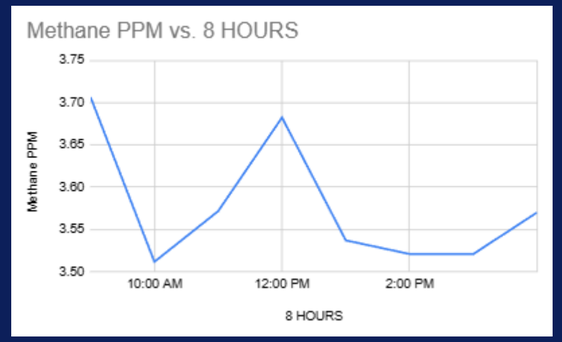
Day 5

Average: 4.95
Standard deviation: 1.00
Maximum: 6.98
Minimum: 3.11



Day 6

Average: 4.49
Standard deviation: 1.07
Maximum: 6.94
Minimum: 3.17



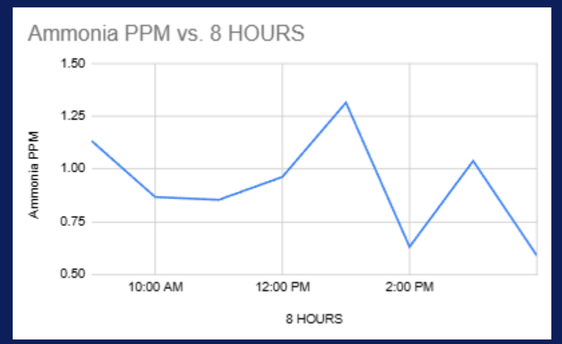
Day 7

Average: 3.58
Standard deviation: 0.25
Maximum: 3.99
Minimum: 3.11

Data gathered from Day 1 to Day 7 for Methane

Day 1

Average: 0.48
Standard deviation: 0.29.
Maximum: 0.99
Minimum: 0



Day 2

Average: 0.92
Standard deviation: 0.63
Maximum: 1.98
Minimum: 0

Day 3

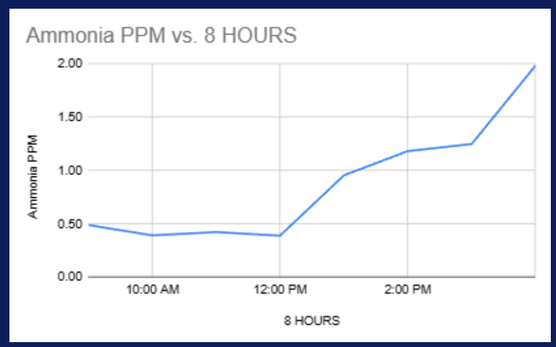
Average: 0.97
Standard deviation: 0.62
Maximum: 1.98
Minimum: 0.01

Day 4

Average: 0.69
Standard deviation: 0.47
Maximum: 1.49
Minimum: 0.01

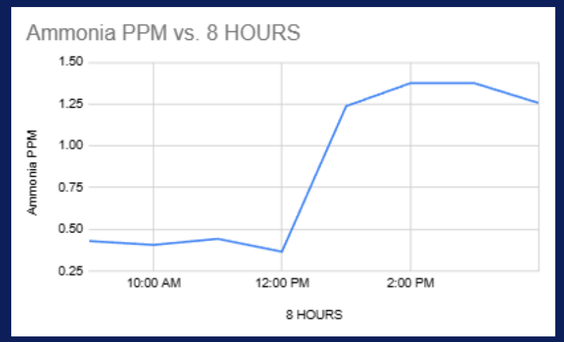
Day 5

Average: 0.78
Standard deviation: 0.48
Maximum: 1.49
Minimum: 0.01



Day 6

Average: 0.90
Standard deviation: 1.17
Maximum: 11.45
Minimum: 0.02



Day 7

Average: 0.82
Standard deviation: 0.50
Maximum: 2.2
Minimum: 0.02

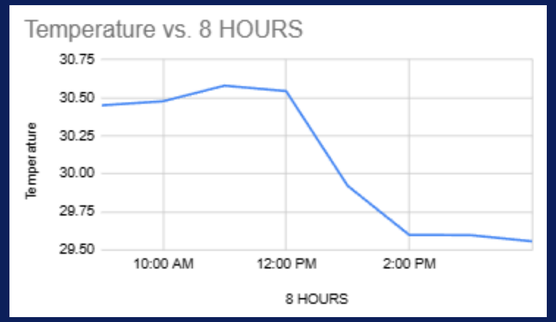
Data gathered from Day 1 to Day 7 for Ammonia

Day 1

Average: 32.61
Standard deviation: 0.24
Maximum: 33
Minimum: 32.11

Day 2

Average: 32.01
Standard deviation: 0.98
Maximum: 33.92
Minimum: 33.23

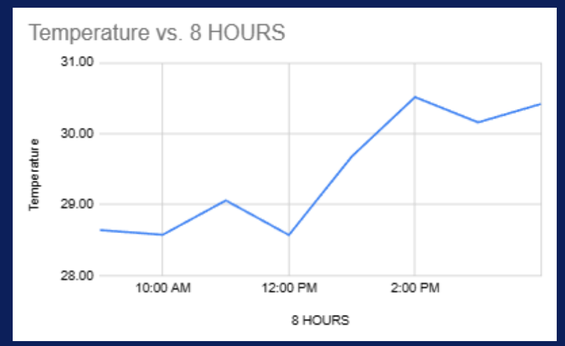


Day 3

Average: 30.084
Standard deviation: 0.76
Maximum: 31.91
Minimum: 29.12

Day 4

Average: 29.43
Standard deviation: 1.13
Maximum: 31.92
Minimum: 27.29



Day 5

Average: 29.46
Standard deviation: 1.16
Maximum: 31.82
Minimum: 27.32

Day 6

Average: 29.532
Standard deviation: 1.18
Maximum: 31.85
Minimum: 27.28

Day 7

Average: 29.38
Standard deviation: 1.20
Maximum: 31.94
Minimum: 27.26

Data gathered from Day 1 to Day 7 for Temperature

Day 1

Average: 54.56
Standard deviation: 0.28
Maximum: 55.1
Minimum: 54

Day 2

Average: 54.53
Standard deviation: 0.30
Maximum: 54.98
Minimum: 54.02

Day 3

Average: 42.26
Standard deviation: 4.44
Maximum: 49.84
Minimum: 35.15

Day 4

Average: 46.058
Standard deviation: 4.64
Maximum: 54.81
Minimum: 36.48

Day 5

Average: 46.88
Standard deviation: 4.25
Maximum: 54.68
Minimum: 38.43

Day 6

Average: 45.96
Standard deviation: 4.56
Maximum: 54.42
Minimum: 37.28

Day 7

Average: 46.38
Standard deviation: 4.79
Maximum: 54.96
Minimum: 36.76

Data gathered from Day 1 to Day 7 for Humidity

Analysis

The methane levels in the closed space area ranged from approximately 3.58 parts per million (ppm) on Day 7 to 9.98 ppm on Day 2. The data indicates fluctuations in methane levels throughout the monitoring period.

Ammonia levels: The ammonia levels in the closed space area varied from around 0.48 ppm on Day 1 to 0.97 ppm on Day 3. The data shows some variability in ammonia levels during the monitoring period.

Summary of the Findings

Methane Levels:

Closed space area: 3.58 to 9.98 PPM
Calajunan Dumpsite: 19.39 to 730.91 PPM (higher than closed space area)

Ammonia Levels:

Closed space area: 0.48 to 0.97 PPM
Calajunan Dumpsite: 0.55 to 13.05 PPM (generally higher than closed space area)

- The landfill area showed significantly higher methane and ammonia levels compared to the closed space area.

- The prototype demonstrated its reliability in detecting elevated gas concentrations in the landfill area.

Conclusion

- Developed IoT-based hazardous gas monitoring and notification system.
- Functionality and reliability demonstrated.
- Prototype successfully detected methane and ammonia levels.
- Real-time data monitoring displayed on LCD interface.
- Integration with ThingSpeak IoT platform for data visualization and remote access.
- Buzzer sound and LED indicators for immediate feedback.
- Email notifications ensured user awareness regardless of proximity to device.