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COLLEGE OF SCIENCE AND TECHNOLOGY

IOT BASED TOXIC GAS DETECTION AND LEVEL OF LANDFILL

(Case Study: NDUBA LANDFILL)

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College of Science and Technology

African Center of Excellence in Internet of Things

Msc in Internet of Things-Wireless Intelligent Sensor Networking

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RESEARCH THESIS TITLE

"IOT BASED TOXIC GAS DETECTION AND LEVEL OF LANDFILL"

(Case: NDUBA LANDFILL)

A dissertation submitted in partial fulfillment of the requirements for the degree of Masters in Internet of Things -Wireless Intelligent Sensor Networking.

By

Jacqueline MUKAMANA (Ref No: 220004047)

Under the Guidance of

Supervisor: Dr JAMES RWIGEMA **Co-Supervisor: Dr ALEXANDER NGENZI**

CERTIFICATE

This is to certify that the" **IOT BASED TOXIC GAS DETECTION AND LEVEL OF LANDFILL**" research project work is a record of the original bonafide work done by **Jacqueline MUKAMANA (Ref.No:220004047**) in partial fulfillment of the requirement for the award of a Master's Degree in Internet of Things-Wireless Intelligent Sensor Networking from the University of Rwanda-College of Science and Technology through the African Center of Excellence in Internet of Things, during the Academic year 2019-2021.

Date: …../…../…… **Date: …../…../…..**

…… .....

Dr James Rwigema **Dr Alexander NGENZI**

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DECLARATION

I, Jacqueline MUKAMANA (Ref. No:220004047), declare that the research thesis titled "**IOT Based Toxic Gas Detection and Level of Landfill** " for the award of a Master's degree in Internet of Things-Wireless Intelligent Sensor Networking is my original work and has never been presented in any University or Institution for the same purpose.

Signed by

Jacqueline MUKAMANA (Ref.No: 220004047)

Date:……./…../……

Master Student in Internet of Things-Wireless Intelligent Sensor Networking.

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LIST OF ACRONYMS

Co2: Carbon dioxide

NH3: Ammonia

CH4: Methane

DS18B20 Waterproof Temperature Sensor:

SMS: short message service

BLE: Bluetooth Low Energy

REMA: Rwanda Environment Management Authority

CoK: City of Kigali

SLW: Solid and Liquid Waste

RCL: Rwanda Compost Ltd

IOT: Internet of Things

PAC: Public Accounts Committee

SDGS: Sustainable Development Goals

IPV6: Internet Protocol Version 6

IoE: Internet of Everything

ICT: Information Communication Technology

USA: United States of America

LFG: Landfill Gas Emission

GPS: Global Positioning System

RFID: Radio Frequency Identifier

GIS: Geographical Information System

GSM: Global System for Mobile Communication

GPRS: General Packet Radio Service

GPS**:** Geographical Positioning System

RS: Remote Sensing

Wifi: Wireless Fidelity

VHFR: Very High Frequency Recorder

LandGEM: Landfill Gas Emission

H&E: Health and Environment Department

L.A: Local Authorties

P.C: Private Company

W.L: Workers on the Landfill

C: Citizens

MQTT: Message Queuing Telemetry Transport

RURA: Rwanda Utilities Regulatory Authority

TTL: Transistor–Transistor Logic

Ppm: Particle per Molecule

IC: Integrated Circuit

SPI: Serial Peripheral Interface

UART: universal asynchronous receiver-transmitter

I²S: Inter integrated Circuit

CPU: Central Processing Unit

DMA: Direct Memory Access

REST: Request, Response Model

API: Application Programming interface

CSV: JavaScript Object Notation

HTTP: HyperText Transfer Protocol

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ABSTRACT

As the world's population grows, so does the amount of waste increased. The majority of landfill emits toxic gases into the environment and the people living near landfill. For the sake of safeguarding the health and wellbeing of the environment and people, efficient landfill management is required. According to the conclusions of the Literature Review, emerging countries continue to face issues in managing landfills due to the economic impact, new technologies necessitate new infrastructure, and even current technology requires qualified and knowledgeable people. As a result, an IOT-based Toxic Gas Detection and Landfill Level was built using ultrasonic sensor, gas sensor, temperature sensor to gather data from physical environment which is Nduba landfill and those data are being processed by microcontroller and are transferred to the Adafruit IO Cloud Service using wifi. Then TwilioSms Application Programming interface send text messaging of status of Nduba Landfill to the concerned Persons. The goal of the thesis is to improve the management of the NDUBA Landfill in the GASABO District. This goal is reached through the use of qualitative methods in the research thesis. The results obtained would be helpfully to reach on Sustainable Development Goals like Good health and well-being of the people, clean water and Sanitation and Climate Action.

Keywords: Toxic Gas Detection, Landfill Level Prediction, IOT Cloud Platform and Notification System

CHAPTER 1: INTRODUCTION

Nowadays, the increasing of Population in our Country of Rwanda affects the increase of waste means in our environment many harmful gases affect the nearest Society produced by Landfill. The biggest challenge in landfill management is getting the real-time information needed to the concerned authorities regarding the Level of Landfill and Detection of the Harmful gas provided from the Landfill for decision-making or other measures to be taken. Those Gases are harmful to the Environment and nearest Society of Landfill because the problems like Cholera, Skin Diseases, Cancer and Breathing Problem, etc may encounters to these society and environment.

The prototype system of an IOT Based Toxic Gas Detection and Level of Landfill is the system that mainly focused on the Gas Detection, Level of Landfill by deploying different sensors like Gas Sensor to detect Toxic Gas which are Methane (CH4) gas, Carbon Dioxide (CO2), Ultrasonic Sensor used to indicate the level of Landfill, With a simple 1-Wire interface, the DS18B20 Waterproof Temperature Sensor Probe is used to precisely monitor temperatures in wet situations. This system helps to notify the Concerned Authorities based to the threshold values of Produced Gas and Level of Landfill. Those notifications will be sent to the concerned Authorities via SMS Notification where Local Government are responsible to take decisions or other measures like producing Compost from that waste storage Tank used by the Farmers for increasing the productivity of the soil and searching the way to relocate the nearest Society to protect against Hazardous or harmful gases caused by Landfill Gas Emission. ESP32 Development Board is a Microcontroller with built in wifi and Bluetooth BLE for processing the entered data from the perception Layer and a Communication Technologies for accessing real-time information stored on a Cloud server for further Processing, analytics, and Storage using Personal Computer or smartphones.

1.1. BACKGROUND

In Rwanda, precisely in Kigali City, we have two Dumpsites for waste disposal. Where One Landfill is located in NYANZA, KICUKIRO District, and the other one is Located NDUBA Sector in GASABO District. The Nyanza site in Kicukiro District has a surface area of 20.8 Ha, opened in 1983 and closed in 2012 after 29 years of service. Nduba dumpsite starts its operations on 1st May 2012 after the closure of the Nyanza landfill. Nduba Landfill started with a surface area equivalent to 15 ha and there is an additional area of 19 Ha that enables landfills to be secured for future expansion of the solid waste management project[1] .

Currently, the active landfill is 28.6 ha, and the expansion area of the landfill is 24 Ha. The total area of the landfill is 52.6 Ha, however, the buffer zone to the Landfill is estimated to 18 Ha.
Currently, Nduba Landfill receives on daily basis between 500-550 tons of solid waste
Collected across the entire city of Kigali [2] .After the City of Kigali is facing the issue of poor management of solid waste management value chain related mostly to the operational challenges of the existing dumpsite at Nduba. This indicates that is not a sanitary landfill and there are both environmental and health impacts from the waste disposal because Nyanza dumpsite as a closed dumpsite since 2012 is always subjected to landslides issue and any other contamination of the surrounding areas especially the fauna and flora near the closed dumpsite.
The Nduba dumpsite was created to avoid potential disasters, poor sanitation standards, and other concerns, however it has issues such as not having technology used in management of landfill and not having the way of detecting toxic gas presence[3]. These figures represent the old pictures of Nduba Landfill and current pictures highlighting the improvement in terms of the daily management of Nduba Landfill [1].
This figure below indicates how the wastes are disposed in recent years .

Figure 1-1: Old Pictures of Nduba Landfill

1.2. PROBLEM STATEMENT

Cities are becoming increasingly more polluted as a result of population increase and improved living standards around the world, and diseases are spreading at an alarming rate, causing serious health difficulties. The primary challenges in landfill management systems include how garbage is managed and appropriately disposed of, as well as the toxic gas produced by landfills. In fact, there is an increasing concern associated with the waste provided by Citizens of Kigali City while the Land is remaining Constant and as there is an increase of temperature, the toxic gases generated at high rate and can cause the health problem on the nearest people of landfill. Therefore, those populations produce much more waste collected and deposited in only one Landfill of Kigali City located at Nduba Sector, NDUBA hill is located in Muremure cell, about 10 kilometers from Kigali. [3] This Landfill produces toxic gases that harmful the nearest Society of Landfill.

The waste deposited in NDUBA Landfill generates Toxic Gases like Methane Gas, Carbon Monoxide, Carbon dioxide, Ammonia.

As there is increases of Waste produced by the population of Kigali City thus enables many harmful gases to be generated and are dangerous to the nearest Society of Landfill, Environmental and Ground Water. Toxic gases can cause a lot of problems, including death, as well as respiratory problems, cancer, skin disorders, and other health issues.

The Research will solve the above highlighted challenges caused by the harmful gases provided by Landfill in order to protect the nearest Society by relocating them before facing the problems associated with the harmful or poisonous gases, protect also the environment and Ground Water[4].

In 2016, During the Audit Report made by the Office of Auditor General of State Finances, RWANDA talked about "Performance audit on management of solid and liquid (sewage) waste in kigali city from May 2012 to December 2015" Indicated that through the reviewed Documentations regarding guidelines on how gases can be treated and noted that guidelines issued by REMA provide all measures regarding the treatment of gases and the main concern is that they are not applied by the CoK (City of Kigali). This will lead to the adverse impacts if not fixed [4].

Office of Auditor General of State Finances, RWANDA recommends that CoK take advantage of SLW by transforming it into compost and biomass in order to limit the amount of gases released into the atmosphere. In addition, CoK should put in place suitable measures to address all long-term impact of improper solid and liquid waste management for long-term environmental protection [4].The Cok stated in the management comment that they will minimize the emission of gases into the environment by waste compaction and soil coverage, but they will also put in place procedures to ensure waste is transformed into compost or other non-polluting products [4].

Rwanda Compost Ltd (RCL) had secured a 25-year concession to build and run a composting facility at Nduba waste, according to the proposed composting plant at Nduba landfill. However, the contract was terminated by the City of Kigali after the investor failed to meet the contract's requirements.

MP Suzanne Mukayijore stated in the [21] that water contaminated by landfill garbage infects into the water that residents in the surrounding town fetch for consumption, causing a serious health issue to them.

PAC President Muhakwa Valens told IGIHE that the City of Kigali has decided to conduct a preliminary study, which will show how much money should be spent [20]. Based on the gap still exist in the management of Nduba Landfill of providing harmful gases, water contamination, Cleanliness and Sanitation.

1.3. MOTIVATION

Referring to the reports of many Institutions that have been revised and the information that were collected indicates Nduba landfill can be described as an open-air dumping site, and they demonstrated that it has a lot of environmental issues [5]. These include a lack of management, as seen by the Auditor General's assessment of Kigali's waste management. This results in dangerous methane gas explosions, as well as leachate flowing into nearby neighborhoods, bad smells, and the presence of mosquitoes in the landfill and environmental society. [5]. Due to these challenges, I feel motivated to undertake the Research on Landfill management of NDUBA Located in GASABO District of Kigali City where an "IOT Based Toxic Gas detection and Level of Landfill" will help to detect Toxic Gases, Level of Landfill and notifying the concerned persons when the threshold value reaches at high rate and can cause some problems. Thus, the Prototype solution is also developed for the purpose of protecting against those harmful Gases from nearest society and Environment.

1.4. OBJECTIVES

1.4.1. GENERAL OBJECTIVES

To design and implement an IoT-based Toxic Gas Detection and Landfill Level Management system. Nduba Landfill is a case study.

1.4.2. SPECIFIC OBJECTIVES

- ✓ To design a new system that uses the Internet of Things Technology for better management of Nduba Landfill.
- ✓ To design a prototype system that detect toxic gases, landfill level, temperature and give notification to the relevant persons who has responsibilities of taking measures based on the real time information highlighted by landfill.
- ✓ To help Local Authorities to know information at real time and helps to take decision to relocate the nearby society of landfill before being damaged by the produced Toxic gas when the threshold value of toxic gases reaches to the highest level.

1.5. STUDY SCOPE.

This thesis focuses on the management of landfill where the wastes are disposed. This research will be focusing on Toxic Gas Detection, Temperature and Level of Landfill in a waste Storage Tank and Notification to the Concerned Persons. The study will be limited to improve the ways of managing Nduba Landfill by detecting the presence of harmful gases, Temperature and the Level of Landfill refers to the threshold values that were highlighted. Within the implementation of a prototype, the solution will eliminate the gaps existing in the Literature during the detection of harmful gases and the Level of Landfill.

1.6. HYPOTHESIS

IOT Based Toxic Gas Detection and Level of Landfill will come up to solve the challenges faced of not getting information at real time about the management of Nduba Landfill. This prototype will be used to facilitate the concerned persons for taking decisions or measures according to the real-time information obtained. This research will help also the nearest Society to protect against harmful gases produced by Nduba Landfill by following the Rules and Guidelines given by the Local Government. Thus, the Good Health and Well-being, Clean Water and Sanitation, Sustainable Cities and Communities, and Climate Action will be achieved.

1.7. SIGNIFICANCE OF THE STUDY

The thesis aim is to design and implement an IOT Based Toxic Gas detection and Level of Landfill in waste Storage Tank, especially NDUBA Landfill located in Kigali City, GASABO District, NDUBA Sector. The project can serve the implementation of real system solve the addressed problem caused by Toxic Gas generated from NDUBA Landfill and enables the Landfill to contribute to the achievement of Sustainable Development Goals (SDGs) connected to the environment and the well-being of the local community. SDGS, for example, has GOAL 3: Good Health and Well-Being, GOAL 6: Clean Water and Sanitation, GOAL 11: Sustainable Cities and Communities, and GOAL 13: Climate Action.

1.8. ORGANIZATION OF THE STUDY

Chapter one (I): This chapter introduces the research thesis's background and describes the research thesis's motivation. The introduction to technologies is followed by a description of problems statement that set the objectives, the study scope, significance and organization study for this project. The chapter ends with a conclusion.

Chapter two (II): Is the description of the Landfill management by detecting Toxic Gases and Level of Landfill basing on gaps and technologies reviewed in existing systems for IOT Based Toxic Gas detection and Level of Landfill in cities and how these technologies have been implemented.

The Chapter three (III): Indicates the methods used for this Research thesis, system design, prototype model and their parameters.

Chapter four (IV): Discusses on obtained results and makes analysis based on graphs findings.

Chapter five (V): Concludes the discussion and finals remarks.

CHAPTER 2: LITERATURE REVIEW

This chapter will illustrate the challenges of using Internet of Things Technology in developing countries, obstacles happen in developing countries as well as the description of technologies and the uses of those technologies based on the existing research.

2.1. CHALLENGES OF INTERNET OF THINGS IN DEVELOPING COUNTRIES

Some of the most modern systems and infrastructures have become so complicated that they are difficult to manage properly. While many aspects of daily life have become more interconnected, others have remained unsatisfyingly under connected. Other aspects of a person's everyday life, on the other hand, may be more difficult because the integration of new devices will necessitate new infrastructure and technology.[6]

In developing countries, technological and human capabilities are frequently insufficient. Financial support for integrating new technology is insufficient. In local communities, there aren't enough technically skilled people with IT abilities who can integrate the usage of sensors and other devices into their daily lives[6] **.**The following is the list of new IoT challenges[6] are shown in the following Figure 3:

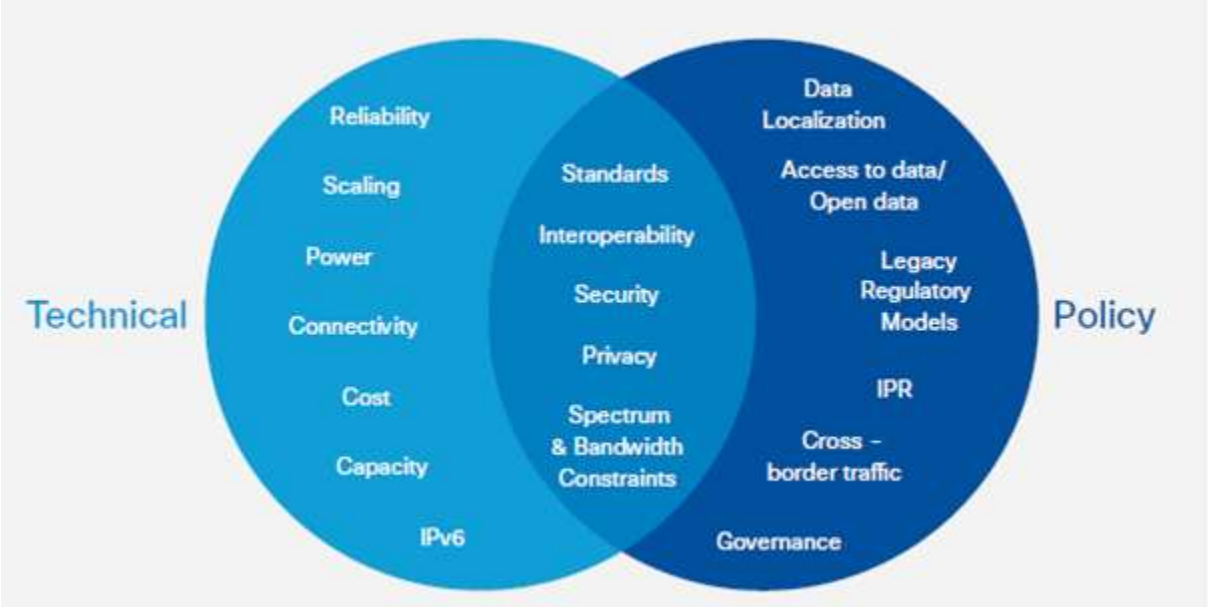

Figure 2-1: Indicates technological and policy considerations in respect to IoT and data challenges.

In the above figure, Reliability is described as the problem of assuring the lifetime of devices to resist external conditions, where sensors must be standardized to ensure high accuracy. In terms of scalability, determining which resources are scaled to match IoT growth could be challenging. To improve present capabilities, data centers, for example, are constantly updated in terms of electrical power, cooling resources, and space architecture. The connectivity requirements of billions of connected things, as opposed to millions, place extremely different demands on data centers. IP networks must be able to manage the massive scale of device connectivity as the Internet of Things scales up from billions to tens of billions of linked devices. The data network coverage will also hinder connectivity. Then there's power, which varies a lot, with higher bandwidth devices requiring a lot more. [6]

Because IoT applications are developed and managed with the help of many IoT devices, the expenses associated with sensors, connectivity modules, and connectivity service may still be too expensive for many interventions. Inadequate human capacity may be a major issue in some areas, resulting in small-scale businesses not being properly trained to use this Internet of Things technology.

Human behavior may pose additional difficulties, since people are frequently resistant to changing their behavior to match with systems, preferring instead for systems to adapt to meet their demands by adopting some technical hurdles to overcome the barriers that occur in developing countries. According to Deloitte, one electrical utility provider installed smart meters in millions of homes across North America in the hopes that users would check online dashboards of monthly usage and change their behavior to save money and energy while also helping the environment. Only 6% of homes had consulted the dashboard at all three years after the meters were installed, and fewer than 2% had consulted it more than once.

Shift to IPv6 has made difficult for several countries and companies in the short term. [6]

In terms of policy issues, data localization requirements and cross-border traffic barriers may limit managers' capacity to send data to cloud-based servers for analysis. While governments are increasingly adopting Open Data rules, there are examples of governments restricting access to data gathered and created by sensors.

As legacy regulatory models (e.g. power utility regulations) may prove inadequate to deal with new technologies (e.g.'smart grid' technologies), the 'full' IoT or Internet of Everything (IoE) is likely to require more 'joined up' regulation, with telecom/ICT regulators working more closely with their counterparts in data protection and competition, but with emergency services, health and highway authorities, as legacy regulatory models (e.g. power utility regulations) may prove Similarly, greater governance issues may cause the Internet of Things (IoT) to be delayed)[6].

In large-scale IoT deployments, privacy and security are frequently mentioned as two of the most important (and closely linked) challenges. Anonymity, privacy, and security are all connected but distinct concepts. The ability to define the intended target audience for data (connected to secrecy) is known as privacy. The attribute or situation of being unknown to the majority of people is known as anonymity. A secure system is one that is free of errors or vulnerabilities.
The address space of linked devices is another issue relating to privacy and security. Identifiers used in one network must be understandable and/or useful in another network (i.e. interoperable). There will be billions of things in the Internet of Things that must be uniquely recognized, a task for which there is presently no internationally accepted solution, however Internet Protocol version 6 (IPv6) may eventually become the standard. Spectrum and bandwidth constraints may inhibit IoT device and service adoption. Car IoT devices will generate a broad set of network requirements, resulting in higher prices for wireless spectrum to allow wireless data transmission[6].

2.2. OBSTACLES OF LANDFILL MANAGEMENT HAPPEN IN DEVELOPING COUNTRIES.

Few countries have made initiatives to build, maintain, or operate landfills at the national and municipal levels. The majority of African countries disposed of solid trash in open landfills. South Africa was the one exception, as well as the only country having particular legislation and guidelines managing solid waste disposal [7] .Some African countries are beginning to improve their waste disposal policies. Kampala City, Uganda, built a landfill with World Bank funding, while Ghana plans to create its first properly sited, engineered, and constructed landfills with the World Bank's "Urban Environmental Sanitation Project." Tanzania, Botswana, Namibia, and Rwanda, among others, were looking for locations to build new landfills. [7].

The strategies used to solve waste collection and management issues in developed countries differ from those used in developing countries, and these differences must be explored in greater depth to better understand the barriers to the implementation of sustainable waste collection and management in both socioeconomic groups [8]. For the purposes of this research, it appears that obstacles to sustainable trash collection and management will be addressed in both developing and developed countries in the next decades [8].

Urbanization, inequality, economic growth, cultural and socioeconomic aspects, policy, governance and institutional issues, and international influences are all barriers to integrating solid waste management in developing countries, limiting not only the applicability of successful approaches in developed countries, but also the burden placed on municipal budgets due to the cumulative generation of waste. The financial problem on the municipal budget made implementing an integrated solid waste management system even more difficult[8]. In developing countries, the economic barrier is one of the most significant obstacles to implementing integrated solid waste management. It means that implementing financially sustainable solid waste management services in developing countries is a huge problem, as demonstrated by the case of Bahir Dar, Ethiopia (Lohri et al. 2014)[8].

Because Rwanda is an African developing country, the City of Kigali planned a number of programs (from 2013 to 2018) to address the problem of solid and liquid waste management by implementing the conversion of waste to energy, which not only solves the waste problem but also provides energy, construction of a composting facility that will produce compost manure (fertilizer) from biodegradable garbage, constructing an incinerator to burn toxic and infectious waste, design for a new landfill and recycling center that would allow for the long-term management of SLW while also reducing waste volume through recycling. Following that, according to the Office of Auditor General of State Finances' Audit Report, only the project of creating an incinerator has been implemented out of the four above.

Based on the gap still exist because Nduba Landfill doesn't have an IOT Technology used for detecting harmful gases, level of Landfill and notifying the relevant person. It is in this regards, an IOT based Toxic gas detection and level of Landfill prototype system would be designed and implemented.

2.3. LANDFILL MANAGEMENT IN DEVELOPED COUNTRIES

The initial waste policy tools, developed in the 1970s in most developed countries, concentrated primarily on the regulation of technical requirements to control and avoid contamination caused by faulty waste management [8]. These regulatory or "command and control" instruments are primarily based on emission limit values for specific pollutants or guideline value concentrations of pollutants in various environmental compartments (e.g., air, water, and soil), both of which are generally established based on their toxicity to public health.

The challenges and obstacles that industrialized countries face are largely related to new waste management paradigms, but they are also related to waste management's foundation. In similar to existing computing, each of the identified barriers and challenges where ICTs automated several elements of waste management, namely data gathering, identification, communication, storage, and analysis, are addressed in this paper [8]. Although LFG management began in the 1960s and 1970s in the United States, the first LFG usage technology was installed in Germany in mid-1970 [9]. When a landfill is mismanaged, it can result in uncontrolled emissions of LFGs such as CH4 and CO2, which contribute significantly to climate change; strong smell, litter, and dust in the surrounding area; and seepage of leachate generated in the landfill into ground and surface water. In developed countries, this LFG Technology is used to generate electricity while lowering greenhouse gas emissions, stench in the surrounding area, and other factors [9].

The majority of African countries have insufficient electrical generation. As a result, as the Moroccan government has done, developed countries encourage African countries to employ LFG technology transferred from developed countries to improve LFG utilization plants, reduce toxic gas emissions and pollution, and offer revenue and energy to people. The developed one then advises developing country authorities to encourage and establish more landfill sites in order to reduce the number of illegal dumpsites in Africa. [9]

2.4. DESCRIPTION OF TECHNOLOGIES

In landfill waste management, information and communication technology (ICT) plays a critical role. As shown in table 1, the various ICT technologies used in solid waste management are divided into four categories: spatial technologies, identification technologies, data acquisition technologies, and data communication technologies. These technologies are used to plan, monitor, collect, and manage solid waste[10] and are described below as some of them could be used in Landfill management.

Table 2-1: Technologies: Overview

Classification	**Sub class**	**Application**
Spacial Technologies	GIS	Site selection, environmental impact assessment, features monitoring, planning, management, optimization and estimation, billing
	GPS	Optimization of routes and collections, vehicle tracking, planning, scheduling, and billing
	RS	Site selection, environmental impact assessment, and feature monitoring are all steps in the process.
Identification Technologies	Barcode	Garbage management, intelligent recycling, waste disposal, landfill space reduction, and risk management are all examples of risk management.
	RFID	Tracking, optimization, sorting, and recycling of bins and drivers
Data Acquisition Technologies	Sensors Sorting Imaging	Sorting, optimization, measurement of moisture, energy, and odor, and scheduling Sorting waste, optimizing routes and collections, and monitoring
Data Communication Technologies	GSM/GPRS ZigBee WiFi Bluetooth VHFR	Communication over a long distance Communication across a short distance Communication across a short distance Communication across a short distance Communication over a long distance

Among the technologies, Internet of Things (IoT) mostly enables to have smart devices used to collect data from physical environment, exchange data, analyze data and give real time decision making based on the exchange of the data. IoT related research has been undertaken on how the waste in the landfill are monitored and managed. As illustrated in the study [11] works on a Smart Garbage Management and Clearance System based on the Internet of Things, which uses sensor systems to verify the waste level against the threshold value set before over the dustbins. This system changed to concern approved by GSM/GPRS Communication Technology as soon as it was recognized. According to this, I see that they are limited on checking the level of Landfill and send a notification to the Authorized Users; the only gap is that there isn't a way of Detecting the Gas Presence.

In the study [12] works Using Arduino to create a Garbage Alert System Garbage is monitored using smart sensors, and when it reaches a certain level, the driver sends out a signal using an RFID tag, and the bin is cleaned right away. In relation to this, I observe that they are only allowed to check the garbage level and send a notification to the driver, the gap of detecting the Gas Presence, notification to the Concerned Authority Like Company and Local Government.

Manoj Kumar Naidu Katta proposed management of using the internet of things to collect garbage is a waste of time. With the use of sensors, poisonous gases and odors are prevented. Bacterial and viral infection causes serious diseases; the internet of things is being utilized to safeguard the population from these diseases. Here, there is Gap in detecting the Presence of Gas and the Level of Landfill[13].

This study [14] works on a smart bin method that assists the public in remaining safe and clean. In this case, sensors are installed in public bins to detect the level of waste in the container. When garbage hits the threshold limit, the status of the bin is updated in the cloud, and the concerned authorities can access this status to take prompt cost-effective measures. As a result, consistent garbage bin management will help to maintain the environment clean and safe.In this paper, there isn't a way of Detecting Gas presence.

In this study [15] proposed The system monitors the garbage bins and informs on the level of waste collected in the garbage bins via a web page, according to the Smart Garbage Management System using the Internet of Things (IoT).

All information is also sent to waste collection vehicles via this website. According to this, I see that they are limited on checking the level of garbage and send a notification to the garbage collection vehicles; the only gap is that there isn't a way of Detecting the Gas Presence.

Study [16] proposed IoT-based Smart Garbage Detection System that allows for two-way communication between city infrastructure and operators/administrators. Our goal is to create a centralized system for real-time management. As a result, both the municipality and the inhabitants benefit from an efficient system that saves money and reduces pollution in the city.

Refers to the study [17], propose a cost-effective and efficient system for remotely managing landfill subsurface methane and carbon dioxide concentration levels, we've called it Remote Real-Time Management of Subsurface Landfill Gas Migration. The proposed sensing platform was capable of executing complicated analytical measurements in situ and successfully transferring the results to a cloud database based solely on an autonomous sensing architecture. .In this paper, there is a gap for notification to the concerned Authorities, which means that they have to access Information from Cloud Server. And they use Temperature and Humidity Sensor Separately while I use DB DS18B20 Waterproof Temperature Sensor that sense the temperature in wet environment. This study proposed [15], this uses sensor devices to monitor the garbage level in the bins. As soon as it was discovered, the system was changed to a concern permitted through IoT. By automatically cleaning waste and providing a more effective solution for citizens, this initiative provided a new approach for integrating IoT for the green environment. According to this, there is only one gap in terms of detecting the presence of gas..

In the study [18] proposed GSM-Based Notification System and Location Tagging Using GPS for Smart Recycle Bin for the design and development of a system to detect the level of recyclable waste in a smart recycle bin and then send notification signals including the locations coordinates to assist the authority in collecting and emptying the bin, and then the use of GSM module to enable the SMS text notification system and some software to manage all the notifications received from the bin. The only difficulty here is detecting the presence of gas.

In the study[19] this work develops a system that enhances waste management authority in planning and combating the threat of improper solid waste disposal based Geographical Information System, where this work develops a system that enhances waste management authority in planning and combating the menace of improper solid waste disposal.

The created method addresses the issues of waste bin distribution and relocation, the lack of recyclable waste bins, and the lack of direct communication between citizens and waste management authorities. For preprocessing and accessibility by authorized users, there is a lack of notification and cloud platform. This study [20] The level of the bin is monitored on a regular basis in the suggested system, and real-time analysis can be performed on a webpage at any time and from anywhere in the globe. When the bin is full, it sends a text message to the garbage collector informing him that "THE BIN IS FULL." In the study [21] Worked on a cloud-based IOT-enabled Solid Waste Monitoring system for smart and connected communities, in which solid waste is recognized by containers and sent to an IOT Cloud Platform, where things communicate over WiFi. This is restricted to the amount of solid waste in the container and Twitter notification.

2.5. USE OF THE TECHNOLOGIES BASED ON THE EXISTING RESEARCH.

However, this is limited to a few developed countries, while there are few policies and controls for landfill gas emissions in Africa.

The lack of skilled expertise, inadequate knowledge of the technology involved, lack of political will, inadequate funding for LFG utilization projects, and control of the power sector are all factors that could have influenced the low development of LFG utilization in Africa, according to this article[9].

Table 2-2: Overview of research, technologies and Benefits in various contexts

Study	Developed countries	Developing countries	Technology or Model	Research	Benefits
[9]	German		LFG (Landfill Gas) Technology	A Review of Africa's Landfill Gas Production and Utilization	To generate Electricity
[22]	USA		Waste –To- Energy Technology	Municipal solid waste is a significant renewable energy resource: a global	to generate heat and energy

				opportunity for energy recovery through Waste-to-Energy Technologies	
[23]		Malaysia	Technology for renewable energy	An overview of the Malaysian context for energy recovery from municipal solid wastes (MSW).	To produce Electrical energy
[24]	United States		Interpretive structural modeling	Interpretive structural modeling was used to examine development obstacles in landfill communities.	Use of low-cost technology to convert municipal waste into a renewable resource
[25]	Greece		LandGEM (Landfill Gas Emission) emission model	Estimation of landfill greenhouse gas emissions: Application to the Akrotiri Landfill (chania, greece)	
[26]		Philippines		Monitoring of Sanitary Landfill Greenhouse Gas Emissions and Groundwater Leachate Leakage	
[15]		India	Technology for the Internet	The Internet of	

			of Things (IOT)	Things is being used to create a smart garbage monitoring system.	
[27]		South Africa		Residents living near a landfill face health and environmental risks: a case study of the Thohoyandou dump in South Africa's Limpopo province.	
[28]		Brazil	Energy Recovery	Energy recovery from Municipal Solid Waste (MSW) in Brazil: a techno-economic analysis and environmental effect assessment	Produce biogas and electricity with the energy you generate.
[21]		Nigeria	Technologies such as the Internet of Things (IoT) and Cloud Computing	For smart and connected communities, a cloud-based IOT-enabled solid waste monitoring system is being developed.	Detecting fill level of waste in the Container and enable the Concerned persons to take measures at real time.

The analysis of the related works shown in the above Table 2, indicates a little pictorial representation of research on landfill management in the developed countries and developing Countries in the whole world. The modern technologies shown during analysis of landfill management in developed countries indicate that there are still little in the developing countries. This thesis focuses on Rwanda, one of developing countries and precisely finds the way of improving the Nduba Landfill management located at Gasabo District in Kigali City.

CHAPTER 3: RESEARCH METHODOLOGY

3.1. HOW EXISTING SYSTEM WORKS: DATA COLLECTION

The conducted research was concentrated on data of how the Nduba landfill located in Kigali City, Gasabo District is being managed. Then, the three major techniques that have been used when collecting information are Interviews, Questionnaire, Observation and Documentary approach.

Interviews are a fact-gathering methodology in which systems analysts obtain information from humans through face-to-face interaction. This shows that it is an important strategy for gathering data in a research thesis focusing on how the Nduba landfill is managed qualitatively. It is very useful to gain the data needed through the interview made by interviewer and interviewee.

To achieve the development of this prototype, data collection was conducted through informal interviews with Citizens and employees from different private companies [29] and it will take place on Thursday, June 26, 2021.

- COPED Ltd which is operating in Nyarugenge District and
- Ubumwe clearing which is operating in Kicukiro District Ltd,
- Isuku Kinyinya Ltd which is operating in Gasabo District about how and where they dispose the waste and know the level of fill in Nduba Landfill.
- Citizens about which the problems faced while Nduba Landfill is closest to them.
- And I will expect to make an Interview with Local Government about how to manage and monitor Nduba Landfill and how to solve the problems caused by Nduba landfill for protecting the nearest society and environment while I will get the Authorization of conducting that Interview.

The following table summarizes the unstructured interviews from different partners who have responsibilities of management and monitoring Nduba Landfill and the surrounding persons.

Table 3-1: Summary of Interview from different partners

Situation / Partners	Responsibilities	Achievement (%)	Challenges faced in Nduba Landfill	Automated Technology currently in use	Communication channel
COPED Ltd	Disposal of waste to Nduba Landfill	Disposal of waste at the rate of 89%	-The wastes are disposed in disorder way on the Surface of Land. -They don't know the level of fill. -The road is not good - They don't know Toxic gas presence that reach and damage the nearest society and environment	No one	Mobile phone
Ubumwe cleaning Ltd	Disposal of waste to Nduba Landfill	Disposal of waste at the rate of 87%	-The wastes are disposed in disorder way on the Surface of Land. -They don't know the level of fill. -The road is not good	No one	Mobile phone

			-They don't know Toxic gas presence that reach and damage the nearest society and environment		
Isuku Kinyinya Ltd	Disposal of the waste at Nduba Landfill	Disposal the waste at the rate of 89%	-The wastes are disposed in disorder way on the Surface of Land. -They don't know the level of fill. -The road is not good - They don't know Toxic gas presence that reach and damage the nearest society and environment	No one	Mobile phone
Citizens	Prevention and following rules and Regulations given by	Prevention at rate of 95% and Follow rules and	-Mosquitoes -Bad Odors -Illness -Contaminated	None	Face to Face

	the Local Authorities	Regulations at 97%	water.		

The Questionnaire Method is the method used also to collect information on Nduba Landfill management where data are collected through different departments in three Districts located at Kigali City. The One who are in Charge of Managing and Monitoring how the Companies ensure that their responsibilities are achieved at high rate and the Citizens get the better Quality of Service.

This Graph shows the information gathered from different partners using Questionnaire method

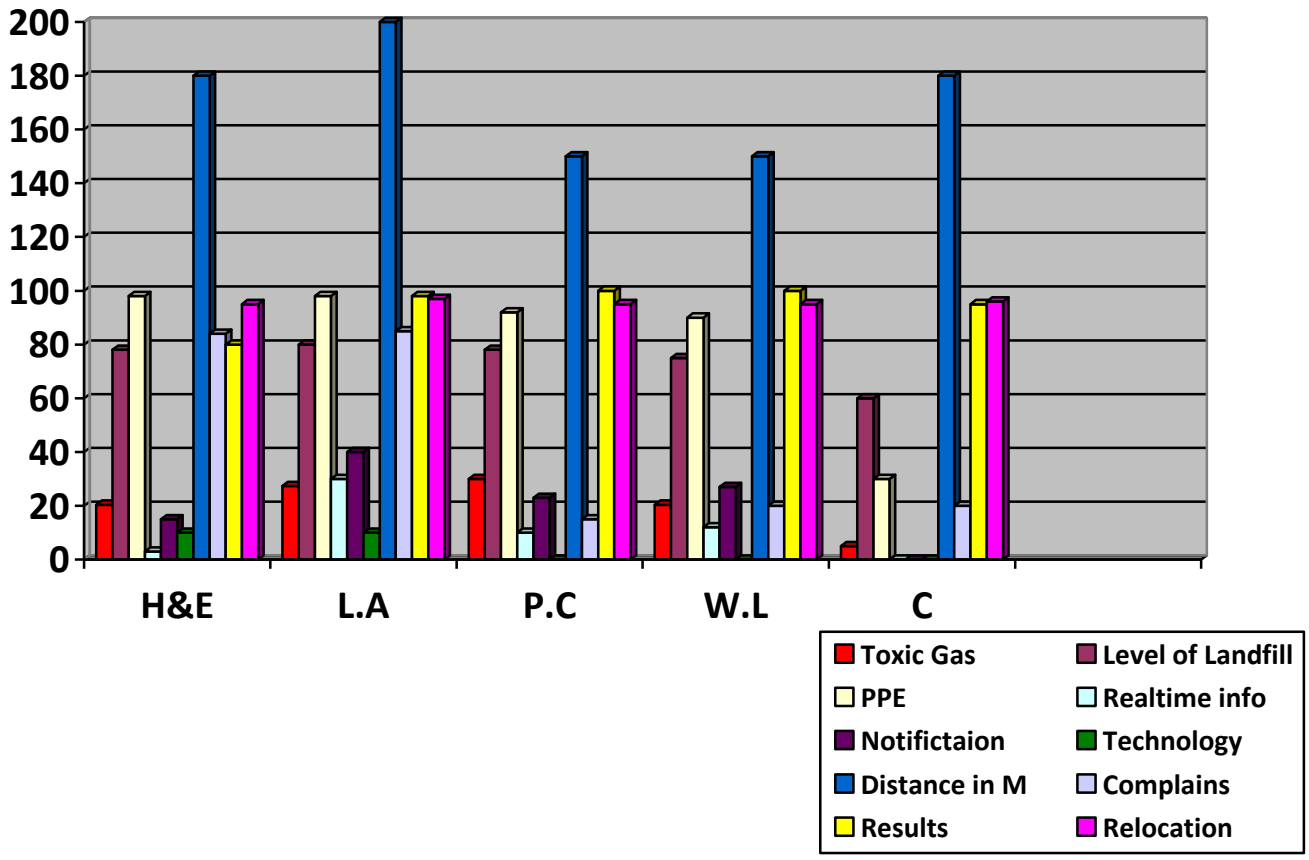

Figure 3-1: Data Collection Findings through Questionnaire Method

Table 3-2: Information Gathered from different Respondents

		A	B	C	D	E
	QUALITY Criteria	H&E	L.A	P.C	W.L	C
1	Toxic Gas	20.4	27.4	30	20.4	5
2	Level of Landfill	78	80	78	75	60
3	PPE	98	98	92	90	30
4	Realtime info	3	30	10	12	0
5	Notifictaion	15	40	23	27	0
6	Technology	10	10	0	0	0
7	Distance in M	180	200	150	150	180
8	Complains	84	85	15	20	20
9	Results	80	98	100	100	95
10	Relocation	95	97	95	95	96

Based to the information gained from different respondents as shown on the above figure and Table, below is the Table of proposed system.

Table 3-3: Findings after Analysis of the working of the system and gathering information

		Existing System	**Proposed System**	**Achievement**	**Comment**
No	**Quality Criteria**	**%**	**%**	**%**	
1	Toxic Gas Detection	20.64	95	100	Better to use that system of detecting Toxic Gas Presence.
2	Level of Landfill	74.2	98	100	Facilitation of Monitoring landfill

3	Personal Protective Equipment	81.6	100	90	Better to reach at 100%
4	Real Time Information	11	96	100	Nice Things and achieved at the Highest Level
5	Notification	21	100	90	Not reached at the highest, I recommend others to notify by using Email
6	Technology	4	100	100	Excellent and it will be better for being Updated to new technology and used it.
7	Distance in m (Above 100)	98	98	97	Very Good
8	Complains	44.8	20	45	The way they

					receive complains is rarely means there aren't many Problems related to the Toxic gas
9	Relocation	95	90	95	Very Good

The Observation Method**:** During the observation, the research data findings were based on seeing the way the wastes are disposed and the management of Nduba Landfill were being done. Therefore, the research made on Nduba landfill management indicates that:

- The solid wastes are disposed in disorder at Muremure Hill.
- The drivers' Companies don't know the level of fill.
- The Local Government and Authorities are not getting information concerning Toxic gas presence and level of fill of Nduba landfill at real time.
- Solid and Liquid wastes are disposed separately.

The existing system that is currently in use indicates that there is still problem of managing Nduba Landfill for better provision the good services to the partners by getting information at real time and other measures to be taken for protecting the surrounding people and environment. Due to those difficulties or challenges of landfill management, the proposed prototype will come up with the aim of improving the management of Nduba landfill located at Gasabo District in Kigali City.

The Documentary approach**:** This is the third methodology which has helped me to gather all necessary information in order to perform well this research thesis.

Different Books, papers and reports of some of Institutions have been consulted in order to reach to the research thesis objectives. This technique is the method based on reading books, documents, reports, and websites for gathering much information related to the Nduba Landfill management.

The following Table shows the documents and Reports done by some Institutions by indicating how Nduba Landfill is being managed.

Table 3-4: Some documents or Reports reviewed regarding Nduba Landfill management.

No	Document name	Document source
[4]	Performance audit report on Kigali's solid and liquid waste (SEWAGE) management.	Office of the auditor general of state finances, Rwanda, 2016
[30]	REGULATION No 002/R/SANEWATSAN/RURA/2017 OF 01/03/2017 GOVERNING THE PROVISION OF SERVICES OF HAZARDOUS WASTE MANAGEMENT	RURA,2017

The outcomes from the reports shown above describes the policy and regulation for Nduba Landfill management where the partners like City of Kigali, Companies, Cooperatives and Local Authorities works together for the purpose of achieving the Nduba landfill management and monitoring.

3.2. PROTOTYPE SYSTEM DESIGN

The observation made on Landfill, views from different Partners through interviews and Questionnaires would help to design and develop a prototype system for effective and efficient landfill management by detecting Toxic gas presence, level of fill and Notification. The deployment of Sensors enables data to be captured from physical environment and sent to the microcontroller for processing purpose. Then, the microcontroller performs the processing of data that have gotten from the sensors, then the results would be sent on Cloud Platform namely Adafruit IO where the one who have access right can access those real time information on the

Dashboard and provide the notification to the concerned persons while the sated threshold value limit is achieved by help of an free cloud service called TwillioSms.com. After processing, the data will be sent to the server (IOT Platform) for further analysis and monitoring whereby Text Messaging will be sent to the concerned persons.

3.3. SYSTEM DESIGN

The system design of this thesis describes the system Technologies, Hardware Requirements, Software Requirements, Conceptual system architecture, algorithm and system functionality, Verification of the prototype application that enables the improvement of Nduba landfill management located at Gasabo District in Kigali city.

The thesis will help in developing the prototype system that will detect the gas presence, the fill level of Nduba Laandfill and give notification to the concerned persons using Internet of Things technologies for the purpose of removing the challenges faced during the management of Nduba Landfill by getting information at real time. The prototype system will ease the management of Nduba Landfill by obtaining the real time information remotely.

The Figure 4 demonstrates how the prototype will perform its tasks, its main parts from the sensing data, data processing, communication channel, server and data visualization on the IOT Platform. Gas sensor, temperature sensor and Ultrasonic sensor are used to capture data from physical environment, then microcontroller process it and after some processing and analysis, the data are sent directly to the server application using internet connection then some analysis and decision are being taken for providing notification to the concerned persons using twilliosms .com.

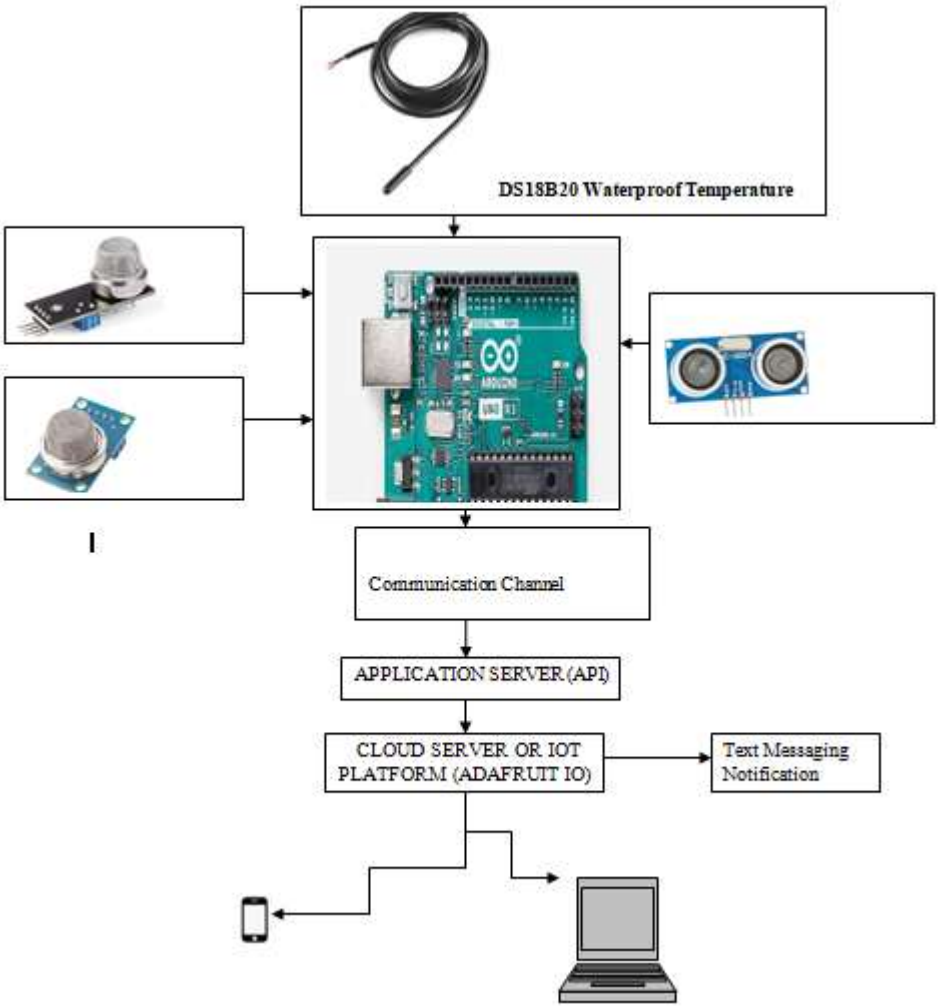

Figure 3-2: IOT Based Toxic Gas Detection and Level of Landfill system Design

3.3.1. SYSTEM TECHNOLOGY

In order to improve the process of managing Nduba Landfill, a prototype system for managing Nduba Landfill will be developed. That system helps in detecting Toxic gas presence, level of fill through waste storage tank and give the notification to the concerned persons for taking measures. For that, the following technologies are being used for making landfill operation healthier.

Data acquisition technology: This is the technology that connects the data acquired by sensors and changes it into a signal that can be used directly by another device to be processed, managed, and analyzed by the server.[10]

Data communication technology: This is utilized to communicate between the perception and network levels, as well as the application layer. Wifi and IoT technology are used as a communication channel to send data signals from one device to another over an Internet connection supplied by an access point. [10].

Internet of Things (IoT) Technology: Built on cloud computing and networks of data-gathering sensors, the Internet of Things (IoT) provides a mobile, virtual, and immediate access to landfill conditions. It also has the ability to make all landfill equipment and systems "intelligent." [31].These sensors and controls can be located at one landfill or it can be distributed into multiple landfills [31].

Remote monitoring Technology: This technology is used to remotely monitor and regulate landfills when car employees is not available 24 hours a day or is not on site at all times. Many locations in developed countries, for example, are beginning to use cameras that are incorporated into monitoring software that can be remotely watched to ensure that if anything occurred to the explosion, they would be aware of it and could respond [31].

Control Technology: This technology can be used for two purposes: to respond to system issues during off-hours, and to control many systems simultaneously [31]. Control technology was developed to enable the automatic operation of systems that do not necessitate the constant supervision and manual execution of regulated activities by a person.

3.3.2. HARDWARE REQUIREMENTS

The prototype is constructed by interconnected devices that form a single platform. This platform is made of ESP 32 development Board and the waste storage Tank equipped with MQ135 Gas Sensor which is able to measure more gases such as Ammonia, CO2 etc, MQ4 Gas Sensor which is used to measure Methane Gas, The level of the waste storage tank is measured using an ultrasonic sensor (HC SR04), DS18B20 Waterproof Temperature Sensor Probe used to measure temperature in wet environment for further measures. ESP 32 development Board which is a used as microcontroller and it is interfaced with other peripherals and communication protocols.

MQ135 The sensor is used to detect several chemicals in the air, including ammonia (NH3), benzene, sulfur (SO2), alcohol, carbon monoxide (CO2), smoke, and others. [30] where these gases can be harmful to human health if present afar a certain level of concentration .

In this thesis, it is used to detect and anticipate the presence of dangerous gases inside and around a waste storage tank. The MQ135 sensor is appropriate for a variety of applications due to its lower conductivity in clean air and increasing conductivity as the gas concentration rises.

Features

- A MQ135 sensor is used in conjunction with an LM393 IC to create a simple adjustable comparator circuit.
- Designed to work with Arduino and other microcontrollers.
- Power:5VDC power supply
- Output: TTL Compatible Digital & Sensor Direct Analog OutputsLEDs for Output and Power status indication
- Detection Zone: 10-300ppm.

Figure 3-3:MQ135 Sensor

2. MQ4 Sensor: This is the methane gas sensor, which detects the presence of methane gas in the air and converts the reading into an analog voltage. The MQ4 Gas Sensor is extremely sensitive to Methane, as well as Propane and Butane. The sensor could be used to detect several combustible gases, including Methane; it is low-cost and suited for a variety of applications [31]. In summary, it has a wide range of combustible gas sensitivity, high sensitivity to natural gas, long life and low cost, and a simple drive circuit**.** [31].

Features

Figure 3-4:MQ4 Sensor

- High sensitivity to Combustible gas in wide range
- High sensitivity to Natural gas, Methane, Coal gas
- Fast response
- Stable performance and long life
- Simple drive circuit
- Temperature from -10 to 50°C
- Current :Less than 150 mA
- Power :5V
- Wide detection range of 300 ppm to 10,000 ppm

3. Ultrasonic Sensor (HC_SR04)

The HC-SR04 ultrasonic range sensor is seen here. Trigger and Echo are used to measure and calculates the distance to an object. Ultrasonic sensor has two openings namely transmitter [20], a receiver . The level of waste in waste storage tank will be checked using ultrasonic sensor; this allows the concerned persons of the system to get real time data.

There are only four pins found on the HC-SR04

- VCC (Power),
- Trig (Trigger),
- Echo (Receive), and
- GND (Ground).

Features

- Operating Voltage: 5V DC
- Operating Current: 15mA
- Measure Angle: 15°
- Ranging Distance: 2cm – 4m

Figure 3-5: Ultrasonic Sensor

4. DS18B20 Waterproof Temperature Sensor Probe.

With a simple 1-Wire interface, this sealed digital temperature probe allows you to precisely detect temperatures in moist conditions. The DS18B20 uses a 1-Wire interface to deliver 9 to 12-bit (adjustable) temperature readings, requiring only one wire (and ground) from a central CPU [35].Note: This sensor's pinout is as follows: RED=Vcc WHITE=SIG WHITE=GND

Figure 3-6: DS18B20 Waterproof Temperature Sensor Probe

Features

- 3.0-5.5V input voltage
- Waterproof
- -55°C to+125°C temperature range
- ±0.5°C accuracy from -10°C to +85°C
- 1 Wire interface
- Probe is 7mm in diameter and roughly 26mm long. Overall length (including wire) is 6

5. Wi-Fi+ Bluetooth Ultra-Low Power Consumption Dual Core BRD44 ESP 32 DEVELOPMENT BOARD

The ESP32-WROOM-32 is a powerful Wi-Fi+BT+BLE MCU module that may be used in a wide range of applications, from low-power sensor networks to the most demanding tasks.

Features

- Small volume, easy to integrate into other items
- Supporting three modes: AP, STA, and AP+STA
- Strong function with support for LWIP protocol, Freertos

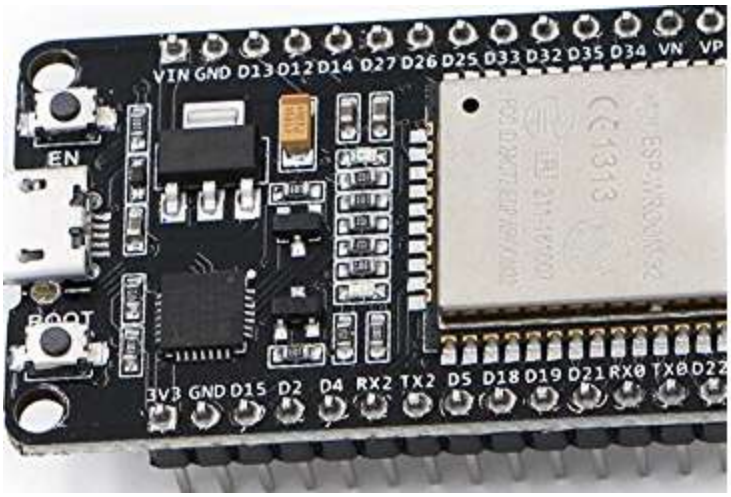

Figure 3-7: ESP 32 Development Board

6. Breadboard

This little white breadboard is ideal for prototyping small projects.

Figure 3-8: Breadboard

3.3.3. SOFTWARE REQUIREMENTS

Adafruit IO is an Internet of Things (IoT) platform or cloud service for storing, viewing, and controlling deployed devices. Adafruit IO supports a variety of protocols, including REST and MQTT, but implementing them natively in any language is difficult. This Adafruit IO allows you to see the data collected by several sensors.

TwillioSms is an IOT Cloud platform that used in providing SMS as Service. This means that TwilioSms is also an SMS Gateway where message.create function will be used to request and response of text messaging when the threshold value reaches to the limit. This cloud platform work together with Adafruit IO by integrating project information consists of Account Social Security Identification (ACC_SSID) and Authentication Token for communication purpose.

These project information indicates who is authorized to access and viewing the information in the Feeds through Adafruit IO.

MQTT: Message Queuing Telemetry Transport

MQTT protocol stand for Message Queuing Telemetry Transport is used by the IOT module within the Perception Layer. MQTT is a machine-to-machine (M2M) "Internet of Things" connectivity protocol means in briefly, it is a communication standard for IOT. MQTT is a lightweight, publish-subscribe network protocol that transports messages between devices over TCP/IP Protocol. MQTT uses a topic based mechanism, refers to the data gathered from the different sensors through the physical environment, the MQTT publisher, publishes the topics according to the sensor readings in to MQTT Broker namely io.Adafruit.com, when needed the MQTT Subscribers (authorized clients) will make a connection with the MQTT broker and take the feeds for its use. When the MQTT server gets the data from Perception Layer consist of feeds, it publishes the topic namely Landfill's Feeds to the MQTT Broker. According to the threshold levels defined for the Methane Gas, Carbon Dioxide, level of waste in Landfill and Temperature, the alert messages will be sent by the MQTT broker to the MQTT subscribers informing the dangerous level of measurements of Methane Gas, Carbon Dioxide, Level of fill and Temperature.

3.3.4. CONCEPTUAL SYSTEM ARCHITECTURE

The below Figure 14 shows the Conceptual system architecture consists of three main parts namely sensing part, processing part and data storage & analysis part. Sensors sense data from physical environment, the stimulus captured are being processed through Microcontroller then with API the data is transmitted to the cloud platform for processing, analysis, and storage, and it is here that the decisions are made.

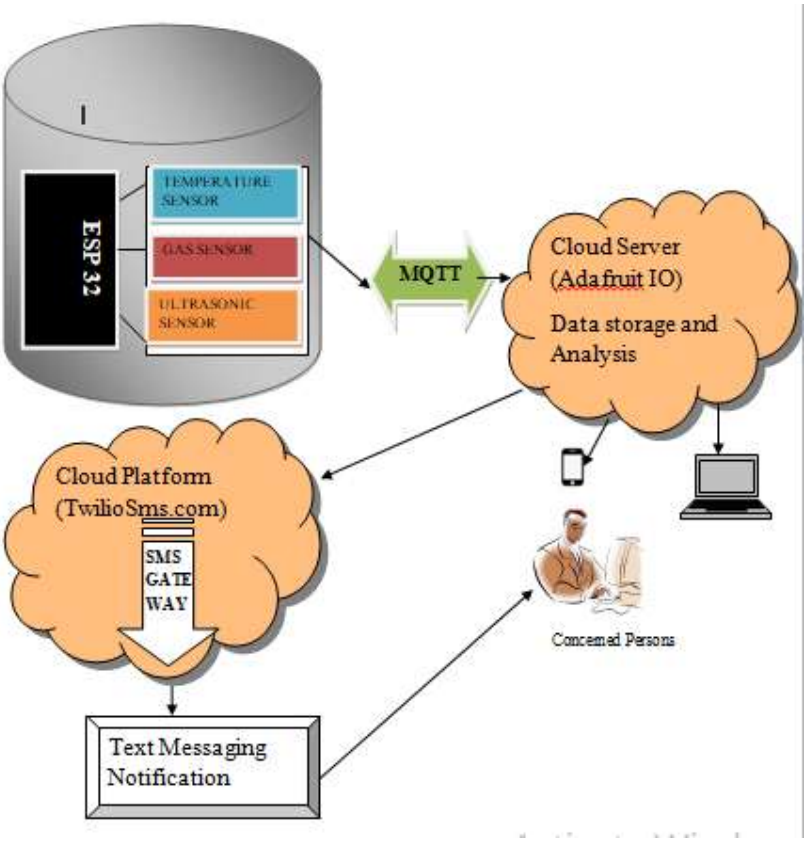

Figure 3-9: IoT Based Toxic Gas Detection and level of landfill System architecture

BLOCK DIAGRAM OF SYSTEM ARCHTECTURE

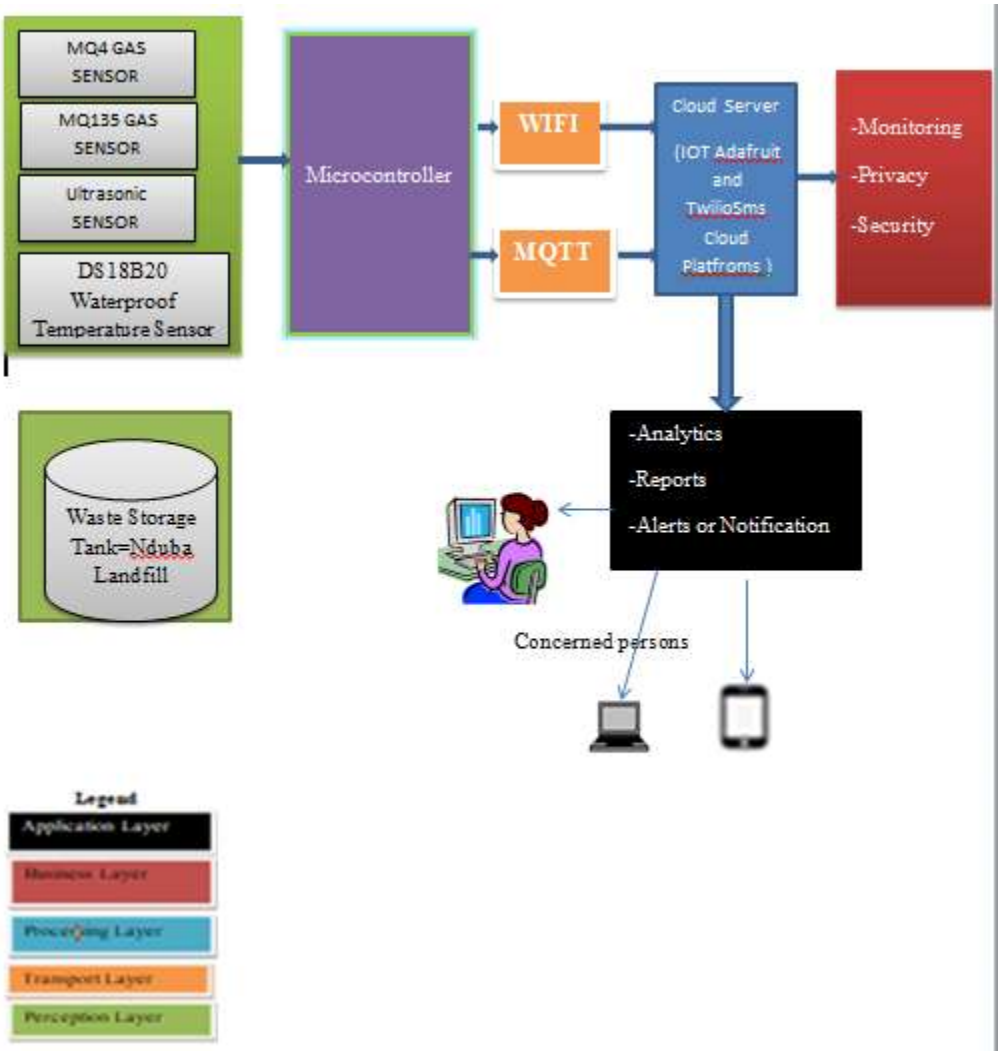

Figure 3-10: Five Layered Model for the System indicated with Block Diagram

In this thesis the five layer architectures have been implemented as it is focusing of Internet of Things. Perception layer, transport layer, processing layer, application layer, and business layer are the layers covered [34]. These five layers describe the data transfer from physical to digital. devices to application in addition to to the business services of the application.

In IoT based Toxic Gas and level of waste detection in Landfill, each layer has the functionality of describing to their state and how the data are behaving within its corresponding tasks.

The perception layer: Temperature sensors, ultrasonic sensors, and gas sensors make up the physical layer, which detects temperature, waste level, and gas level. The temperature sensor measures the temperature within the waste storage tank and it is helpful in detecting gas presence refer to the increase of temperature inside waste storage tank ,the ultrasonic sensor sense waste filling level inside waste storage tank based on measurement of distance by using ultrasonic waves and the Gas sensors namely MQ-135 and MQ-4 Sensors sense gas level of Carbon Dioxide and Methane Gas respectively on the waste storage tank and in the air .Therefore, the system shows the presence of Toxic gas, level of waste in Waste storage tank and then proceed the levels to microprocessor.

The transport layer transfers sensed data of temperature; gas and waste levels are transferred from the perception layer to the processing layer via a wireless fidelity network and Application Programming interface for the communication Purpose.

The processing layer: This is the layer that helps in storage, analysis, and processing data that originates from the transport layer. The data are stored and analyzed enable actions to be taken to the application layer for taking a decision.

The application layer delivers specific services to the concerned persons. Various applications services have been developed specifically by making join of services in between and data visualization. In this project, the Internet of Things was used and enable waste storage tank to be smart the reason why is considered as Landfill.

The business layer: his is the layered architecture's fifth and final layer, and it's in charge of managing applications based on Text Message notifications and user privacy.

3.3.5 ALGORITHM USING FLOWCHART AND SYSTEM FUNCTIONALITY

This part illustrates a set of instructions to perform certain task from sensing to reporting parts. It describes the step by step to detect the Toxic gas and level of landfill using Internet of Things based on landfill management, how to speed up real time information to the concerned persons. The main tasks worked on in landfill management are toxic gas, temperature and level of landfill management based on the threshold value sated by considering the distance available to reach to the nearby people around the Nduba Landfill.

When the gas and waste levels are detected and reach to the threshold values, an Email and Text Message notification are sent to the concerned people for taking decisions.

In addition, when the person brings the waste to the waste storage tank without informed before, the concerned person s announce the workers and the Driver the waste storage tank is full or not and also see the gas presence and its level if it is harmful. Once the waste storage tank is full, he/she goes to search other waste storage tank planned to hold those waste and while the detected gas presence shown at the highest level, notification would be sent immediately to the concerned persons. The below Figure of 11 indicates an algorithm using flowchart by talking about how the IoT based toxic gas detection and level of landfill in this thesis. The system functionality continues its tasks of detecting toxic gas presence, level of landfill, Temperature and notifying the concerned persons in an automatic way except if there are technical issues. The system functionality is based on embedded devices; integrated system consists of both software and hardware parts.

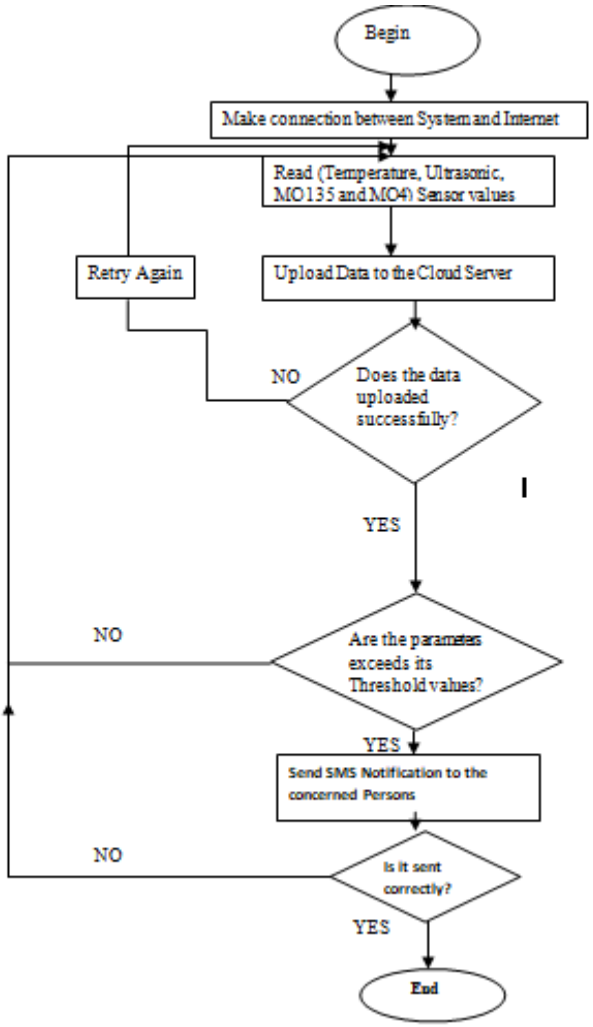

Figure 3-11: IoT Based Toxic Gas Detection and Level of fill system functionality.

CHAPTER 4: PROTYPE SYSTEM IMPLEMENTATION AND RESULTS ANALYSIS

This chapter shows the results and finding obtained during implementation of an IOT Based Toxic Gas Detection and Level of Landfill. According to the limitation that were encountered during the implementation within the prototype implementation and the results findings gained. The project is explained in terms of hardware connectivity, design and implementation.

4.1 HARDWARE CONNECTIVITY

The Figure indicates the hardware connectivity and prototype components for the whole system.

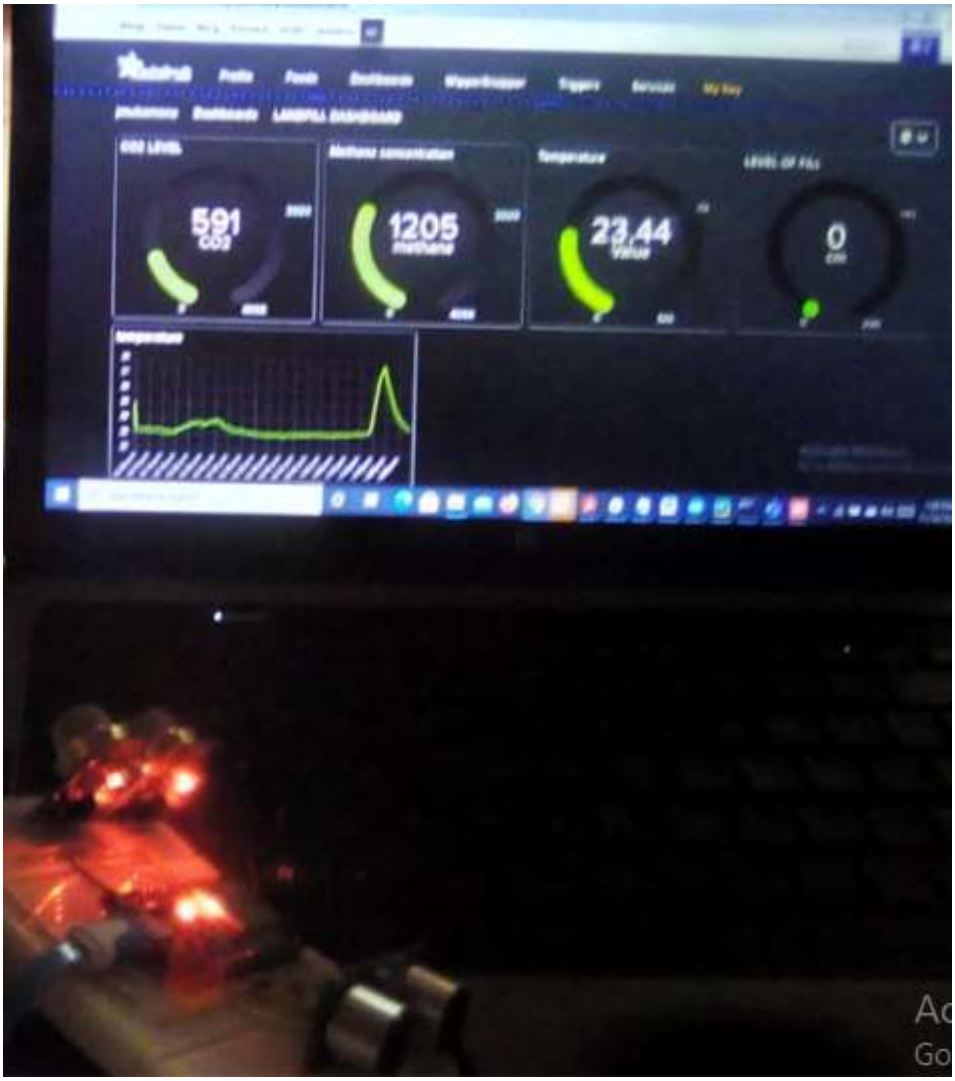

Figure 4-1: Prototype components and hardware connectivity

4.2. SYSTEM DESIGN PURPOSE AND LIMITATIONS

Based on different findings in Literature Review indicates that in the developing Countries especially in Africa, we are still having the gaps of managing landfill or open dumpsite by detecting toxic gas presence, level of landfill and notifying the relevant persons for talking other decisions and there is a gap of skilled and knowledgeable people in the new technology like internet of things (IOT).So that, the goal of designing and implementing the IOT Based toxic gas detection and level of landfill helps to overcome some challenges and helps in providing good services to the partners case ok Kigali City-Nduba Landfill.

Due to the functionalities of IOT based toxic gas detection and level of fill tried to be designed and implemented , the system is feasible and it is operating to facilitate in developing countries to handle the challenges faced during landfill management and monitoring.

After Developing, testing and verification of the implemented system, the findings are shown on the Adafruit IO Cloud Server by using MQTT Publish method where the results are stored, analyzed, visualized and processed on the Adafruit IO Platform as shown in the Figures below. Then, the TwilioSms Application helps in triggering an SMS based on the event when the sated threshold value reaches at the highest level and it helps to send Text Message to the concerned persons. These Figures indicate how Landfill Dashboard is in different periods by indicating the feeds namely CO2, Methane, Temperature and level of Fill.

This Screenshoot indicates that I have an Account in AdafruitIO Cloud Platform,and Landfill Dasboard was Created.

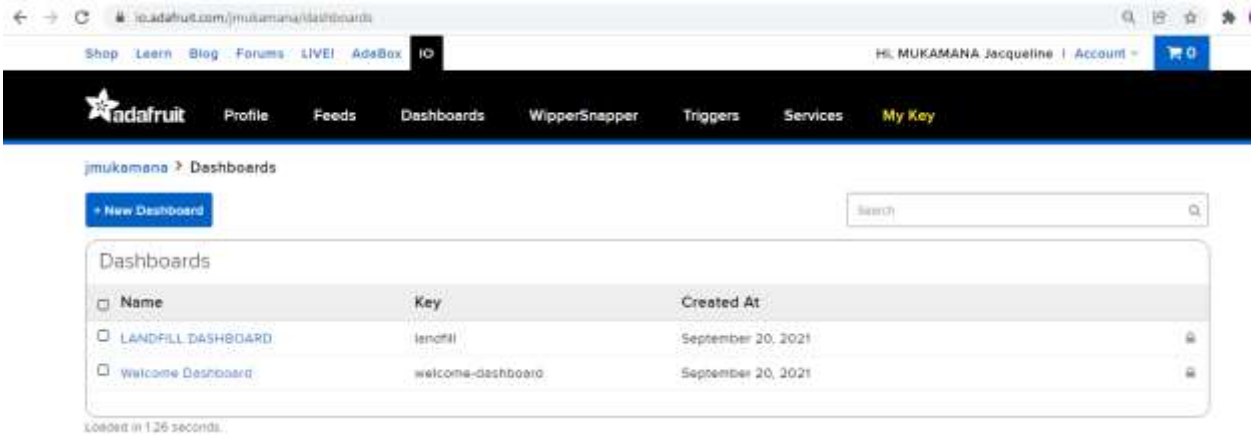

Figure 4-2: Account Login and Landfill Dashboard Created.

This screenshoot indicates what Landfill dashboard includes.Those names are Called Feed created before for the Purpose of being appear on the Dashboard and its values time to time.

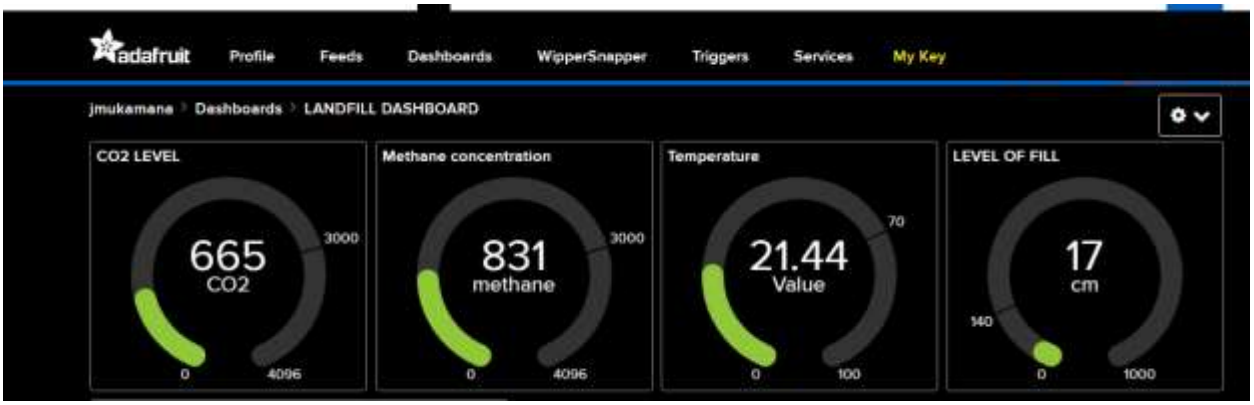

Figure 4-3: Feeds on the Dashboard and its values at a certain time

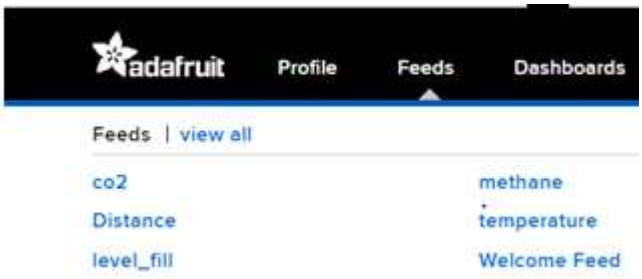

Figure 4-4: This Screenshot indicates the Feeds that the System has.

4.2.1 SYSTEM'S APPLICATION TESTING AND RESULTS OBTAINED ON ADAFRUIT IO CLOUD PLATFORM.

The IOT based Toxic gas detection and level of landfill were tested by connecting waste storage tank on the Adafruit IO Cloud server by help of an Application programming interface for notifying the relevant persons. The Ultrasonic, Temperature, MQ2, MQ4 that sense temperature in wet environment, waste level and toxic gas level respectively are sent directly to the Adafruit IO Cloud Platform by help of the automated system built. The gathered obtained data are being visualized and analyzed and graphically presented through the Adafruit IO Platform's Dashboard interfaces and this gathered information are presented in form of CVS format or in JSON format.

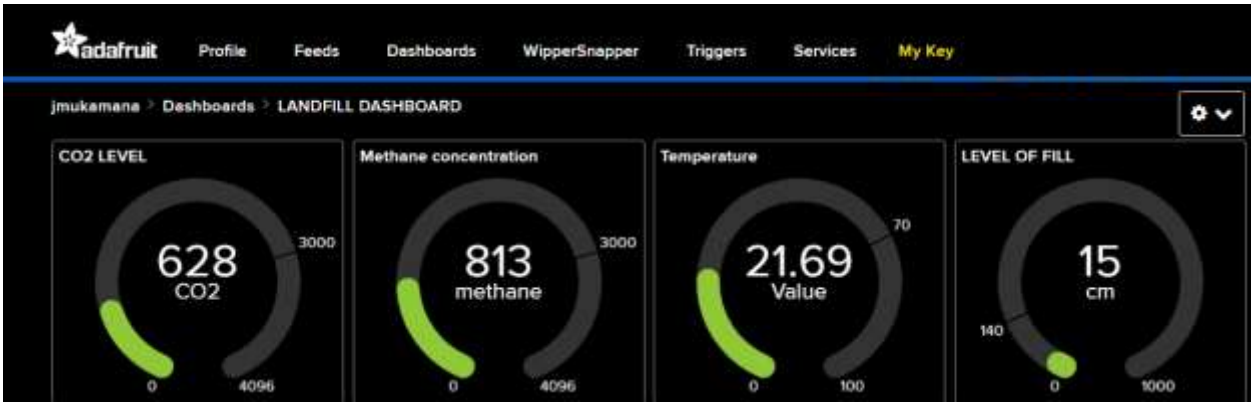

Figure 4-5: Different Values validated on the feeds

Figure 4-6: Feeds of CO2

This Screenshoot indicates tha its possible to download all Value Using JSON format or CVS Format

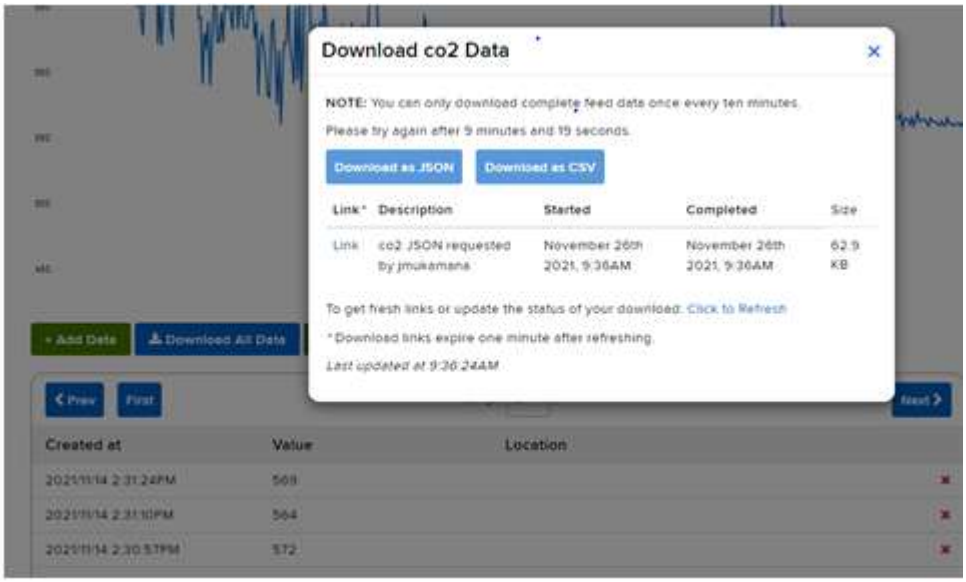

Figure 4-7: How to downolad the data in JSON or CVS Format

This graphics indicates how the Methane concentration

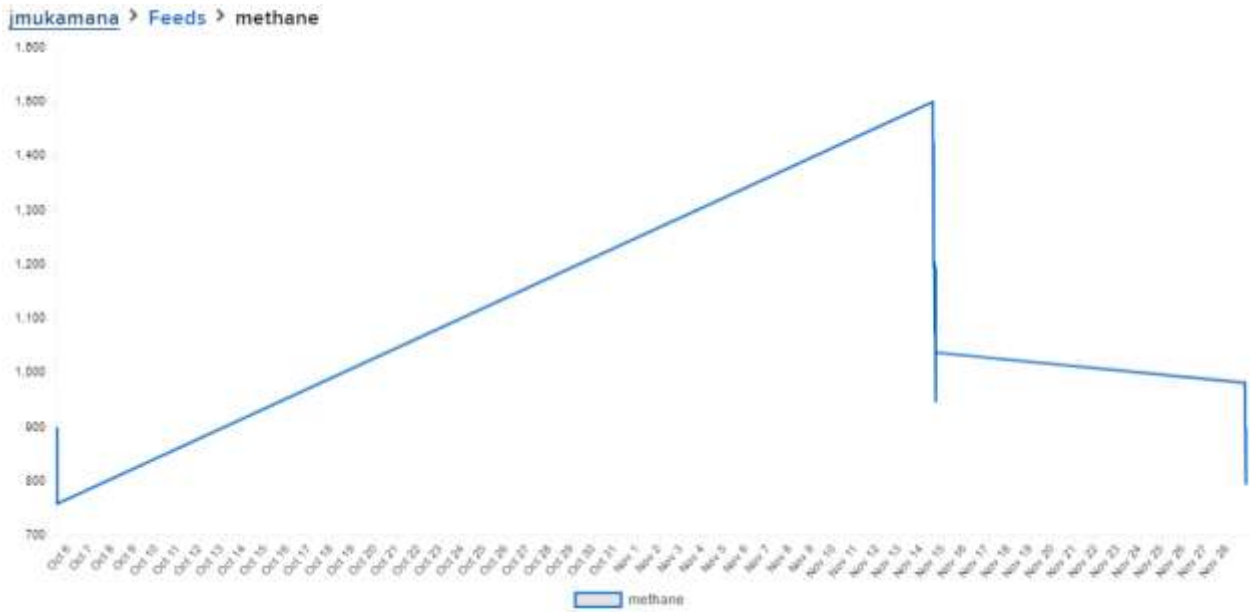

Figure 4-8: Methane concentration

This graphic indicates the Carbon Dioxide concentration

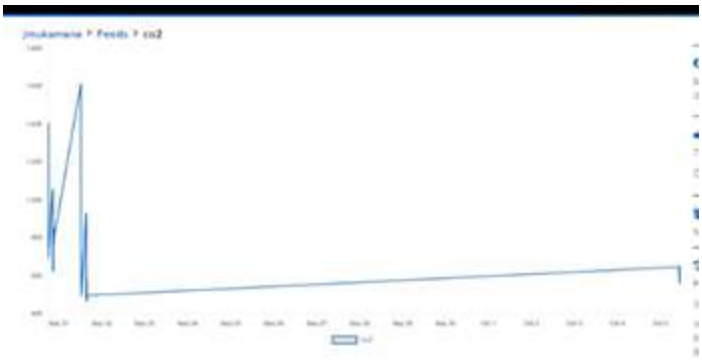

Figure 4-9:CO2 Concentration

This graphic indicates the Temperature level inside the waste storage tank.

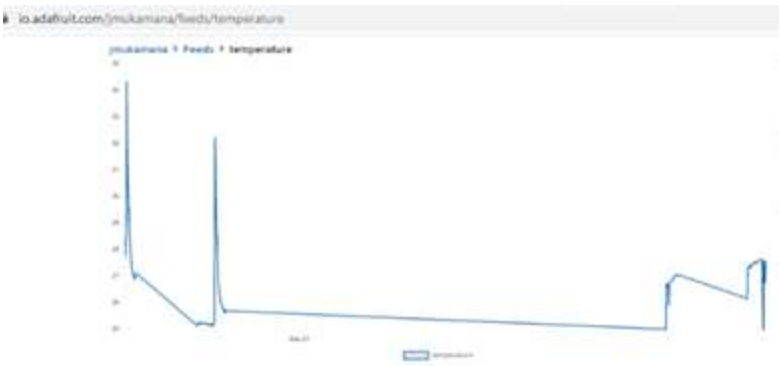

Figure 4-10: Temperature variation

This Graphic indicates the Level of Fill of waste into the waste storage Tank

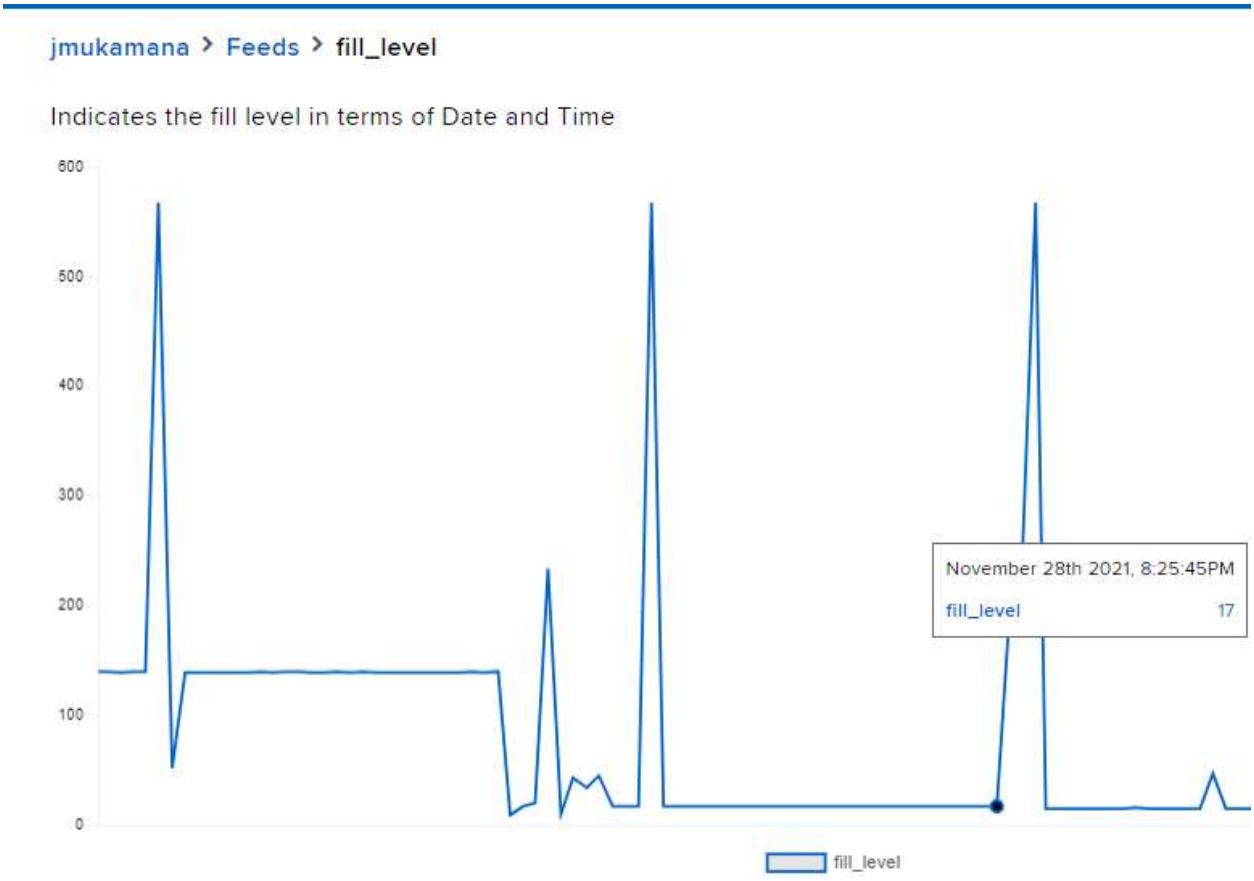

Figure 4-11: Level of Fill.

4.2.2 TWILIOSMS NOTIFICATION SYSTEM

This screenshoot shows an account created in TwilioSms.com,it indicates the Account SID and Authentication Token to be Used by the Granted user of the System's owner.It also highlight the Sender Phone number for the Last Line.

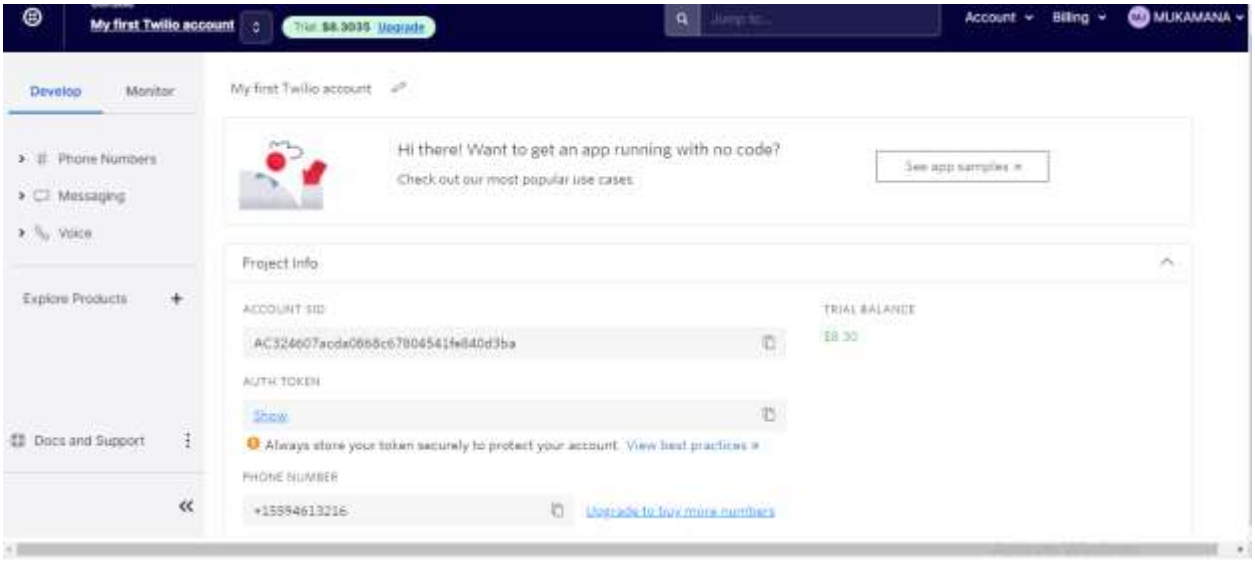

Figure 4-12: Project information

This Screenshoot shows the Verified Caller IDS means that those number shown in this screenshoot are the ones which receive Text Messaging when some of the feeds reaches on the Threshold value Limit as Sated.Here the phone numebes could be added by passing on Add new Caller ID or it could be removed by clicking on Remove Button.

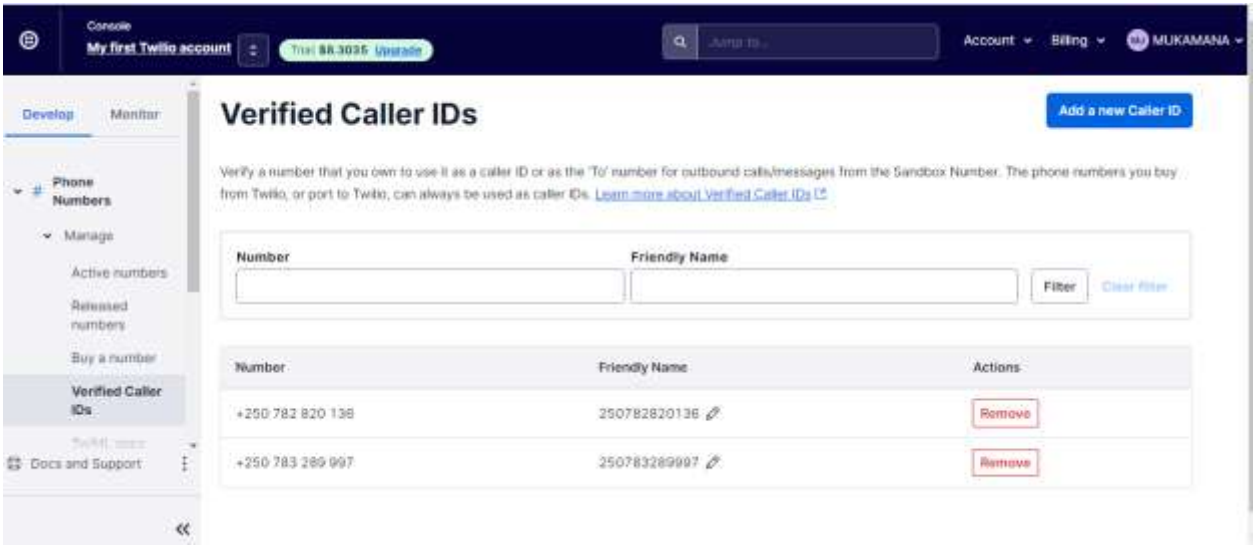

Figure 4-13: Phones Configuration

While the Concentration reach to the threshold value sated, the message goes to the Configured Phone number Look like this, this message was sent from your Twilio trial account. - CO2 LEVEL IS High.Co2 concentration is: 3500.**This message was sent from your Twilio trial account. - Ikimoteri gikenewe kuvidurwa. kigeze kuri cm:568**

This message was sent from your Twilio trial account. - CO2 LEVEL IS High.Co2 concentration is: 3100.This message was sent from your Twilio trial account. - Methane Level is High.CH4 concentration is: 3100

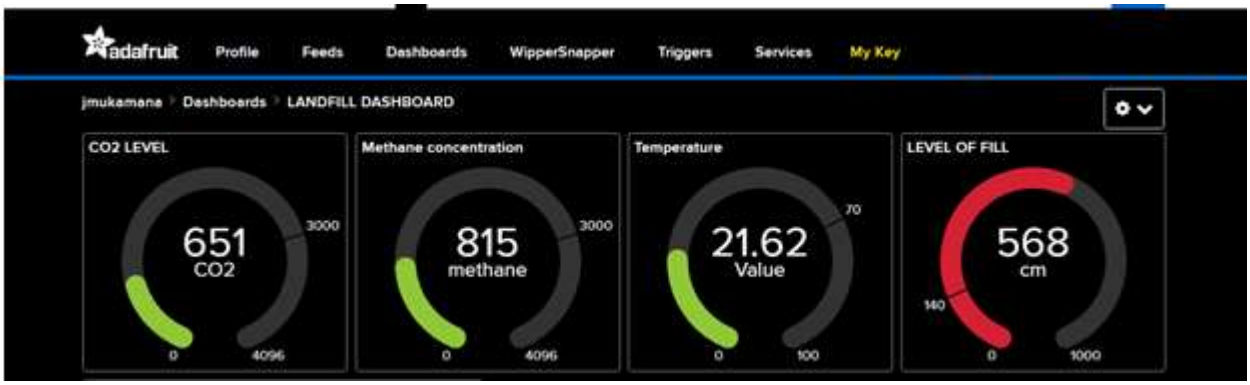

Figure 4-14: Notification system when some feeds reaches to the threshold values

4.3 DISCUSSION

Based on the challenges of using new technologies, economic impact, insufficient skilled people in the developing countries, it seems that the landfill has still problems of being managed using the modern Technologies as highlighted in Literature Review and even in our country of Rwanda. Developed Countries use the new technology at the highest level by managing and exploiting the landfill by producing the things needed by their citizens like energy, electricity and Composting. In the developing Countries, Some of the most modern systems and infrastructures have become so complicated that they are difficult to administer properly. On the contrary, a person's daily life may become more challenging when new infrastructure and technologies are required to integrate new devices.[6]**.** In emerging countries, technological and human capabilities are frequently lacking. Financial support for integrating new technology is lacking. In local communities, there aren't enough technically skilled people with IT abilities who can integrate the usage of sensors and other devices into their daily lives.[6]**.**

Therefore, my contribution on the research thesis is the design and implement of an IOT Based Toxic gas detection and Level landfill used in management of Nduba Landfill where Currently in different views from different partners indicates that there is no automated system used for better management, monitoring and for giving good service to the citizens live nearby Nduba Landfill ensure better environment protection and people wellbeing.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

The chapter indicates the comparison of the existing system and work has been done and talk about the conclusion of the project that has been done refers to the project scope and Limitation.

5.1 CONCLUSION

The thesis of an IOT Based Toxic Gas detection and Level of Landfill was developed, tested, verified and successfully implemented. The prototype would help the Managing Team of Nduba Landfill to manage, control and provide real time status of Nduba Landfill. The system will also provide better service to the partners and notifying the concerned persons for taking appropriate decisions using Text Messaging. This Prototype helps also the Local authorities to relocate the nearby people around Nduba Landfill before being damaged by the produced Toxic gas when it reaches to the highest level. The designed and implemented system would help in attaining the SDGs' goals like having good health and well-being, clean water and sanitation, sustainable cities and communities, and climate change.

5.2 RECOMMENDATION

Due to the COVID-19 Pandemic disease and time, I wasn't develop a fully operational system but I tried to come up with the prototype system that will be helpful in managing Nduba Landfill and notifying the concerned persons based on information obtained at real time. It is in this regards, I would like to recommend the future researchers to think about using a machine learning that will help in the prediction of that being produced by the designed system.

5.3 FUTURE WORK

The project prototype that was developed indicates that there are some limitations; there is security issue of systems' hardware to be thought about and resolved in the future work. Researchers should think of producing electricity and Composting facility using these wastes in our landfills.

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