Open Access
Online ISSN: 2992-5487
Print ISSN: 2992-6068
NIJEP
Publications
NEWPORT INTERNATIONAL JOURNAL OF ENGINEERING AND PHYSICAL SCIENCES
(NIJEP)
Volume 4 Issue 2 2024
https://doi.org/10.59298/NIJEP/2024/421928.2.1

Integration of Gas and Ultrasonic Sensors for Monitoring Air Quality and Smart Waste Bin levels determination: An IOT illustration in Solid waste management

[1]Chika Lilian Onyagu, [2]Akawuku I. Godspower, [3]Joshua John and [4]Chika Okonkwo

[1, 2,4]Department of Computer Science, Nnamdi Azikiwe University, Awka, Nigeria.
[3]Institute of Computing and ICT, Ahmadu Bello University, Zaria, Nigeria.

ABSTRACT

Solid waste management in Nigeria faces significant challenges, primarily due to the lack of proper coordination in waste disposal activities and inadequate government supervision, which has largely been delegated to contractors. The current management system is also not automated, leading to improper waste disposal methods such as open dumping and burning in public areas like roads and markets. This study aims to address these issues by developing an improved solid waste management system in Nigeria utilizing smart IoT technologies. In this research, IoT sensors were deployed to monitor waste bin levels and air quality at various dumpsites. These sensors, including an Ultrasonic Sensor for waste bin level measurement and an MQ135 sensor for air quality assessment, transmit real-time data to a web-based system for analysis. The system facilitates the timely evacuation of waste by alerting the waste management agency when bins are full or when air quality deteriorates. Prototyping and Modelling was used for the hardware design with Embedded C++ language used for the sensor control algorithms. Key components of the system include the ESP32 microprocessor, LCD display, and SIM900 module for connectivity and data transmission. The system was tested in various environments, revealing that high levels of air pollutants could persist even when waste bins were not yet full, posing health risks to nearby residents. The monitoring system also ensures transparency in the waste evacuation process by keeping record of number of times waste bins are evacuated with date and time. This, enables performance tracking of disposal truck drivers. The air quality data from the sampled dumpsites was analyzed and compared with the World Health Organization (WHO) air quality standards using a six-membership performance index (MID). The system achieved an 83.33% compliance rate, capturing five out of the six MID. The integration of hybrid technologies—IoT sensors and a web-based management system—demonstrates significant improvements over the existing waste management systems in Nigeria.
Keywords: Gas Sensors, Ultrasonic Sensors, Air Quality, Smart Waste Bin, Internet of Things (IoT).

INTRODUCTION

Waste is generally defined as any substance or object that the holder discards, intends to discard, or is required to discard. It encompasses a wide variety of materials, including household refuse, industrial waste, agricultural by-products, and more. According to the [1], waste generation is a growing issue globally, driven by rapid urbanization, population growth, and changing consumption patterns. In particular, the management of solid waste has become one of the most pressing environmental concerns, especially in developing countries where infrastructure and governance structures are often insufficient. Waste management refers to the processes involved in the collection, transport, treatment, and disposal of waste. It also includes efforts to reduce waste generation and recycle or reuse materials to minimize the impact on the environment [2]. According to [3] emphasize that effective waste management systems are crucial for maintaining public health, environmental integrity, and resource conservation. Inadequate waste management can lead to a myriad of problems, including pollution, the spread of diseases, and adverse impacts on ecosystems. In Nigeria, the issue of waste management is particularly acute. The country faces several challenges in effectively managing its solid waste, most notably the lack of proper coordination in waste disposal activities. The responsibility for waste management has largely been left in the hands of contractors, with minimal government oversight. This has resulted in inconsistent service delivery, with some areas receiving regular waste collection, while others are neglected. Furthermore, there is often a lack of transparency and accountability in the operations of these contractors, leading to inefficiencies and corruption [4]. Another significant challenge is the lack of automation in the current waste management system. In many parts of Nigeria, waste collection and disposal are still carried out using traditional methods, with little to no use of modern technology. This lack of automation leads to delays in waste collection, with waste often left to accumulate for days or even weeks. This not only results in unsightly heaps of refuse in public spaces but also poses serious health risks to the local population. Open dumping and burning of waste in roads, markets, and other public areas are common practices, further exacerbating the problem [5]. The absence of a systematic and automated approach to waste management also means that there is no reliable data on waste generation, collection, and disposal. This lack of data hinders effective planning and decision-making, making it difficult for the government and other stakeholders to implement strategies for improving waste management practices. The result is a vicious cycle of inefficiency, where poor waste management leads to environmental degradation and health hazards, which in turn contribute to a decline in the quality of life for the affected communities [6]. The challenges faced by Nigeria in managing its solid waste are not unique. Many developing countries grapple with similar issues, which are often compounded by limited financial resources, inadequate infrastructure, and weak regulatory frameworks. For instance, in many parts of Africa, Asia, and Latin America, waste management systems are often characterized by low collection coverage, uncontrolled dumpsites, and minimal recycling activities [7]. One of the primary challenges in developing countries is the rapid pace of urbanization, which has led to a surge in waste generation. Cities in these regions are growing at an unprecedented rate, with populations expanding faster than the infrastructure needed to manage the resulting waste. This has led to an increase in the number of informal settlements, where waste collection services are often non-existent, and residents are forced to resort to illegal dumping or burning of waste [8]. Another challenge is the lack of public awareness and participation in waste management. In many developing countries, there is a low level of awareness about the importance of proper waste disposal and the benefits of recycling. This is often compounded by cultural practices and attitudes that view waste as a nuisance rather than a resource. As a result, there is little motivation for individuals and communities to engage in waste reduction or recycling activities, leading to increased waste generation and environmental degradation [9]. [10], explained that the present state of waste management in Nigeria is of major concern because of the rate of waste generation and poor management practices. The author further explained that Nigeria produces an estimation of 32 million tons of solid waste per year, with only about 20-30 percent collected and managed correctly. The remainder of the waste is either dumped in unauthorized places or burned, contributing to pollution and health risks. Furthermore, the informal sector plays a significant role in waste management in many developing countries. Informal waste pickers, who collect and sort waste for recycling, often operate without any legal recognition or support from the government. While these workers contribute significantly to waste reduction efforts, they often work in hazardous conditions and face numerous challenges, including harassment, lack of access to markets, and inadequate compensation [11]. The Internet of Things (IoT) has revolutionized various industries, including solid waste management. Smart sensors have been adopted in this field to enhance efficiency and sustainability. These sensors are capable of collecting and transmitting real-time data on waste levels, temperature, and other parameters, allowing waste management companies to optimize collection routes, reduce costs, and minimize environmental impact [12]. Furthermore, the integration of IoT smart sensors with waste bins and containers enables remote monitoring, predictive maintenance, and timely waste collection, ultimately leading to improved waste management practices [13]. IoT in waste management involves the integration of sensors, communication devices, and data analytics to optimize collection, disposal, and recycling processes. Developments in technology systems have allowed waste managers to use data sources such as Global Positioning Systems (GPS) and Geographical Information System (GIS) systems to make the waste collection more efficient with mapping and path optimization [14]. Given the challenges outlined above, there is a clear need for an improved solid waste management system in Nigeria. The aim of this research is to develop a system that leverages smart IoT (Internet of Things) devices to address the inefficiencies in the current waste management practices. By incorporating IoT technologies, the proposed system will enable real-time monitoring of waste bin levels and air quality at various dumpsites, facilitating timely and efficient waste collection [15]. The use of IoT sensors will allow for accurate data collection on waste generation and disposal, which can be used to optimize waste management operations. For instance, data on the fill levels of waste bins can be transmitted to a central web-based system, which will alert waste management agencies when bins need to be emptied [16]. This will help to prevent the accumulation of waste in public spaces and reduce the health risks associated with uncollected waste. In addition to improving the efficiency of waste collection, the proposed system will also enhance transparency and accountability in waste management operations. By tracking the performance of waste collection contractors and monitoring revenue generated from waste disposal activities, the system will help to ensure that resources are used effectively and that services are delivered equitably. Ultimately, the implementation of a smart IoT-based waste management system has the potential to transform waste management practices in Nigeria, contributing to a cleaner, healthier environment and improving the quality of life for the country's citizens.

Theoretical Framework

Overview of Waste and its Management

Municipal Solid Waste Management means classifying waste according to their category and processing them so that the volume of waste get reduced and it lower down environmental load. Municipal Solid Waste Management (MSWM) consist of various steps, which are direct waste generation, storage collection, source separation, processing, transport, treatment, recovery and disposal. If proper waste management is not carried out, then it will create various problems and pollution issue. Such as causing land pollution due to open dumping of waste without treatment, causing water pollution if waste is discharged into water bodies and cause air pollution due to burning of waste under free atmosphere. Improper disposal of waste directly & indirectly effects on human body & surrounding living organisms. It gives bad appearance & produce bad smell so it becomes intolerable to survival near such sites. It was found that some disease also spread such as dysentery, cholera, plague, typhoid, infective hepatitis etc. Municipal solid waste management become a very critical and important issue in Nigeria [17]. The majority of household and veterinary practice waste is considered "solid waste," regardless of whether it is actually "solid" in physical form. The U.S. *Environmental Protection Agency (EPA*) defines solid waste *as "*any garbage or refuse, sludge from a wastewater treatment plant, water supply treatment plant, or air pollution control facility and other discarded material, including solid, liquid, semi-solid, or contained gaseous material resulting from industrial, commercial, mining, and agricultural operations, and from community activities. According to [18] waste is defined as matter that has no use. For example, garbage from industries, trash junks, domestics or ashes. It may be domestic, nonhazardous, hazardous or infectious. Waste is an essential product of human activities; it is also the result of inefficient production processes whose continuous generation is a loss of vital resources [19]. Despite that, the production of wastes remains a major source of concern as it has always been since pre historic period in recent times, the rate and quantity of waste generation have been on the increase. As the volume of wastes increases, so also does the variety of the waste increases [20]. Unlike the pre historic period where wastes were merely a source of nuisance that needed to be disposed of. Proper management was not a major issue as the population was small and a vast amount of land was available to the population at that time. In those days, the environment easily absorbed the volume of waste produced without any form of degradation. A substantial increase in volume of wastes generation began in the sixteenth century when people began to move from rural areas to cities because of industrial revolution [21]. This migration of people to cities led to population explosion that in turn led to a surge in the volume and variety in composition of wastes generated in cities. It was then that materials such as metals and glass began to appear in large quantities in municipal waste stream [22]. The large population of people in cities and communities gave rise to indiscriminate littering and open dumps. These dumps in turn formed breeding grounds for rats and other vermin, posing significant risks to public health. The unhealthy waste management practices resulted in several outbreaks of epidemics with high death tolls. Consequently, in the nineteenth century public officials began to dispose waste in a controlled manner in other to safe guard public health. Most developed countries passed through a period when they were developing environmentally. Today, however, most of these countries have effectively addressed much of the health and environmental pollution issues associated with wastes generation. In contrast, the increasing rate of urbanization and developments in emerging countries is now leading to a repeat of the same historical problems that developed countries have had to address in the past [23]. A substance regarded as a waste to one individual, may be a resource to another. Therefore, a material can only be regarded as a waste when the owner labels it as such. Despite this subjective nature of wastes, it is important to describe clearly, what constitutes a waste because. This is because the classification of a material as a waste will form the foundation for the regulations required to safeguard the populace and the environment where the wastes are being processed or disposed of.

Air Quality: Measurement and Standards

Air quality refers to the condition of the air within our surroundings, with a focus on the presence and concentration of pollutants that can harm human health and the environment. The measurement of air quality involves assessing the levels of various pollutants in the atmospheric air, such as particulate matter ($PM_{2.5}$ and PM_{10}), carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), ozone (O_3), and volatile organic compounds (VOCs). Accurate determination of air quality is crucial for identifying pollution sources, evaluating the effectiveness of pollution control strategies, and protecting public health. One of the commonly used methods for determining air quality involves the deployment of sensors that can detect and quantify the concentration of specific pollutants in the air. Among these, the MQ135 gas sensor is widely recognized for its effectiveness in measuring air quality, particularly in detecting hazardous gases such as ammonia (NH_3), benzene, smoke, and carbon dioxide (CO_2). The MQ135 sensor is a widely used tool for measuring air quality by detecting various atmospheric pollutants, including

Open Access
Online ISSN: 2992-5487
Print ISSN: 2992-6068

ammonia (NH_3), nitrogen oxides (NO_x), alcohol, benzene, smoke, and carbon dioxide (CO_2). This sensor operates by measuring the resistance change of a sensitive semiconductor layer in response to the presence of these gases. The output from the MQ135 sensor can be used to estimate pollutant concentration levels, which can then be compared to WHO standards to assess air quality [24]. The MQ135 sensor is often used in conjunction with microcontrollers and data acquisition systems to continuously monitor air quality in real-time. It is particularly favored in low-cost air quality monitoring systems due to its affordability, ease of use, and wide detection range. The sensor is calibrated to produce accurate readings for specific gases, and the data collected can be transmitted to a central system for analysis, allowing for timely interventions in case of high pollution levels. The World Health Organization (WHO) has established guidelines and standards for air quality to protect human health. According to WHO, air quality should be maintained within specific thresholds to minimize health risks associated with exposure to pollutants. For instance, the WHO's air quality guidelines set the annual mean concentration for PM2.5 at 10 µg/m³ and for PM10 at 20 µg/m³ [22]. Exceeding these levels is associated with increased risks of respiratory and cardiovascular diseases. The WHO guidelines also provide limits for other pollutants, such as NO_2, SO_2, and O_3, ensuring a comprehensive approach to air quality management. Air quality is a critical environmental and public health concern, and its measurement is facilitated by technologies like the MQ135 sensor. By adhering to WHO's air quality standards, governments and organizations can effectively manage pollution and protect public health.

Standard Atmospheric Pollutants

Standard atmospheric pollutants, also known as criteria pollutants, are those that pose significant risks to human health and the environment. The U.S. Environmental Protection Agency (EPA) identifies six major pollutants as indicators of air quality: particulate matter (PM), ground-level ozone (O_3), carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and lead (Pb) [21]. These pollutants are primarily generated from industrial activities, vehicle emissions, and other human activities, leading to air quality degradation and associated health issues. Particulate matter, particularly PM2.5, consists of tiny particles that can penetrate deep into the lungs and even enter the bloodstream, causing respiratory and cardiovascular diseases [7]. Ground-level ozone, formed by the reaction of sunlight with pollutants like volatile organic compounds (VOCs) and nitrogen oxides (NO_x), is another harmful pollutant. It can lead to respiratory problems and exacerbate conditions such as asthma [14]. Sulfur dioxide and nitrogen dioxide are primarily produced by fossil fuel combustion in power plants and vehicles. These gases can irritate the respiratory system, lead to acid rain, and contribute to the formation of fine particulate matter (Burnett et al., 2014). Carbon monoxide, a colorless, odorless gas resulting from incomplete combustion, can interfere with oxygen delivery in the body, leading to serious health effects, particularly for individuals with cardiovascular conditions [8]. Lead, historically emitted from vehicles using leaded gasoline, remains a concern due to its toxic effects on the nervous system, especially in children [6]. Efforts to monitor and control these pollutants are crucial for protecting public health and the environment. Regulatory measures, such as the Clean Air Act in the United States, have been instrumental in reducing the levels of these harmful pollutants in the atmosphere [20]. Ongoing research and policy initiatives are essential to continue mitigating the impact of these standard atmospheric pollutants.

WHO Air Quality Standard Index Table

The World Health Organization (WHO) provides guidelines for air quality that specify the maximum acceptable concentrations of various pollutants in the air to safeguard public health.

Table 1: WHO Air Quality Standard Index

Pollutant	WHO Air Quality Guideline (µg/m³)	Averaging Time
PM2.5	10	Annual
PM2.5	25	24-hour
PM10	20	Annual
PM10	50	24-hour
Ozone (O_3)	100	8-hour
Nitrogen Dioxide (NO_2)	40	Annual
Nitrogen Dioxide (NO_2)	200	1-hour
Sulfur Dioxide (SO_2)	20	24-hour
Sulfur Dioxide (SO_2)	500	10-minute
Carbon Monoxide (CO)	10	8-hour

Table 1 is a simplified table representing the WHO air quality guidelines for some common pollutants.

SYSTEM ANALYSIS AND METHODOLOGY

The system aimed at improving the existing systems by developing a robust IoT-web based system integrated with sensors that will read waste bin level and monitor dumpsite area to ascertain air quality. Prototyping and Modelling Methodology was adopted for the hardware design with Embedded C++ language used for the sensor control algorithms.

Sensors at the dumpsites

In the proposed Solid Waste Management System, IoT sensors play a crucial role in monitoring dumpsites, ensuring efficient waste management, and maintaining environmental safety. The system employs ultrasonic sensors, an MQ135 air quality sensor, and a set of other components, all interconnected to provide real-time data on waste levels and air quality at various dumpsites.

Ultrasonic Sensors (for Waste Bin Level Monitoring and automatic opening of the waste bin)

The new system uses two ultrasonic sensors mounted on the waste bin, the sensors plays significant roles in ensuring effective waste collection and involves two major task: monitoring the waste bin's fill level and detecting the presence of a human to enable automatic opening and closing of the bin [7]. The first ultrasonic sensor is positioned to measure the fill level of the waste bin. It sends out ultrasonic waves and measures the time it takes for the waves to bounce back from the waste surface. Based on this time interval, the sensor calculates the distance to the waste level, determining how full the bin is. This real-time data is transmitted to the waste management system, enabling efficient scheduling of waste collection. When bins reach a certain threshold, waste collection services are alerted to empty them, optimizing routes and reducing unnecessary trips, thereby saving costs and resources [8]. The second ultrasonic sensor is aimed at detecting human presence near the bin. When a person approaches, the sensor triggers the bin to open automatically, allowing hands-free disposal of waste. The bin remains open for a few minutes to ensure all waste is disposed of, and then closes automatically, minimizing contact and maintaining hygiene.

Power Supply

The power supply system consists of a 3.7 V battery connected to a BUCK converter, which steps up the voltage to 5V, the required output for the sensors and microcontroller to function effectively. The battery's output is stabilized by a voltage regulator to ensure a consistent voltage supply. A switch connects the regulated battery to a charger, which maintains the battery charge levels, ensuring continuous operation. The 5V output powers several components at the dumpsite, including the ultrasonic sensor for measuring waste levels, the MQ135 sensor for air quality monitoring, and the ESP32 microcontroller, which manages data processing and communication [9].

Air quality Sensor (MQ135)

The MQ135 sensor is a critical component in monitoring air quality at dumpsites within the Solid Waste Management System, providing valuable data on the concentration of various gases such as ammonia (NH_3), nitrogen oxides (NO_x), alcohol, benzene, smoke, and carbon dioxide (CO_2) [7]. The Gas sensor is connected to the ESP32 controller's analog pins. The ESP32 processes the sensor's analog readings, converts them to digital values, and calculates the corresponding air quality index (AQI) based on pre-determined calibration data. The MQ135 sensor detects the concentration of gases in parts per million (PPM). The sensor reading algorithm converts these PPM readings into corresponding AQI levels, (from ppm to $\mu g/m^3$), allowing for accurate assessment of air quality based on WHO standards. This conversion is crucial as it translates raw sensor data into meaningful information that can be directly compared to health guidelines. The calculated AQI is then transmitted via the GSM module to the cloud-based platform ThinkSpeak. ThinkSpeak stores the data in its database, allowing for real-time monitoring and visualization. A customized web-based system, connected to ThinkSpeak's API, retrieves the stored data and presents it in a user-friendly format. This enables Waste Management Agency to track air quality changes, identify trends, and take appropriate actions to mitigate environmental impacts [9].

WHO Air Quality Index (AQI)

The WHO AQI is a standardized system used to measure and communicate the quality of air based on the concentration of key pollutants. These include PM2.5, PM10, CO, SO2, NO2, and O3. The MQ135 sensor primarily detects CO2 and other VOCs, making it relevant for assessing air quality in the context of these pollutants.

AQI Categories [7].

The WHO AQI categorizes air quality into six levels:

1. Good (0-50 AQI): Air quality is considered satisfactory, with no significant risk to health.
2. Moderate (51-100 AQI): Air quality is acceptable, though sensitive individuals may experience minor effects.
3. Unhealthy for Sensitive Groups (101-150 AQI): Sensitive groups may experience health effects, while the general public is less likely to be affected.
4. Unhealthy (151-200 AQI): Everyone may begin to experience health effects, with sensitive groups being more severely impacted.

5. Very Unhealthy (201-300 AQI): Health alert for everyone, with a higher risk of adverse health effects.
6. Hazardous (301-500 AQI): Emergency conditions with widespread health impacts.

Data Transmission and Analysis

The converted AQI data from the MQ135 sensor is transmitted via a SIM900 module to a cloud-based API, (ThingSpeak), which is connected to the backend of the web-based waste management system. The backend program logic then compares the computed AQI levels with whose AQI categories to determine the air quality status at the dumpsite. For example, if the sensor detects a CO2 concentration that corresponds to an AQI of 180, the system would classify the air quality as "Unhealthy," triggering alerts and actions to mitigate the potential health risks. The analyzed data is then displayed on the system's dashboard, providing real-time insights for users to monitor and manage the air quality effectively [12].

Disposal monitoring switch

A switch mounted on the waste bin is connected to an ESP32 microcontroller, which is powered by a 5V power supply. This switch serves as a crucial component for tracking waste disposal activities. Each time the waste bin is evacuated, the switch is activated, sending a signal to the ESP32 controller. The controller is programmed to count each activation of the switch, thereby recording every instance when the bin is emptied. This data is logged and transmitted to the waste management system in real-time via the ESP32's wireless communication capabilities. The recorded data is transmitted to the web-based system's backend, where it is processed and displayed on the user dashboard. This dashboard provides stakeholders with real-time insights into the waste collection process, including the status of each bin, the timing of evacuations, and the performance of truck drivers [9].

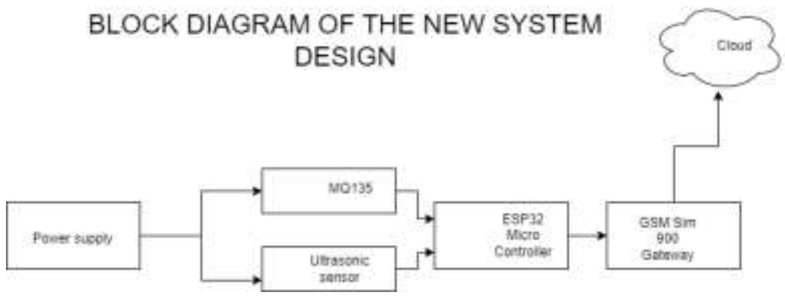

Figure 1 Block diagram of the new system at dumpsite

Circuit Design

The waste management circuit design integrates several components to monitor the waste bin's status and surrounding environmental conditions. The ultrasonic sensor continuously measures the waste level in the bin, detecting when it reaches a predefined threshold. Simultaneously, the MQ135 sensor monitors air quality, identifying hazardous gases emitted from the waste. A humidity and temperature sensor tracks environmental changes around the waste bin [4]. All these sensors are powered by a 3.7V battery connected to a BUCK converter, which steps up the voltage to 5V, ensuring adequate power supply to all components. A disposal check switch, attached to the waste bin, is connected to the ESP32 microcontroller to count the number of times the bin is emptied. When the bin is evacuated, the switch sends a signal to the controller, which resets the count. The ESP32 microcontroller processes data from all sensors and sends it to an LCD display for real-time monitoring. The microcontroller also communicates with the GSM SIM900 module to transmit the collected data to the Thing Speak API for further analysis. A voltage regulator maintains a stable 5V supply to the entire circuit, ensuring consistent performance [9].

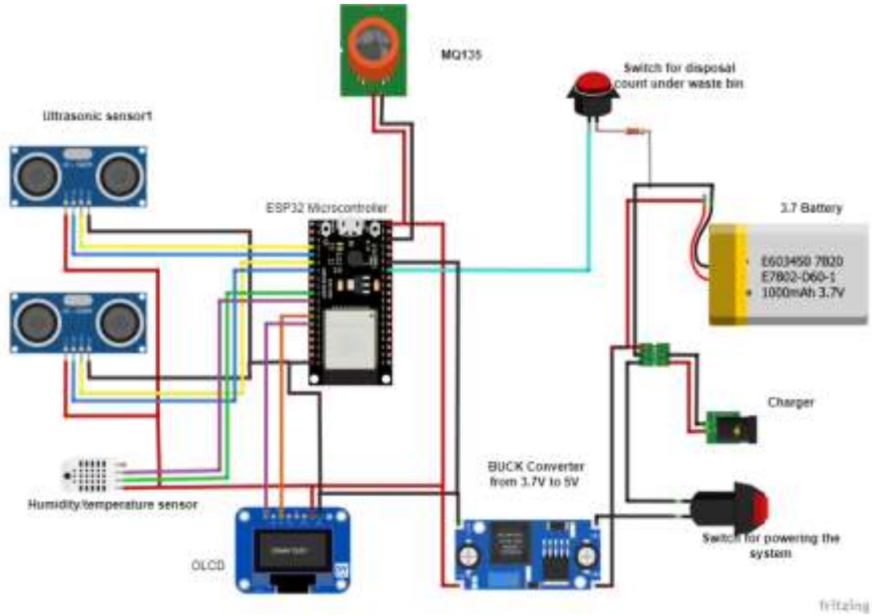

Figure 2 Circuit Design of the Hardware components

Figure 3 Architecture of the system

Hardware Setup Testing

A 50-liter waste bin was used with ultrasonic sensors and an MQ135 gas sensor connected to an ESP32 controller, powered by a 5V power supply. After configuring the hardware, sample waste was placed in the bin at varying levels, and the sensor readings were captured and transmitted to the ThinkSpeak cloud using a GMS WiFi module. Methane gas was introduced to test the gas sensor, which successfully recorded the gas levels, decayed waste was taken from an open dumped waste to test the gas emission, MQ135 sensors reading shows high level of gas emission. The waste was dropped in small quantity and the sensors reads and transmit data on various levels to the cloud API. Additionally, the waste disposal process was tested by evacuating the waste, with the disposal switch count being recorded and transmitted for visualization. The successful reading of sensor data and its real-time transmission confirmed the system's effective functionality [7].

Open Access
Online ISSN: 2992-5487
Print ISSN: 2992-6068

Figure 4: Waste bin readings at different levels

Figure 1 shows the test view of waste level when there are no waste in the waste bin and when some quantities of waste were in the waste bin. When the waste bin is empty, the reading is at 0, when small quantity of waste was added, the readings move from 0 to 35.

Figure 5 Gas sensor readings at different exposure

Figure 2 shows the gas sensor readings at different exposure, when dumpsite is free from air pollution, the sensor reading was at 50 which is normal Air quality level according to WHO. When the dumpsite was exposed to Methane gas and decayed waste from open dumpsite, the sensor reading, recorded 570, which is hazardous to human health.

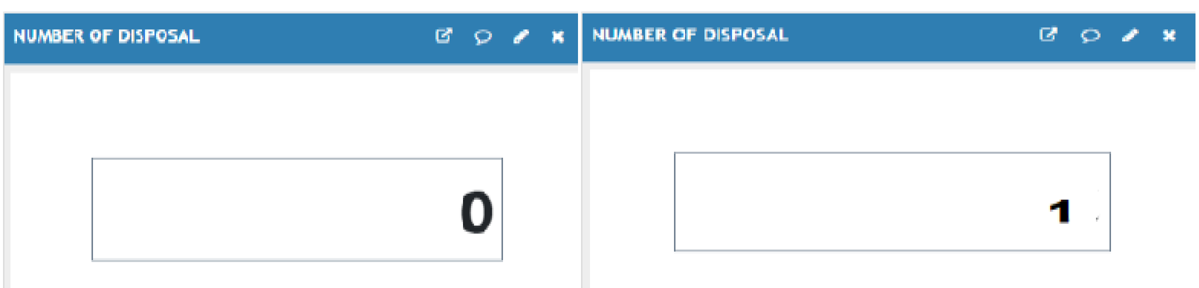

Figure 6 Disposal count at different occasions

Figure 3 shows the readings of disposal count when the waste bin was evacuated, it counted and recorded 1 and 0 when the waste bin has not evacuated

Summary and Conclusion

This research focus on using load cell sensor to monitor the weight of waste bin as the waste increases in the bin. The system also uses three gas sensors (MQ5, MQ7 and MQ135) to detect the concentration of Methane, Carbon II Oxide and Ammonia gas at the dumpsites. The data from the sensor is transmitted to the Thinkspeask API for analysis. The robust nature of the system provides two basic features; the customized system, which provides several modules for management, purposes, public users relations with the stakeholders of the waste management and the Government agency in charge of environmental sanitation. The system was tested with data from simulated environment and compared using WHO air quality index standard and results were generated. With the new system full implementation, the management of solid waste in Nigeria will be highly improved, thereby creating a clean and a healthy environment free from air pollution from incessant dumping of refuse or waste.

REFERENCES

1. Abonyi, N. N., & Eleje, J. N. (2020). Industrial Waste Management and Environmental Pollution in the Niger Delta Region of Nigeria. ESUT JOURNAL OF SOCIAL SCIENCES, 5(2). Retrieved from https://esutjss.com/index.php/ESUTJSS/article/view/43
2. Adekunle, I., Oguns,O., Shekwolo,P., &Ogunkoya, O(2012).Assessment of Population Perception Impact on Value-Added Solid Waste Disposal in Developing Countries, a Case Study of Port Harcourt City, Nigeria. DOI: 10.5772/29305
3. Anderson, J. O., Thundiyil, J. G., and Stolbach, A. (2012). Clearing the air: A review of the effects of particulate matter air pollution on human health. *Journal of Medical Toxicology*, 8(2), 166-175.
4. Afolabi, A. O. (2018). Waste management in Nigeria: Problems and prospects. The Journal of Solid Waste Technology and Management 44(2):163-172DOI: 10.5276/JSWTM.2018.163
5. Alamo, P., and Ahmade, K., (2013). Impact of solid waste on health and the environment. International Journal of Sustainable Development and Green Economics (IJSDGE),3(2). Retrieved from https://www.researchgate.net/publication/306150450
6. Alter, S. (2013). Decision Support Systems: Current Practice and Continuing Challenges. In Handbook on Decision Support Systems 1 (pp. 1-17).
7. American Veterinary Medical Association: "Waste". https://www.avma.org/resources-tools/one-health/waste-disposal-veterinary-practices/definitions-what-waste.
8. Anyanwu, K., and Adefilia ,O.,(2014). Environmental Waste Management and Sustainable. International Journal of Applied Science and Engineering 4(2): Retrieved from
9. Arogundade,S.(2021).Waste Management Outlook for Nigeria. Retrieved from https://www.bioenergyconsult.com/waste-management-outlook-for-nigeria/
10. Aschemann-Witzel, J., De Hooge, I., Amani, P., Bech-Larsen, T., & Oostindjer, M. (2015). Consumer-related food waste: Causes and potential for action. Sustainability, 7(6),Doi:6457–6477.
11. Barros, A., Dekker, R., & Scholten, V. (1998). A two-level network for recycling sand: A case study. European Journal of Operational Research, 110(2), 199-214. https://doi.org/10.1016/S0377-2217(98)00093-9
12. Babayemi, J.O. and Dauda, K.T. (2009) Evaluation of Solid Waste Generation, Categories and Disposal Options in Developing Countries. A Case Study of Nigeria. Journal of Applied Science and Environmental Management, 13, 83-88.
13. Bell, M. L., McDermott, A., Zeger, S. L., Samet, J. M., and Dominici, F. (2004). Ozone and short-term mortality in 95 US urban communities, 1987-2000. *Journal of the American Medical Association*, 292(19), 2372-2378.
14. Beretta, C., & Hellweg, S. (2019). Potential environmental benefits from food waste prevention in the food service sector. Resources, Conservation and Recycling, 147(19), DOI: 10.1016/j.resconrec.2019.03.023
15. Berkun, M. Aras, E., Anialn,T.(2011).Solid Waste Management Practices in Turkey. Journal of Material Cycles and Waste Management. 13(4) DOI: 10.1007/s10163-011-0028-7
16. Bovea and Powell (2006). Life cycle assessment of municipal solid waste management scenarios on the small island of Mauritius. The Journal for a Sustainable Circular Economy doi/10.1177/0734242X16679883
17. Braimah,E.(2023). The current state of waste management in Nigeria and the challenges of transitioning to a circular economy
18. Brown, R., and Williams, P. T. (2017). Waste Incineration and Public Health. Critical Reviews in Environmental Science and Technology, 47(13), 1166-1203.
19. Buah, W. K., Cunliffe, A. M., & Williams, P. T. (2007). Characterization of Products from the Pyrolysis of Municipal Solid Waste. Process Safety & Environmental Protection, 85(5), 450-457. https://doi.org/10.1205/psep07024
20. Brunner, P., and Rechberger, H., (2014). Waste to energy - key element for sustainable waste management. Elsevier. Retrieved from https://doi.org/10.1016/j.wasman.2014.02.003
21. Bishop, C. M. (2006). Pattern Recognition and Machine Learning. Springer. Retrieved from https://link.springer.com/book/10.1007/978-0-387-45528-0
22. Burnett, R. T., Pope III, C. A., Ezzati, M., Olives, C., Lim, S. S., Mehta, S., ... and Anderson, H. R. (2014). An integrated risk function for estimating the global burden of disease attributable to ambient fine particulate matter exposure. *Environmental Health Perspectives*, 122(4), 397-403.

23. Christensen, T. H., and Anderson, L (2011). Greenhouse gas emissions from municipal solid waste management: A comparative analysis using life cycle assessment. *Waste Management*, 31(8), 1585-1596. doi: 10.1016/j.wasman.2011.03.021
24. Chen, W., Wang, Y. and Huang, P (2019).IoT waste management system for Hazardous materials. Conference on 1st International Cognitive Cities Conference (IC3). DOI: 10.1109/IC3.2018.00-24

CITE AS: Chika Lilian Onyagu, Akawuku I. Godspower, Joshua John and Chika Okonkwo (2024). Integration of Gas and Ultrasonic Sensors for Monitoring Air Quality and Smart Waste Bin levels determination: An IOT illustration in Solid waste management. NEWPORT INTERNATIONAL JOURNAL OF ENGINEERING AND PHYSICAL SCIENCES, 4(2):19-28. https://doi.org/10.59298/NIJEP/2024/421928.2.1