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A TECHNICAL REPORT ON THE DESIGN AND CONSTRUCTION OF A SMART WASTE BIN FOR MEDICAL WASTE MANAGEMENT

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ABSTRACT.
Our project is about the design and construction of a smart waste storage device as an immediate means to mitigate the problems associated with poor Medical waste management through sterilization.

Medical waste is waste generated during the diagnosis, treatment, and immunization of human beings or waste generated by healthcare establishments, research facilities, and laboratories. These medical wastes are categorized by level of infectiousness and their effects on human beings and the environment. For example, non-infectious waste is usually put in black disposal bins), infectious waste is usually put in yellow disposal bags or bins and highly infectious waste is usually disposed in red bins. The highly infectious wastes pose a greater degree of infection to persons who come into direct contact with such wastes. This infection can be bacterial, fungal, and viral infections, infections resulting from chemical spills and radioactive substances.

Depending on the volume and the type of medical waste generated, hospitals have several options when it comes to waste disposal. On-site as well as off-site options are available to some but before medical waste can be transported off the property of a medical waste generator, some of it must be properly treated to reduce or eliminate the infectious potential of that waste before it hits the road to its disposal location.

The pre-treatment not only reduces the volume of internal medical waste heading to landfills (as non-infectious or decontaminated waste) but also ensures a reduction or complete removal of potentially infectious materials found in the variety of the medical waste streams produced by the hospital. Two primary options applicable for pre-treatment or destruction of wastes for the hospital are incineration or autoclaving. However, the effectiveness of medical waste management using the available primary options in every health facility depends majorly on the awareness of the health personnel, waste management team, and the general fraternity of the hospital including the patients, availability of personal protective gear, internal and external regulatory framework, and financing organ.

In our project, the team focused on designing an automatic waste storage device. It operates in a way that when a person is within the set distance, a sensor outside the waste bin detects him/her and the lid opens automatically with the help of a motor that functions on the principle of servo mechanism.

Keywords: Smart waste bins, Medical waste management, Waste storage
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Introduction

Medical wastes are wastes generated during the diagnosis, treatment, and immunization of human beings or waste generated by healthcare establishments, research facilities, and laboratories that include pharmaceutical waste, infectious waste, sharps waste, chemotherapy waste, and pathological waste. Medical waste is a special type of waste produced in small quantities but carrying a high potential for infections and injuries (Shahida Racheed, 2005). Health care or medical wastes are considered to be the second most hazardous and catastrophic waste globally after radioactive waste (Arab M). These wastes encompass various forms of wastes such as sharps, human body parts and blood, chemical wastes, pharmaceutical wastes, and medical devices (AJ., 2013).

These wastes are generated a significant amount daily in Health care institutions such as diagnostic centers, blood banks, autopsy centers, and nursing homes among others (Annanthachari., 2016). Of the total amount of waste generated by healthcare activities, about 85% is general waste and 15% is hazardous waste. The significant volume of these wastes is due to several factors that even contribute to poor management of the wastes the health facilities as well. These factors include; a lack of medical waste regulation, disposal systems, and awareness. Globally, it is estimated that accidents caused by sharps account for 66,000 cases of infection with hepatitis B virus,16000 cases of infection with hepatitis C virus, and 200 to 5000 cases of HIV infections amongst the personnel of healthcare facilities (al, April 2014)

Unlike in the past, when the rate of infections was community-based infections, today with the world's invasion by the COVID-19 pandemic and epidemic, the use of personal protective equipment or gear such as face masks, and gloves has been adopted in the community as directed by the World Health Organizations through the MoH. These wastes when improperly managed pose significant devastating effects on human health such as various hospital-acquired infections, occupational health hazards, and food contamination (SV., 2004), because they present a high potential for microbial and viral infections. These poor waste management practices eventually subject medical waste management teams that include garbage handlers, and patients who are all susceptible to infections (AJ., 2013), and can be infected with Hepatitis B, meningitis, Hepatitis C, HIV/AIDS, TB, and air born respiratory diseases ((WHO n.d.). The infections could be contracted either through direct contact or indirect exposure to such contaminated wastes.

In Uganda, the Medical waste generated averaged 92 kilograms per day in hospitals while primary health facilities (level IV health centers, level III health centers, and level II centers) generate about 42 kilograms, 25 kilograms, and 20 kilograms respectively daily (AIDSTAR-one, 2000). Moreover, most of these primary health facilities lack proper waste management facilities (Victoria M, 2014). Despite the policy guidelines on injection and health care waste management developed by MoH, Uganda, there is sufficient that medical waste management is not properly handled in most health facilities (Mugabe RK, 2014). Poor medical waste management can eventually result in various hospital-acquired infections, occupation health hazards, and food contamination

Thus to reduce the rate of infections in health facilities, proper waste management practices should be adapted and prioritized.

Problem statement

Proper Health Care waste management in hospitals or healthcare units is essential in our daily lives as far as prevention of either non-communicable or communicable disease infections is concerned. It ensures the protection of the environment against pollution by reducing the spillage of these wastes on the land. Not only that but also, but it also plays a great role in the improvement of the country's economy by reducing the country's expenditure on disease treatment that can even be prevented through simple mitigation measures.

However, in Kayunga Regional Referral Hospital, medical waste management is still a great challenge even though there exists hospital waste management strategies or policies on the ground. There also exists inadequate knowledge on proper waste management by patients evidenced by failure to classify wastes being non-infectious, infectious, and highly infectious. This has resulted in high risks of infections associated with improper medical waste management. In the study conducted at this facility, at least six out of ten people every week who get directly or indirectly into contact with these infectious medical wastes stand at high risk of infections.

With the outbreak of the COVID-19 pandemic, the volume of waste has also greatly increased because the use of personal protective gear like gloves, and face masks among others has been adopted. These used hygienic wastes are disposed of minus being subjected to the disinfection processes yet there exists amongst the type of wastes, those that are considered to be too hazardous to be handled, recycled, and re-used without pre- treatment. Such practices, therefore, have increased the rate of contraction of diseases such as HIV/AIDS, Hepatitis B, Tuberculosis and even further spread of Covid-19 among others. The contraction is either through direct contact with such waste by the medical waste management team, doctors, and any other person or indirectly through cross-transmission.

Therefore, to curb this great challenge, there is a need for prioritization in medical waste management to protect and prevent the hospital fraternity from the devastating effects of improper waste management on human health and the environment.

Existing technology

Hazardous medical wastes such as sharps, pharmaceutical waste, chemical waste, dangerous radioactive waste, and other infectious waste in health facilities need to be treated and disposed of properly to avoid their negative impacts on human health. The wastes are classified based on the degree of contamination

However much there is poor biomedical waste management in the hospital setting, there exists a range of technologies that have been put in place to curb the challenge. These technologies are; disposable bags, dust bins and incinerators.

Disposable bags

These are mostly polyethylene bags of different colours used in different wards to store the different classes of wastes. The technology cannot be re-used even after sterilization hence it is not pockets friendly in the long run.

Dustbins with Lids

These categories of the bins open upon the applied force on the paddle. The user drops the waste when the lid is open. When the force applied on the paddle is withdrawn, the lid immediately closes. The technology therefore subject users to direct contact.

Most of the dustbins are foot-peddle operated lids, graduated marks to the level to be emptied. Some of the bins also have casters that facilitate its rolling and transportation. In addition to the above, these disposal bins have biohazard symbols on their surfaces (et).

Dustbins without lids

These bins do not have lids and paddles and hence it subjects users to a greater risk of infections.

Incinerator

Some hospitals with incinerators burn their wastes into ashes as a means of waste disposal while others without the incinerators recycle, burry the placenta and compostable to fill the land. This technology is very expensive to install, requires a skilled personnel for the routine operation

However much the above technologies have been in existence, there is still a need to find another solution to mitigate this great challenge.

SJ Engineering Africa
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Table 1 showing classification of biomedical waste

Waste type	Classification	Colour coding	Description & disposal method
Infectious	Hazardous	Yellow	Infectious waste which requires disposal by incineration.
Highly infectious	Hazardous	**Red**	Anatomical waste which requires disposal by incineration.
General waste, non-infectious.	Non hazardous	Blac	This is waste should not contain any infectious materials, sharps or medicinal products, and requires disposal by landfill.

Figure 1 showing disposable bags

Vol. 1 No. 1 (2024): January 2024 Issue
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Figure 2 showing the different colours of dustbin in health facility.

Figure 3 showing foot-paddle operated and an open dustbin without lid

Figure 4 showing an incinerator

Objectives of the project

Main objective

- To design a simple smart waste storage device in health facilities to reduce the rate of infections associated with poor medical waste management.

Specific objectivities

- To construct a reliable simple waste storage device.
- To test a simple waste storage prototype.
- To analyze and determine whether there is a reduction in the rate of infections.

CONCEPT OF THE INNOVATION

This chapter consists of the product design specifications, project idea generation, and idea selection.

Product design specifications

Usually, the device requires to be opened by pressing the foot against its lever and then throwing the garbage. Also, the user needs to keep track of when it's full so that it can be emptied and does not overflow. In this design, the device is an Ultrasonic Sensor enabled in the bin which automatically detects the garbage and sets the code in the Arduino circuit board which helps to open and close after detecting the garbage (S.S. Navhhane, May, 2016.).

Following are brief descriptions of the product design specifications.

Functional requirements

The technology provides an effective mitigation measure for the control of health care waste-associated infections. The device can attain at least 98% purposes to obtain reliable results.

Safety to the operator and environment

The design offers a high degree of safety to the operator. In that, injuries resulting from mechanical hazards are minimized.

Energy efficiency

The equipment is capable of operating on a range of 9v to 18v DC power supply. This power requirement is sufficient to supply all components involved in the device. This device is, therefore, in the position of operating in areas with or without an AC power supply.

Sterilizing ability

The device can sterilize waste up to 99.9%.

Sleek and compact design

The device is designed to fit in a small space of not more than 60cm X 60cm and add to the anesthetics of any premise. In addition to this, this device is also light in weight to enable its easy means of transport and handling efficiency.

Reliability and performance

The device is in a position to operate anywhere it is needed and be in a position to perform its function appropriately.

Ease of operation

The device does not require a technical person to specifically run it. Any other person can operate it and requires less manual intervention.

Durability

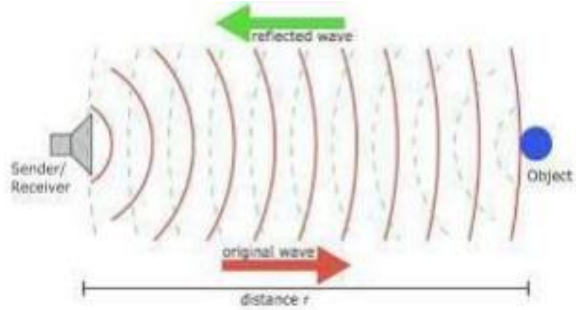

Figure 5 Showing ultrasonic sensor operations.

Smart waste bin:

The team chose a smart dustbin due to its ability to reduce direct contact with the user, reliability, and durable. The device shall be automated and it shall open whenever it senses an object in front of it. An ultrasonic sensor and servo motor are interfaced with a microcontroller (Arduino UNO) for automation of the device. The sensor sends signals to detect an object and thereafter receives the reflected signal. The output of this sensor is then sent to the microcontroller which in turn sends signals to the servo motor.

The Servo motor is tiny, light in weight with high output, and can rotate to approximately 180 degrees. It can use any code, hardware, or library to control it. The Servo motor allows the lid of the device to open.

UV waste bin

The device has a disinfecting unit composed of the UVC LED's circuit. The technology kills and activates germs and bacteria inside the bin. The waste in the bin is sterilized using LEDs. UV light sterilization effectively inactivates microorganisms by damaging the DNA of cells hence hindering cell replication. Absorption of this light by the cells results in pyrimidine dimers that cause two adjacent thymine and cytosine bases to bond with each other, instead of across the double helix as usual. So this DNA molecule with the pyrimidine dimmers is unable to function properly, resulting in the organism's death and inability to replicate. An organism that is incapable of replicating can no longer spread disease. This mechanism is therefore employed in the disinfection of unicellular organisms of microorganisms such as viruses, protozoa, and fungi. The sterilizing unit is effective and kills pathogenic particles at a rate higher than 99.9%

This process involved the selection of the most appropriate method of mitigating the challenge. During this process, these selections were made based on the ranking of the involved parameters where the best option carried the greatest score.

Criteria for success

Operational environment (A)

It is suitable for being used in areas even without an Alternating voltage supply.

Functionality/performance (B)

The design opens automatically with the help of the outer ultrasonic sensor. It is also capable of sterilizing waste before disposal at the incineration point.

Safety (B)

The system is well insulated and the sensors have no life-threatening effects.

Accuracy and reliability(C)

The device produces the most efficient and reliable results.

Affordability (B)

The device is cheap compared to the cost involved in the procurement of sanitizers and other disinfectants involved in reducing the rate of infections.

Size (A)

The device is light as the incorporated components are light thus making it easy to carry in case there is a need to change the location.

Usability (A)

The device is easy to use with the help of the ultrasonic sensors which enables it to open automatically and to detect the user or any object in front of the bin within the angular distance.

The device has a long life span with an absolutely low degree of operational limitations from the environmental factors

Project idea generation

During this process, the team used brainstorming techniques to generate ideas. It involved radial thinking where possible solutions or ideas were generated out of which the most effective ideas were selected. It was a beneficial preliminary stage that involved free interaction of every one. The team came up with the following solutions in an attempt to mitigate this challenge.

SJ Engineering Africa
Vol. 1 No. 1 (2024): January 2024 Issue
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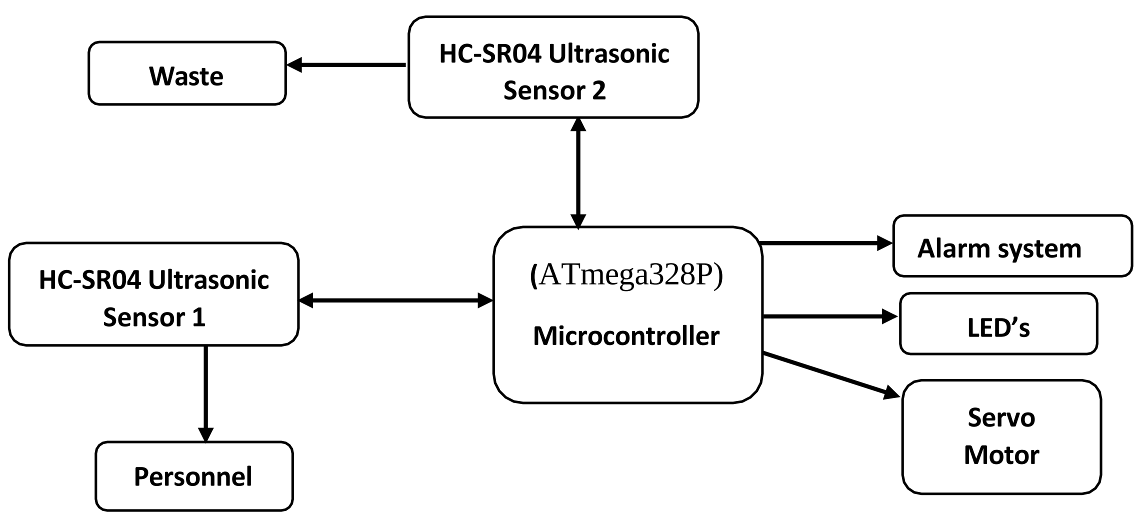
Weighted Design matrix

Specification	Weight	Disposable box	Disposable bags	Smart waste bin
Ability to sterilize	99	9.9 (2)	9.9 (2)	9.9 (10)
Low power consumption	20	1 (10)	0	5 (4)
Automation	40	0.4 (2)	0	4 (10)
Low purchase cost	32	8 (4)	3.2 (10)	0.32 (6)
Re-usability	20	10 (2)	0	2 (10)
Reliability	75	0.75 (2)	0.75 (2)	7.5 (10)
Non toxicity	8	0.48 (6)	4.8 (6)	4 (2)
Total score		40.03 (32)	30.95 (24)	42.22 (62)

*Table 2 showing the grading system and weight design matrix***Block Diagram showing the working mechanism of the device.**



ENGINEERING ANALYSIS OF THE SMART WASTE BIN

Principle of operations

Piezoelectric principle

The smart waste bin is made up of Ultrasonic sensor that works on the principle of object detection. The ultrasonic sensor is made up of piezo-elements that undergo relaxation and contraction as applied voltage is alternately varied. The piezo-electric components within ultrasonic transducers are used for emitting and receiving sound waves. The piezo-elements begin to vibrate when a voltage is applied. This vibration produces high-frequency sound waves. The target reflects these impulses, and the echo returns to the ultrasonic transducer. By measuring the time of flight the echo takes to return, the distance can be calculated using the speed of sound in the air. The equation used is $S = t \times c$ with c=344m/s.

Working mechanism

The smart waste bin is built on a microcontroller-based platform that is interfaced with Ultrasonic sensors. And it is also connected to the servo motor (Ghose, M.K, Dikshit, A.K, Sharma, S.K). Thus, the smart waste bin is made up of mainly the following components; two Ultrasonic sensors, a servo motor, a controller unit, and a sterilizing circuit.

The device is designed with two HC-SR04 ultrasonic sensors that detect the target that is, the personnel or the waste in the bin. The ultrasonic sensors are at the top and front side of the bin, like on the cover of the bin (Ghose, M.K, Dikshit, A.K, Sharma, S.K).

An *ultrasonic sensor 1* attached at the front of the smart bin detects the personnel by measuring the distance to the personnel using sound waves. It works by sending out a sound wave at ultrasonic frequency and waiting for it to bounce back from the object. The output of this sensor is then transmitted to the microcontroller for signal processing. The microcontroller then sends pulses that trigger the operations of the servo motor attached to the upper position of the lid, and the LEDs attached to the lid. The servo motor when triggered can push or rotate an object with great precision at some specific angles or distance. In this, the servo motor in this case allows the lid to open. A 20 cm range is set up for the identification system, therefore, if any personnel is detected within a certain range, the lid will open automatically with the help of the servo motor which is in the upper position of the bin. When the lid is opened, one can put garbage inside and the lid will close automatically when the person is out of the detection range. However, before the lid opens, the microcontroller sends signals to the circuit containing LEDs, rending it into an open state. For this reason, LEDs turn OFF and when the bin is closed, the LEDs turn ON for a set period to sanitize the waste in the bin. This mechanism is to protect the user from UVC light falling onto human skin and to save power.

The *ultrasonic Sensor 2* put on the top of the bin is responsible for determining the level and volume of garbage in the bin. This is done by transmitting sound and the sound waves get reflected by the waste inside the bin. This data is further transmitted to the microcontroller for data processing. Accordingly, information is processed and the controller checks if the threshold level is exceeded or not. The microcontroller then transmits the processed signals to trigger the alarm system. The alarm system is activated whenever the threshold level is exceeded. This alarm is intended to alert the operator or the personnel to empty the bin.

Conversion of distance to % of filled-up waste; $D = (v \times t)/2$.

Where V is the velocity of sound T is the time from the sensor

% FILLED UP **= (100 – 100/H) *D**

Where H is the height of the bin D is the converted distance

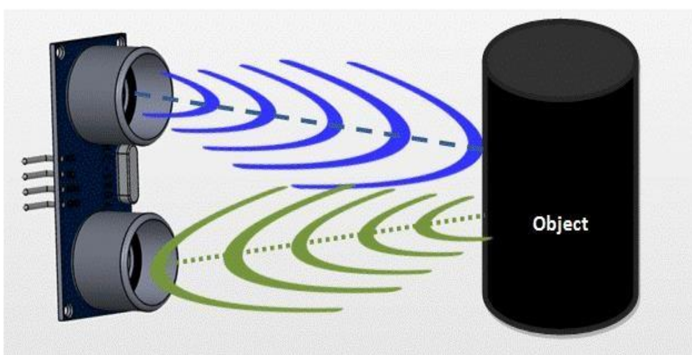


Figure 6 showing the operation of an ultrasonic sensor

Servo motor

A servo motor is an electrical device that can push or rotate an object with great precision. If an object is to be rotated at some specific angles or distance, then a servo motor is used. It is just made up of a simple motor that runs through a servo mechanism. If the motor used is DC powered then it is called a DC servo motor, and if it is AC powered motor then it is called AC servo motor. It is tiny, light in weight with high output, and can rotate to approximately 180 degrees. It can use any code, hardware, or library to control it.

Mode of operation

The servo motor has some control circuits and a potentiometer connected to the output shaft. It has a pot that can be seen on the right side of the circuit board. This pot allows the control circuitry to monitor the current angle of the servo motor (KasiwalManasi H), (http://www.wikipedia.org, n.d.). If the shaft is at the correct angle, then the motor shuts off. If the circuit finds that the angle is not correct, it will turn the motor until it is at a desired angle. The output shaft of the servo is capable of traveling somewhere around 180 degrees. Usually, it is somewhere in the 210-degree range, however, it varies depending on the manufacturer. A normal servo is used to control an angular motion of 0 to 180 degrees. It is mechanically not capable of turning any farther due to a mechanical stop built onto the main output gear (KasiwalManasi H).

The power applied to the motor is proportional to the distance it needs to travel. So, if the shaft needs to turn a large distance, the motor will run at full speed. If it needs to turn only a small amount, the motor will run at a slower speed. This is called proportional control (Alexy Medvedev).

Sterilizing Unit

This unit is composed of the LED's circuit which is attached to the lid. This circuit receives signals from the microcontroller as a result of the signals from the ultrasonic sensor 1. This circuit is triggered at the same time as the servo motor. Upon receiving the pulses from the microcontroller, the LED's power off as the lid is open. UVC LED's type is used in this project.

Background of Ultra-violet light

Ultra-violet light in the electromagnetic spectrum lies between the visible light and X-rays. It is categorized into three major types

Figure 7 showing the electromagnetic spectrum.

UV light	Description
UVA	This makes up the vast majority of UV radiation reaching the earth's surface. It penetrates deep in to the skin and thought to be responsible for up to 80% of skin aging.
UVB	This also have a detrimental effect on human. It can damage the DNA in our skin leading to sun burn and eventually skin cancer. Both UVA and UVB can be blocked by most good sun creams.
UVC.	This is the type of UV which is relatively obscure part of the spectrum consisting of a shorter wave length of light. It is particularly good at destroying genetic material in viral particles and in humans. However, humans are unlikely to encounter the effect before it reaches our delicate skin surface.

Table 3 showing the description on the type of UV

Significance of UVC light

Beneficial effects of UV radiation include the production of vitamin D, a vitamin essential to human health. Vitamin D helps the body absorb calcium and phosphorus from food and assists bone development. The World Health Organization (WHO) recommends 5 to 15 minutes of sun exposure 2 to 3 times a week.

UVC light delivers maximum germicidal effectiveness to inactivate micro-organisms when emitted at an optimum wavelength of 253.7nm, referred to as germicidal irradiation of UVC. The germicidal effectiveness reduces when emitted at wavelengths other than optimal wavelengths. (sung & Mohseni, 2019) This is important in the design of UV LEDs to deliver the right amount of radiation for the intended purpose.

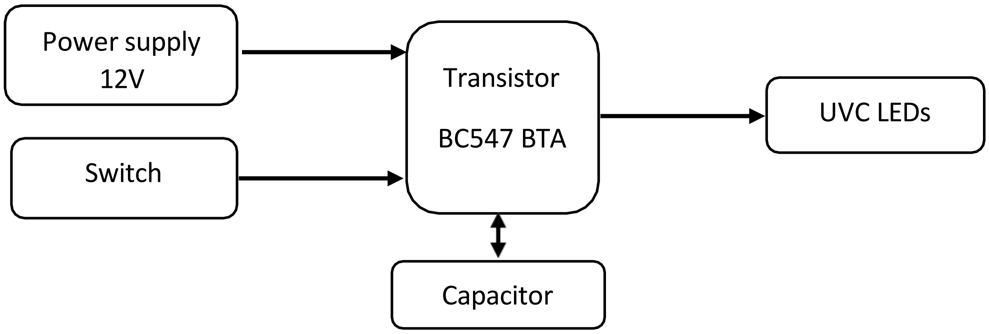
UVC light sterilization effectively activates microorganisms by damaging the DNA of cells hence hindering cell replication. Absorption of this light by the cells results in pyrimidine dimers that cause two adjacent thymine and cytosine bases to bond with each other, instead of across the double helix as usual. So this DNA molecule with the pyrimidine dimmers is unable to function properly, resulting in the organism's death and inability to replicate. An organism that is incapable of replicating can no longer spread disease. This mechanism is therefore employed in the disinfection of unicellular organisms of microorganisms such as viruses, protozoa, and fungi (Beck SE, 2016). (Malayen

AH, 2016) The UVC LEDs are effective and can kill pathogenic particles at a rate higher than 99.9%

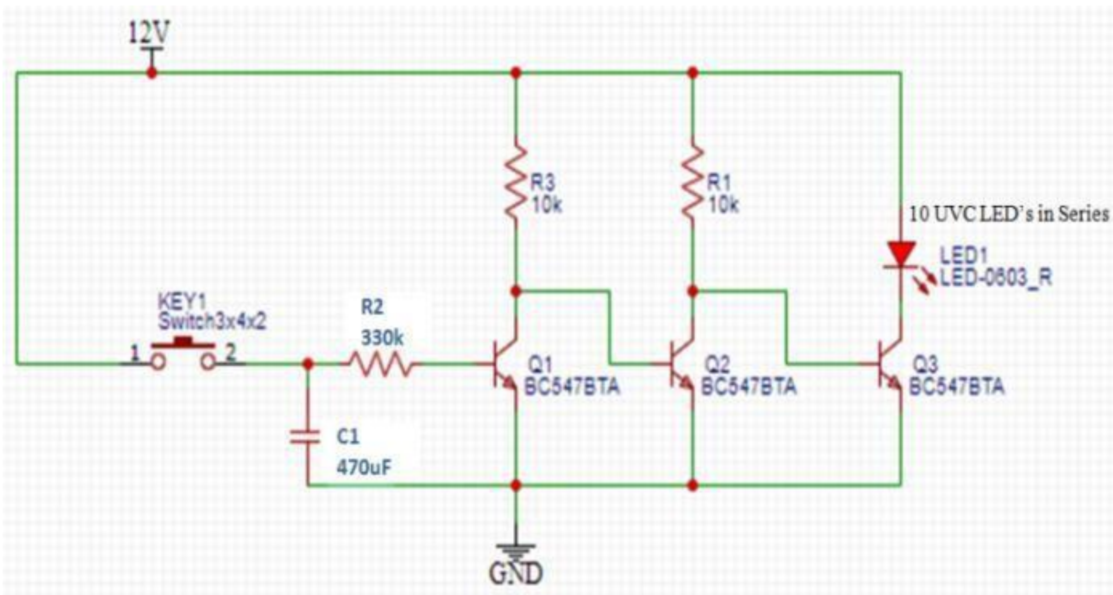
UVC lamps or germicidal lamps produce UVC radiation known as a disinfectant for air, water, and non-porous surfaces. (Tarka & A.) (She RC Clan D, 2020)

Typically, LEDs emit a very narrow wavelength band of radiation. Currently, available UV LEDs have peak wavelengths at 265 nm, 273 nm, and 280 nm, among others. One advantage of LEDs over low-pressure mercury lamps is that they contain no mercury.

Block diagram.



Circuit Diagram sterilizing circuit



This circuit is designed based on RC Circuit (resistor-capacitor circuit), when the limit switch is closed the capacitor will charge. If the limit switch is opened the capacitor will discharge. So when the dustbin is closed the capacitor will discharge and it flows through UVC LEDs. LEDs will be ON until the capacitor completely discharges.

In this design, the UVC Circuit is fixed to the Dustbin Lid and UVC LEDs are spread across the complete Bin lid so that the UV light will spread over the bin. The switch is placed at the closing of the bin lid, if the bin lid is closed the switch will be in ***Open State*** and if the bin lid is open the switch will be in ***Closed State.***

Engineering calculations

Discharge time calculations (LEDs ON time).

- Discharge time of capacitor $T = 5RC$

Due to losses, the practical discharge time is approximately equals to 7.5 minutes. So LED's will be ON for 7.5 minutes.

Sterilization time calculation.

UV dose=I.T where T- exposure time
I- UV intensity

But intensity of light I= power of LEDs/ S.A of the object.

$I_e = (\frac{4000mW}{2lh + 2lw + 2hw})$ mJcm²S

Power= I x V x N.o of LEDs

e.g. 10 LEDs @ 80mA , 5V

Power = 80mA x 5V x 10= 4000mW

$=4x10^3$mJ/s

- For a rectangular bin,

$$S.A = 2lh + 2lw + 2hw$$

Where l is the length of the open end h is the height of the bin.
W is the width of the open end When the bin is empty

Let the height = h_O cm,

$$Ie = \frac{4000mW}{2lh + 2lw + 2hw}$$

- Exposure time for 99.9% sterilization.

$$T = \frac{UV\ dose}{I}$$

$$T = (\frac{333.0}{Ie})\ minutes$$

NB. Max UV Dose Required to kill all the germs

For 90% Sterilization – 111.0 mJ/cm^2

For 99% Sterilization – 222.0 mJ/cm^2

For 99.9% Sterilization – 333.0 mJ/cm^2

SJ Engineering Africa
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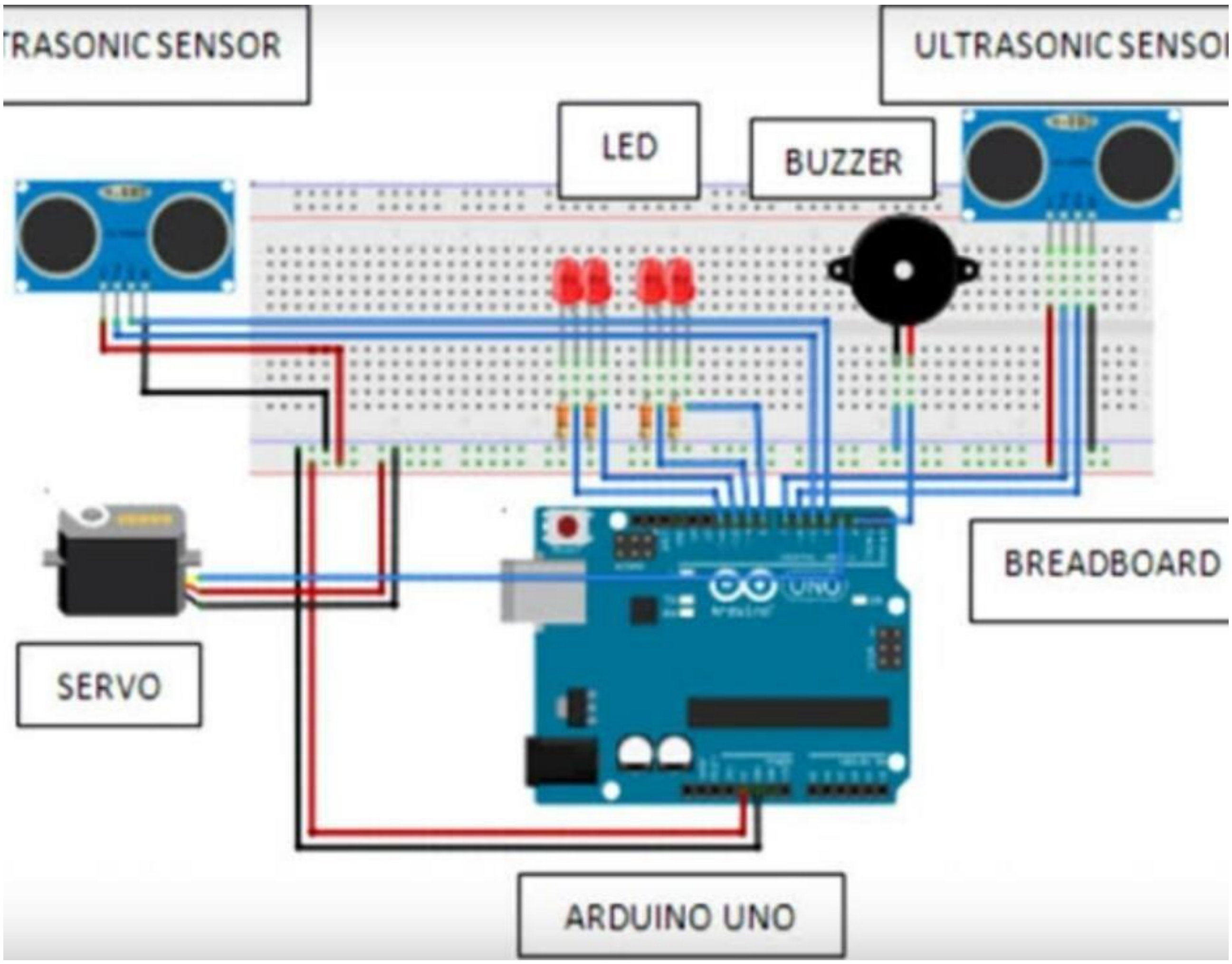
Working

If Dustbin is opened in between 7.5 minutes duration when the UVC LED's are ON, the switch will be in ***Closed State*** and UVC LED's will be OFF, this will protect the user from UVC light falling onto human skin. Once the dustbin is closed the switch will be in ***Open State*** and UVC LED's will be ON for 7.5 minute. After 7.5 minutes UVC LED's will automatically be turned OFF.

When the smart bin is almost filled, the alarm system is activated trying to alert the operator on the percentage of the wastes inside the bin.

The overall circuit diagram.



SJ Engineering Africa
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Material analysis and justification

In this sub-section, two material types that can be used in the design and construction of the device were put into critical analysis. These are plastic and metallic materials. However, this design, plastic is predominately employed. The Plastic smart waste bins is made of High- Density Polyethylene (HDPE), a durable material for plastic products. Following are properties of plastics that suit its use in this project.

Waste bin criterion

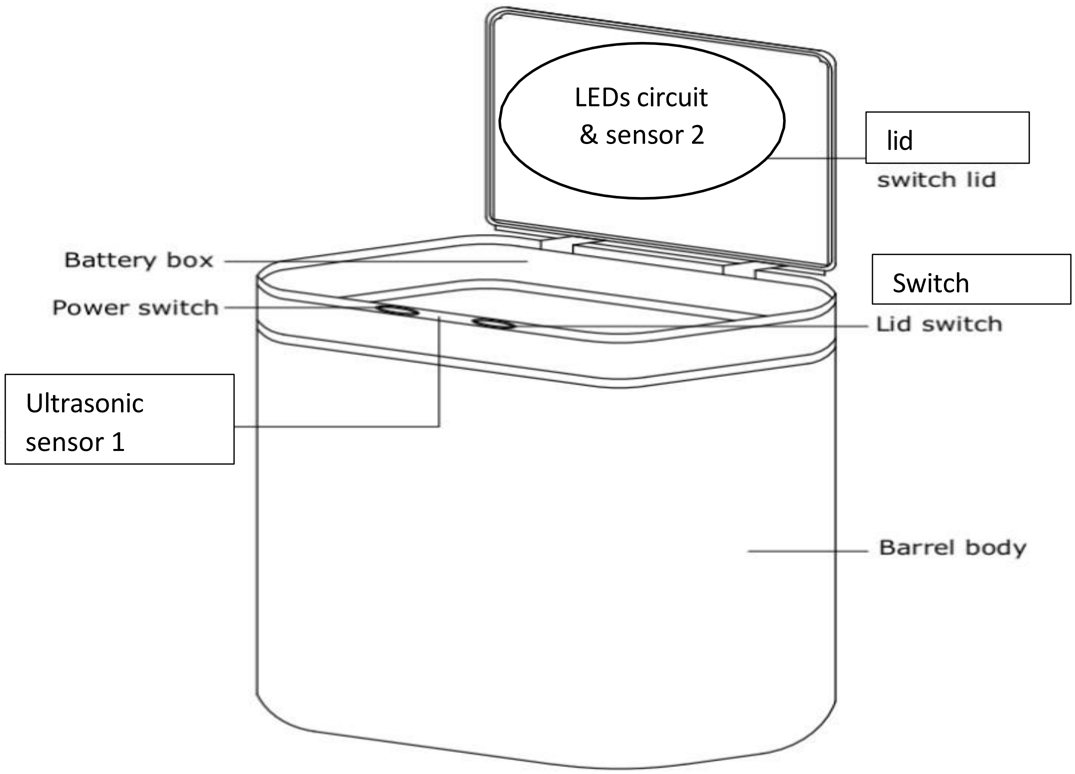
Criterion	**Description**
Ease of Handling	The plastic waste bins are lighter in weight. Thus, manual transporting of a plastic waste bin full of trash is easier moving around or into a lifting vehicle.
Hygiene concern	Due to the nature of HDPE material and body deep colour, plastic waste containers can be cleaned easily. The germs and dirt can be removed from a plastic surface easier than from a metal surface. Using detergents and cleaning liquids do not harm the colour or texture of the plastic. The rust concerns about using water or hot steam on the plastic waste bins are zero.
Weather resistance	Advanced plastics like polypropylene are made with special additives that provide UV protection and are corrosion-resistant. It is also more durable than metal and can withstand harsh weather conditions without being damaged.
Enhanced Safety	Plastic is light-weight and is designed with smooth round edges, one does not need to worry about injuring themselves while handling them.
Waterproof	Plastic bins are made in one shot injection moulding process. Therefore, the body is homogenized without holes, cracks, or penetration gaps. This helps plastic waste bins to withstand water waste and any liquid inside the containers.

Standards	The **EN840** standard is the European standard setting out the basic standard for 2- and 4-wheeled waste containers focusing on comb lifting devices, dimensions, design, lid, casters/wheels type, and positioning and trunnions shape and positioning, performance requirements, Safety and health requirements, etc. Many waste management organizations emphasize not collecting wheelie bins that don't meet this standard. Hence, plastic mobile garbage bins are the proper answer to meet these demands rather than metal waste bins.
Strength	Plastic mobile garbage bins are made of HDPE, which can withstand harsh materials like acids, alkalis, fungi & bacteria. HDPE waste bins are highly resistant to cracks, dents, and bending, especially in humid and windy weather. The plastic mobile garbage bins are durable and stronger against scratch and shock. It is also a good choice as a temporary tank for liquids and wet waste.
Sanitizing and cleaning	Plastic waste bin can be easily and quickly cleaned. They can be hot- washed, steam-cleaned, or chemically sterilized. Therefore, we can enjoy cleaner waste bins and reduce the risk of unpleasant odors remaining after the cleaning procedure. Furthermore, Printing or graffiti can be easily removed with non-toxic cleaners. There is a possibility to eliminate the faded prints and logos to provide a smooth surface for re-printing.
Corrosion & dusting	Plastic waste bins are not vulnerable to rust or corrosion against wet conditions. Exposure to extreme humidity for a long time causes is not a major problem with plastic waste bins.

Noise pollution	Opening and closing the waste bins and lifting and emptying them make noises that could be disturbing in residential complexes and hospitals.
	Although both types of mobile garbage bins, metal, and plastic, make noises, plastic waste bins make less noise prolusion, such as slamming and banging, compared with metal types.
Cost effectiveness	Plastic has always been cheaper than metal, and in some cases, making a whopping cost difference of 25%! Reason being, plastic is relatively easy to manufacture. Thus, there is a lower cost of production combined with the benefit of mass production savings. Furthermore, plastic is sturdy and is less likely to be damaged during shipment or installation. Imagine the expenses saved on repair and maintenance.
Waste sorting	Nowadays, the awareness of sorting waste from its origin is rapidly increasing; therefore, the colour of waste bins matters. Each colour of the waste bin indicates which types of waste you can put in. By adding colour additives, i.e., colour master-batch, we can produce any colour shade of the plastic waste bin.
Durability	Plastic has a longer lifespan when compared to metal. This contributed due to the fact that it cannot undergo corrosion and does not get damaged easily (https://iranplast.com/contacts/, n.d.).

Table 4 showing the waste bin material criterion and justification.

3D Drawing of the design components



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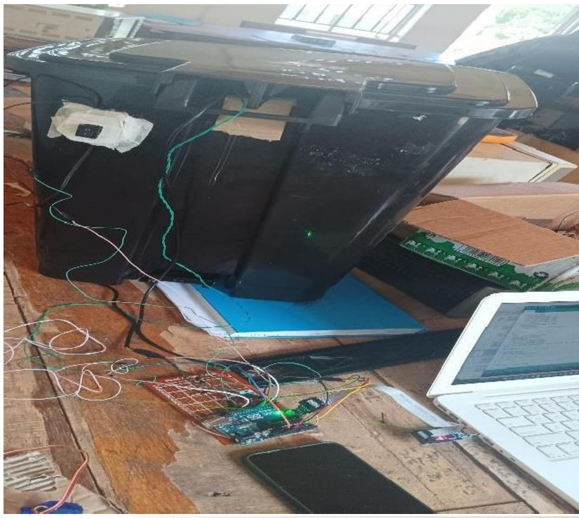
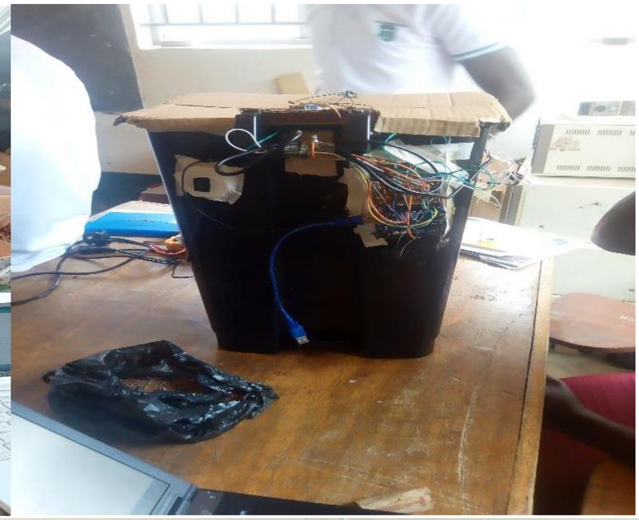
PROTOTYPING AND TESTING

Prototyping of the proposed solution


Result analysis

The project design will have a positive impact on healthcare in terms of preventing infections as;

1) The waste bin automatically opens when a person comes at the set distance; this prevents direct contact with the bin as one does not need to open it manually thus preventing contraction of the possible infections.
2) The smart waste bin will help to notify the user on the status of the waste bin.
3) The waste bin is easy to use as it does not require training and monitoring
4) The components are easily accessed in the market making technical work simpler for after sales servicing.

Future prospect/ plan for the project

Upon successful completion of the project on the design of the smart waste bin, there is need to improve on the waste bin which can alert the person responsible even at a distant area e.g., waste management officer 30 meters and above when it is about to get full. This is done with the help of a Global System for Communication (GSM) thus reducing the high risk of infections that can be acquired from the direct contact of infectious wastes in hospital departments in the developing countries.

Project management

S.NO.	POSITION	RESPONSIBILITY	NAME
1	Team Leader	• Mobilizes the rest of the member for group members. • Keeps record of each every project activity.	OKETHWENGU HERBERT
2	Assistant team leader	• Plays all the roles of the team leader. • Responsible for the office of the account and resource management.	AMISIRI BELINDA
3	Technical personnel	• Programming and coding of the system. • Drawing of the 3D design of the device.	EWARU EMMA Eng. ACHAM FAITH
4	Client	• Advices the team on the taste and preference, shape, and design and ease of functionality. • Provides market for the product.	Sr. JANE DR. WALUGEMBE SHAFIK.

5	Advisory team members	• Advice the team on to the appropriate functional, specifications and the cheapest means of production	Sr. JANE (happy space medical center)

Table 5 shows the team management, position, and responsibilities

Financial Management

The team members mobilized for funds through individual contributions which in turn facilitated the entire processes involved during the project. The expenditures were mostly on the purchase of the electronic components, materials, and tools as stated in the bill of quantity above.

Challenges faced

1. There are no current studies done on infections contracted as a result of handling waste bins since such injuries are underreported.
2. Financial challenges
3. There was difficulty in assembling of the all components that were required for the waste bin
4. It was difficult to get the codes required for our bin and the connection too was tedious.
5. There was limited time given to carry out the whole design process

CONCLUSION

Our design involves the application of the Arduino board, Ultrasonic sensors, and a Servo motor. The system combination allows the automatic opening and closing of the bin. Also, the safety of the users is assured because LEDs turn off as soon as the lid opens. This automatic mechanism prevents the direct interaction of UV rays with the human skin

We believe that the bin will be of great significance in mitigating possible infections like COVID-19, Ebola, and skin infections which can be contracted from direct contact with medical waste.

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