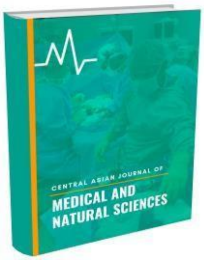

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Article

Design and Fabrication of Uv Sterilization Equipment with Idle Laboratory Metal Cabinet

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Abstract: Sterilization is crucial in healthcare environments to avert the spread of infections and to guarantee patient safety. Ultraviolet (UV) sterilization has surfaced as an effective technique due to its capability to eradicate microorganisms without compromising the properties of materials. In this study, we propose the design and production of a UV sterilization device specifically designed for medical instruments. Prioritizing user safety, the device integrates several safety features to reduce potential hazards. Different components and elements within the device fulfill various roles to enhance the sterilization process. Through thorough testing, we will assess the effectiveness of the device in sterilizing medical instruments. Moreover, evaluations will be conducted to measure the sterilization efficiency of the device on medical instruments. Through this research, we aspire to contribute to the progress of sterilization technologies in healthcare, ultimately improving patient care and safety.

Keywords: Ultraviolet Sterilization, Medical Instruments, Healthcare Safety, Device Fabrication, Infection Control

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1. Introduction

In a world marked by continuous interactions within communal environments, the prevalence of infections poses a persistent challenge to public health and safety. The widespread presence of pathogens and the ease with which infections can propagate highlight the essential need for effective sterilization practices. Whether in healthcare facilities or our everyday environments, the imperative to successfully neutralize and eradicate harmful microorganisms has become crucial. In light of emerging infectious threats, the demand for rigorous sterilization measures stands as a fundamental component in the ongoing fight against the transmission of diseases. As the global community confronts the enduring menace of infectious diseases, the necessity for effective sterilization solutions has reached unprecedented levels.

In the continuously changing realm of sterilization technologies, ultraviolet (UV) sterilization has risen to prominence, garnering the attention and preference of both the global community and the medical sector. UV sterilization, noted for its capability to eradicate a wide range of microorganisms, presents a compelling alternative to conventional methods. The growing dependence on UV sterilization as opposed to other techniques is fueled by a combination of factors that emphasize its unmatched effectiveness, efficiency, and safety.

Problem statement

Ensuring a clean and healthy environment, particularly in healthcare, is increasingly crucial in today's fast-evolving world. Conventional methods for sterilizing medical instruments, such as chemical disinfection or sterilization techniques, may necessitate extended contact durations. Exposure to elevated temperatures or potent chemicals can harm tools or alter their characteristics, resulting in wasted time and escalating costs. A possible solution is to create and produce an ultraviolet sterilization device specifically designed for medical instruments. These devices can be utilized in a broader array of situations and frequently enhance UV sterilization, providing a more thorough strategy for infection control in healthcare environments.

Project Objective

The goal of this project is to create and deploy a UV-sanitizing device aimed at sterilizing medical equipment within hospitals. This device will employ ultraviolet (UV) radiation to effectively eliminate or deactivate microorganisms present on the surfaces of medical instruments, thereby ensuring a high standard of hygiene and mitigating the risk of healthcare-associated infections. The project seeks to design a user-friendly and efficient UV-sanitizing device that accommodates a range of medical tools and equipment typically utilized in hospitals. It will emphasize safety protocols to safeguard healthcare professionals and patients from any potential hazards associated with UV radiation. The device will feature suitable timers and sensors to enhance the sanitization process while reducing the likelihood of human error. Ultimately, the successful integration of the UV-sanitizing device in hospitals will aid in improving infection control measures, curtailing the transmission of pathogens, and bolstering overall patient safety.

Literature Review

The purpose is to present a comprehensive overview of the theoretical background and previous studies related to the use of ultraviolet (UV) radiation in sterilization. It highlights the scientific basis of UV radiation, its classifications, mechanisms of microbial inactivation, advantages and limitations compared to other sterilization techniques, as well as relevant experimental findings from prior research

Ultraviolet Radiation

Ultraviolet (UV) radiation is a form of non-ionizing radiation located between X-rays and visible light in the electromagnetic spectrum. It possesses higher energy than visible light and is subdivided into three main categories based on wavelength: UVA (315–400 nm), UVB (280–315 nm), and UVC (180–280 nm). Among these, UVC has the most significant germicidal effect due to its strong DNA-damaging capability.

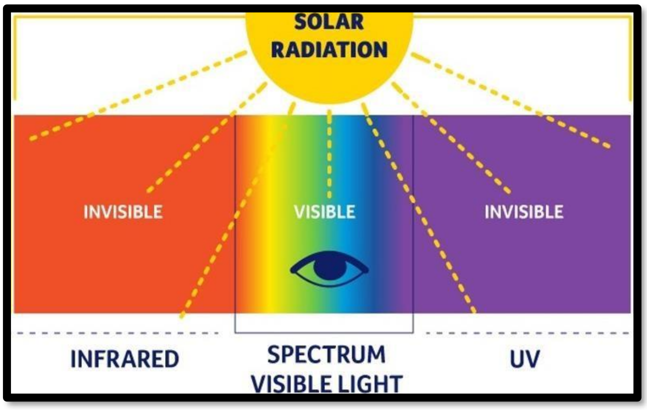

Figure 1. Solar radiation

Applications of UV in Sterilization

Since the late 19th century, UV radiation has been studied for its antimicrobial properties. Historical milestones include the demonstration of microbial inactivation by Downes and Blunt in 1877 and subsequent confirmation by Robert Koch in 1890 on Mycobacterium tuberculosis. Over time, UV germicidal irradiation (UVGI) became widely applied in hospitals, laboratories, and food industries. More recently, the COVID-19 pandemic renewed global interest in UV sterilization technologies for medical and environmental applications.

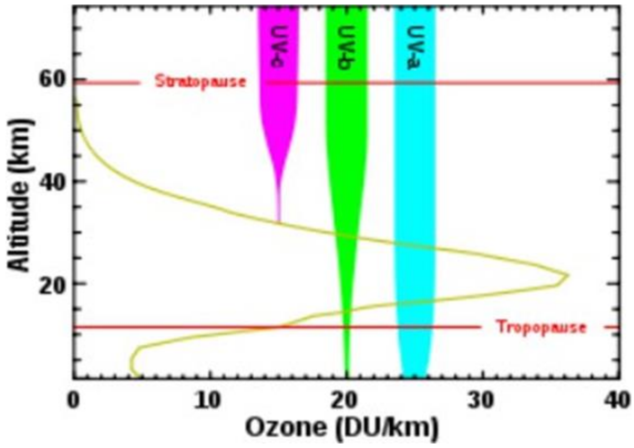

Figure 2. Types of Ultraviole

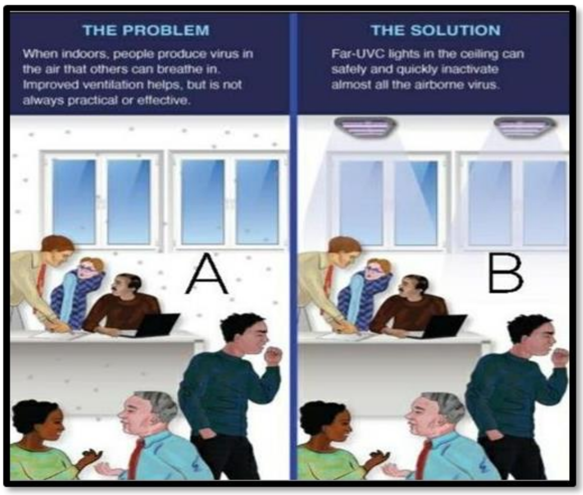

Figure 3. (A) The UVC light is OFF, (B) The UVC light is ON

Mechanisms of Microbial Inactivation

The germicidal effect of UVC radiation is primarily linked to DNA damage. UV photons induce the formation of thymine dimers and other photoproducts, which distort the DNA helix, hinder replication, and eventually cause cell death. This mechanism ensures effective inactivation of bacteria, viruses, and fungi. However, the efficiency of sterilization depends on exposure time, radiation dose, and the type of microorganism

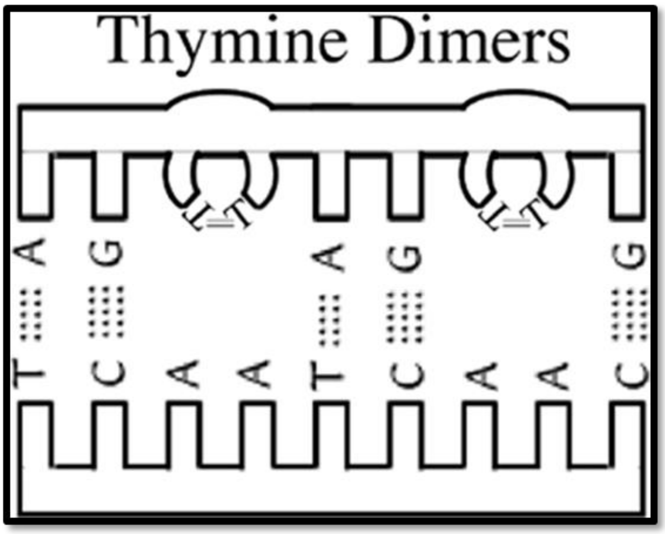

Figure 4. The formation of thymine dimers in DNA

Comparison with Other Sterilization Methods

Compared to heat-based or chemical sterilization, UV sterilization offers several advantages:

a. No chemical residues.
b. Minimal alteration of material properties.
c. Shorter exposure times.
d. Effective against chlorine-resistant pathogens such as Cryptosporidium.

On the other hand, limitations include the inability to penetrate opaque or solid surfaces, safety concerns regarding operator exposure, and reduced effectiveness against highly resistant spores.

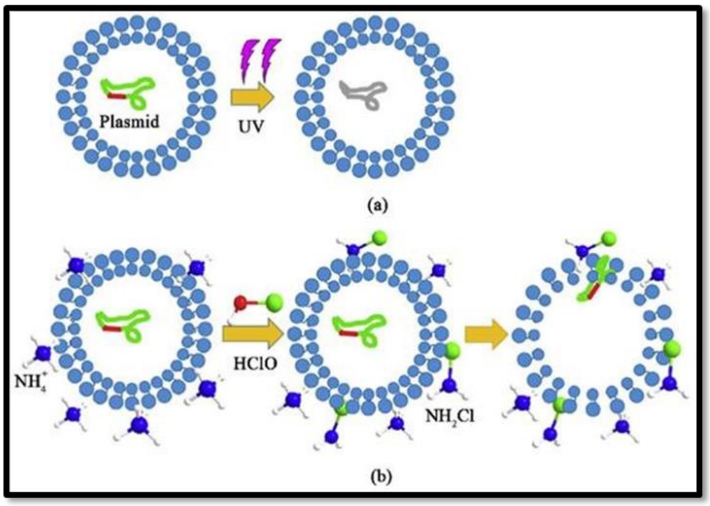

Figure 5. Comparison of the mechanisms of: (a) UV disinfection and(b) chlorination, affecting the ARGs conjugation transfer

Advantages and Precautions

UV sterilization is cost-effective, energy-efficient, and suitable for materials sensitive to heat or chemicals. Nevertheless, strict precautions are required to avoid harmful effects such as skin damage or eye injury caused by direct exposure. Engineering controls, shielding, and sensors are essential to ensure safe operation.

Review of Previous Studies

Numerous studies have confirmed the effectiveness of UV sterilization. For example:

A 2022 study published in Scientific Reports demonstrated that far-UVC light could inactivate over 98% of airborne microbes within five minutes, suggesting its potential in controlling airborne disease transmission.

Research conducted by the Pacific Northwest National Laboratory (2012) showed that UV radiation effectively disinfected surgical tools, providing a faster and less harmful alternative to autoclaving or chemical sterilization.

A 2022 study in the Journal of Indian Orthodontic Society compared different sterilization methods for orthodontic appliances and concluded that UV sterilization was both effective and less damaging to material properties.

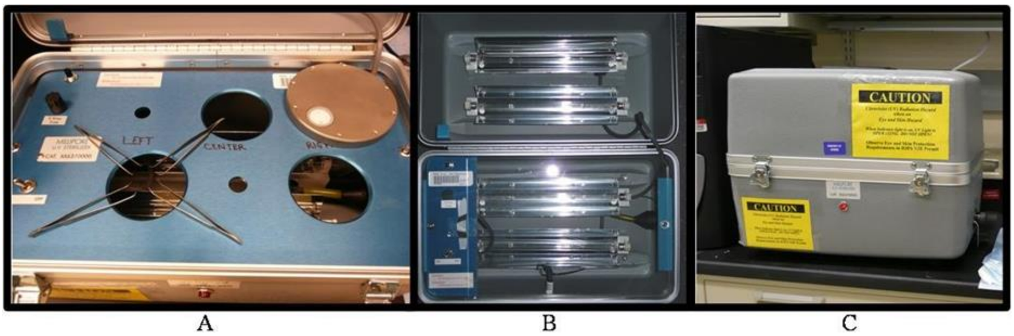

Figure 6. Millipore ultraviolet sterilizer: (A) UV system interior with forceps placed for treatment, (B) UV system modified by replacing most of the blue center plate with a fused quartz glass, (C) Exterior of the UV system

2. Materials and Methods

The main elements of the cabinet

UV lamps

The cabinet included two ultraviolet (UV) light source (Fig 7) with a wavelength range of 254 nanometers (nm). Additionally, the power of each UV lamp is 5 (W), providing the necessary electrical power to generate UV radiation for the sterilization process. The UV lamps installed on the chamber's upper surface.

Reflector layers

The layers of aluminum foil were placed to reflect the ultraviolet radiation coming from the lamps and thus reflect it onto the samples to increase the exposure of the samples to radiation, which increases their sterilization.

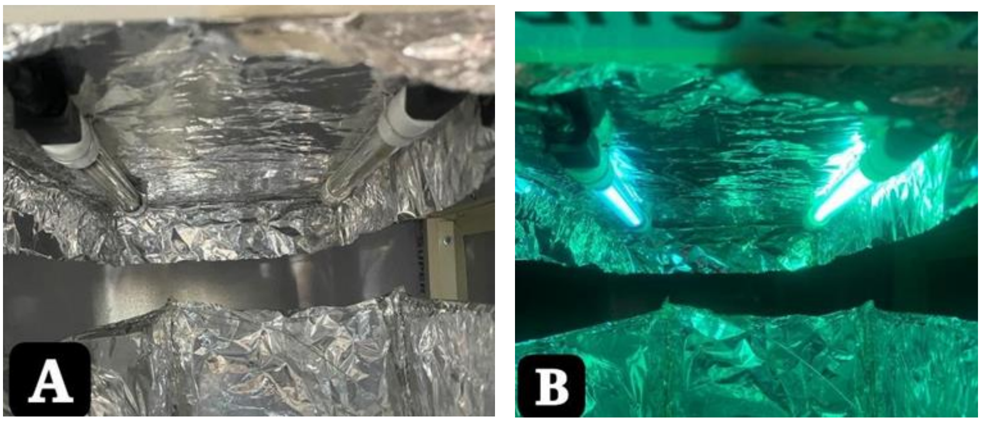

Figure 7. UV lamps: (A) when the lamps is OFF, (B) when the lamps is ON

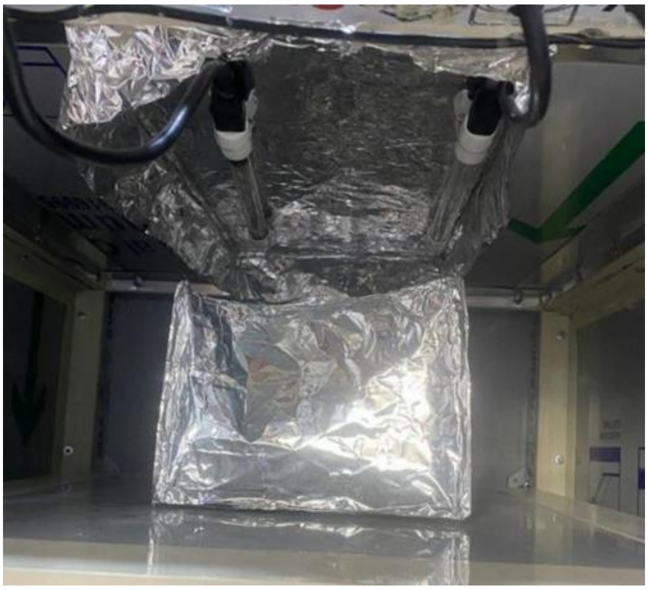

Figure 8. Reflective layers inside the box

The items that attached to the device

Arduino Microcontroller

Arduino (fig 9) is an open-source platform used for building electronics projects. Arduino consists of both a physical programmable circuit board (often referred to as a microcontroller) and a piece of software, or IDE (Integrated Development Environment) that runs on your computer, used to write and upload computer. code to the physical board.

Figure 9. Arduino

LCD 2*16

The LCD screen is highly appropriate for the straightforward display of phrases and numbers. It features a simple connection process (requiring two wires for power and two wires for data transfer) and operates based on the i2c protocol, which transforms data from parallel to serial format. This screen is utilized alongside the i2c piece screen to enhance functionality and connectivity.

Figure 10. LCD 2*16

Relay

The relay functions similarly to a switch, operating based on the application of voltage. It can be activated or deactivated, allowing current to flow or preventing it from flowing.

Figure 11. Relay

Ultrasonic sensor

An electronic device that measures distances by emitting sound waves and capturing the returning echoes. It is capable of measuring objects located up to 4.5 meters away. The sensor is equipped with adjustable pulse widths. When the sound pulse hits an obstacle, the same signal returns to the other sensor head, which records the return time of the signal through sound. Therefore, we have two time intervals: send and receive. Given that our speed (V) is constant, we can calculate the distance using the formula s = v/t, which provides the distance from the sensor to the object. This is the reason the sensor is referred to as ultrasonic.

Figure 12. Ultrasonic sensor

Stepper motor driver

A crucial component that delivers the necessary voltage and current to a stepper motor, ensuring its smooth operation. It operates precisely by utilizing a controller that synchronizes pulse signals with the assistance of a Driver. This motor driver receives pulse signals from a microcontroller and subsequently converts them into the motion of the stepper motor.

Figure 13. Stepper Motor Driver

Buzzer

The buzzer is an electronic component that produces sound by transmitting electrical signals. Its main purpose is to deliver an audible alert or notification, and it generally functions within a voltage range of 5V to 12V. There are several types of these modules, each differing in their sound generation mechanisms, operating principles, and applications.

Figure 14. Buzzer

LDR

(Light Dependent Resistor) A special type of resistor that works on the photoconductivity principle means that resistance changes according to the intensity of light. Its resistance decreases with an increase in the intensity of light.

Figure 15. LDR

Connection switch

A connection switch is a momentary action device that provides tactile feedback upon operation. This physical response assures the user that the switch has been activated and that a signal has been transmitted.

Figure 16. Connection switch

LM35 Temperature sensor

Temperature sensor It is an integrated circuit that has a similar external appearance to a transistor, featuring three inductors. This device is utilized to measure temperature within a thermal range of -55 to +150 degrees Celsius, producing an output that is an analogue voltage, which is proportional to the ambient temperature value.

Figure 17. LM35 sensor

Relay timer

Relay timer is a type of relay that has a built- in time delay function. This means the relay will not immediately activate when it is energized but will wait for a set amount of time before doing so.

Figure 18. Relay Timer

Variable resistance

A variable resistor is a type of resistor whose electric resistance can be modified. Essentially, a variable resistor functions as an electro-mechanical transducer, typically operating by sliding a contact (known as a wiper) across a resistive element.

Figure 19. Variable resistance

Limit switch

Limit switch a switch operated by the motion of a machine part or the presence of an object. A limit switch can be used for controlling machinery as part of a control system, as a safety interlock, or as a counter enumerating objects passing a point.

Figure 20. Limit switch

Design & fabrication of the metal cabinet

First of all, to ensure the cabinet is safe and does not leak ultraviolet radiation to the outside, we manufactured the cabinet from insulated aluminum. We designed it in a cubic shape with dimensions of 60 x 45 x 35 cm (length, width, depth) with a front-hinged door that includes a handle, making the cabinet small and easy to move, as shown in figure (21). Inside the cabinet there is a slide 55 x 40 cm (length, width) on which the samples can be placed. This slide is connected to the door so when the front door is opened, it smoothly pulls out along with the door, facilitating easy access to the samples. Two layers of reflective aluminum foil were also placed, one layer above the UV lamps and another layer under the samples, to serve as reflective surfaces for the rays when radiation falls on them, thus increasing the samples' exposure to radiation.

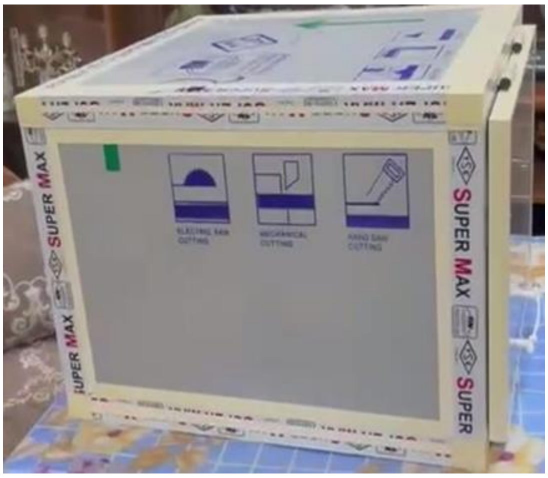

Figure 21. Photograph showing the sterilization box

Figure 22. Photographs showing the sterilization box elements and the slide

Working principle

The working principle of the device involves the interaction of various components as the diagram shown in figure (23) to ensure safe and effective operation. Firstly, the device is operated via operating buttons located on the device, which send commands to initiate specific functions such as opening or closing the door. However, the operation of the device is not solely dependent on these buttons. A series of safety mechanisms are integrated into the system to prevent potential hazards or malfunctions. Upon pressing the operating button, the first limit switch linked to the door checks if the door is open. If the door is indeed open, it prevents the activation of the device, ensuring that the sterilization process cannot commence while the door is ajar. Furthermore, a second limit switch serves to detect any abnormal conditions such as vibrations or sensing someone approaching the device or deviations from the required temperature range. If such conditions are detected, this limit switch prevents the device from operating, safeguarding against potential risks or damage. Finally, the relay plays a crucial role in controlling the

UV lamps. It regulates the power supply to the lamps, ensuring that only 12 volts are allowed to pass through when the lamps are turned on. This control mechanism ensures the safe and efficient operation of the UV lamps, minimizing the risk of overheating or electrical hazards. In summary, the working principle of the device involves a multi-layered approach to safety and functionality, where operating buttons are complemented by limit switches and relays to ensure reliable and safe operation during the sterilization process.

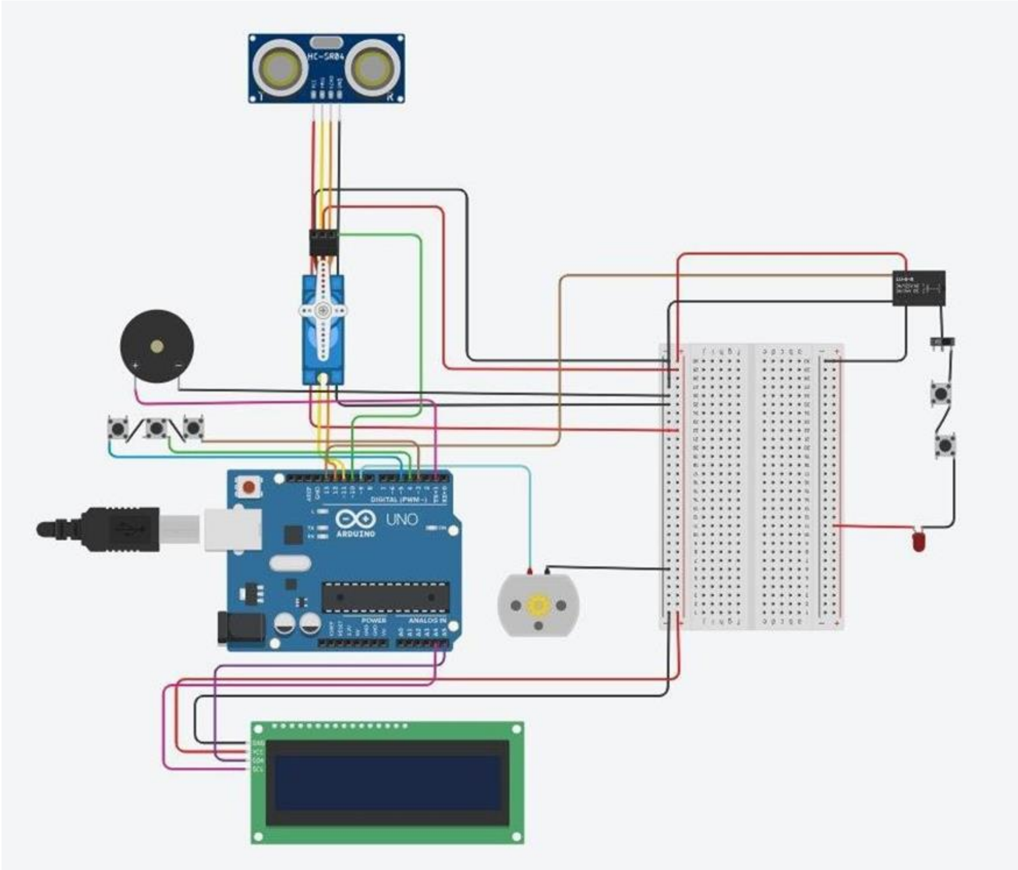

Figure 23. Electronic circuit diagram of the device

Test the device's operation and effectiveness

Culture media test

We will conduct a test to prove to us the device’s operation and the effectiveness of its sterilization. We will conduct the test on a previously used contaminated medical surgical instrument and make sure that there are no bacteria or other micro-pollutants after sterilization by conducting a culture media test, which will be as follows:

Before sterilization

First, we will take swabs from the contaminated instrument, then transfer these swabs onto agar plates to culture the microbes. These plates will be placed in an incubator set to a temperature of 37 degrees Celsius, providing a suitable atmosphere for microbial growth, and left for 24 hours.

After sterilization

After placing the tool in the device and sterilizing it, we will take swabs from the sterilized tool and we also transfer these swabs to new agar plates. These plates will be placed in the incubator as we did previously and in the same atmosphere that was provided for the plates before sterilization. We wait for 24 hours and then see the result.

3. Results and Discussion

To verify the functionality of the device and assess the efficacy of its sterilization process, we performed a test on the device. We conducted the "culture media" test. This test took place at Al-Haboubi General Hospital located in Dhi Qar Governorate. The test utilized one of the medical surgical instruments, specifically a hook or retractor known as the 'FINSEN Modified Retractor'. as shown in the figure 24.

As we shown in the figure (25 A) A Plate containing swabs from the instrument before sterilization, there Swabs were taken from the surgical medical tool already used, and cultured on “Agar Plates” (blood agar and MacConkey agar). After a full day had passed, bacteria and fungi were observed growing on the agar plates. In the next step, this same tool was placed in the device for 10 minutes for the purpose of sterilizing them. It was noted that there was no growth of bacteria or fungi on the day following the implantation as shown in the figure (25 B).

Figure 24 . One of the medical surgical instruments on which the test was conducted, (a hook or retractor instrument called “FINSEN Modified Retractor”)

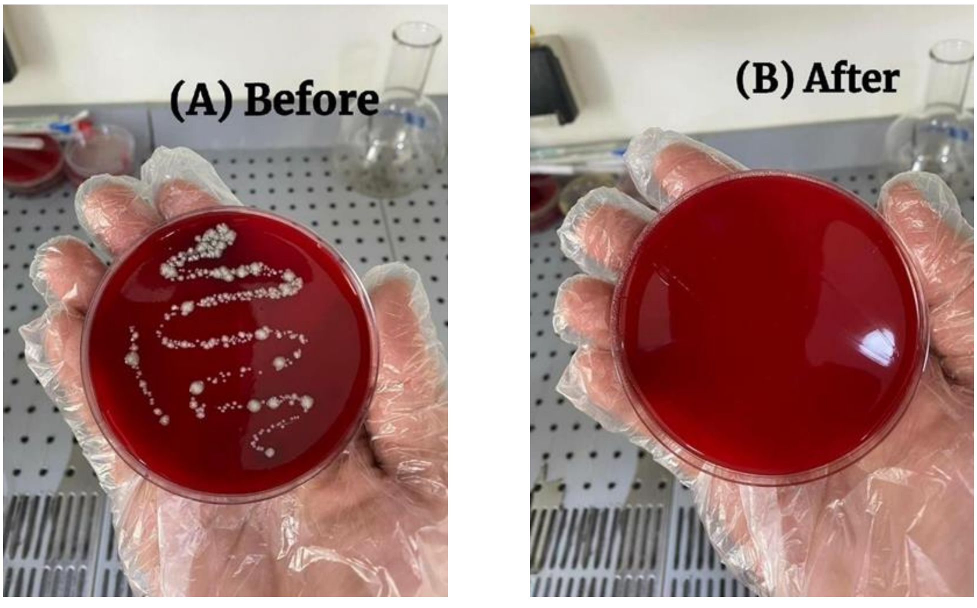

Figure 25. Agar Plates: (A) A Plate containing swabs from the instrument before sterilization. (B) A Plate containing swabs from the instrument after sterilization

4. Conclusion

In today's world, characterized by numerous technological advancements and developments, human lifestyles have undergone significant changes. While these changes offer various comforts and benefits, they also introduce certain drawbacks, similar to any other concept, which have notably impacted hygiene and cleanliness, ultimately affecting individuals' lives negatively. Therefore, sterilization is essential and of utmost importance in the pharmaceutical industry, particularly in the production of medicines and surgical instruments. To address this need, we have developed a UV sterilization BOX that utilizes a UV light lamp for sterilization purposes. This Pass Box operates under specific conditions that must be met to ensure effective and efficient performance. Users can control the Pass Box and its settings through buttons on the interface, allowing them to adjust the sterilization duration. In conclusion, it can be stated that an ultraviolet sterilization device is highly effective for various medical instruments, demonstrating its capability to eliminate microorganisms without compromising the material properties of these instruments, while also prioritizing user safety through the inclusion of multiple safety features designed to reduce potential risks.

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