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Design And Fabrication of Ultraviolet Disinfection Box for Electronic Product and Different Food Items

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Abstract-
In order to prevent the COVID-19 virus and other infections, contacting surfaces that come into touch with people and other dangerous bacteria must be sterilised. An inexpensive sterilisation box prototype is created in this study to clean tiny things. The box uses heat and ultraviolet (UV) radiation. Two studies were conducted to evaluate performance. The first step was to sterilise IgG (a model protein that is identical to the spike glycoprotein of the SARS-COV-2) in an incubator using UV and heat. The protein was shown to be effectively unfolded and aggregated after a 15-minute UV incubation at 70 °C. The protein's hydrodynamic size grew from the native protein's 5 nm to 171 nm under optimal conditions. Likewise, the OD280 values also increased from 0.17 to 0.78 indicating the exposure of more aromatic moieties and unfolding of the protein. The intrinsic fluorescence measurement and FTIR analyses, which revealed a 70% rise in the protein's -sheets and a 22% decrease in its -helixes, further validated the protein's unfolding and aggregation. The SARS-COV-2 was effectively inactivated as evidenced by the constructed box's ability to alter the protein's natural structure. Additionally, the clinically important E. coli bacteria as well as bacteria gathered from everyday items had 100% antibacterial efficiency after 15 minutes of incubation at 70 °C inside the chamber. It is the first comprehensive performance study on the effectiveness of combining heat and UV irradiation to kill bacteria and viruses.
Key words: UV rays, Disinfection Box, Covid-19, Protection etc.

1. Introduction

Since the middle of the 20th century, ultraviolet (UV) light has been utilised to disinfect surfaces. However, research into the bactericidal effects of sunshine dates back to the mid-19th century. It is employed in a variety of home appliances, from toothbrushes to tablet computers, for the treatment of drinking water and wastewater, air disinfection, and the purification of fruit and vegetable juices. UV has long been a choice when purchasing biological safety cabinets in research buildings, and it can also be employed in ductwork. In recent years, UV technology has improved and become more dependable. Modern ballasts can sustain the power output of UV bulbs for a lot longer than they could in the past. Today's UV lamps are rated to last for thousands of hours. As a result, UV systems are now more practical for various applications. Recently, the use of UV has expanded in the healthcare sector as a crucial tool for stopping the spread of hospital acquired illnesses by disinfecting surfaces in addition to conventional cleaning techniques. More customers are interested in acquiring ultraviolet light items to disinfect surfaces in the home, office, transit, and other commercial places after the COVID-19 pandemic, which was brought on by the new coronavirus SARS-CoV-2. Due to its simplicity, quick dosing times, and extensive efficacy, UV light has started to be used more frequently for surface disinfection in a variety of establishments.

2. Problem Identification

The COVID-19 epidemic has caused a shocking loss of life on a global scale and poses an unprecedented threat to food systems, public health, and the workplace. The pandemic's devastating economic and social dislocation puts tens of millions of people in danger of living in abject poverty, and the number of undernourished people, currently estimated at close to 690 million, might rise by as many as 132 million by the end of the year.

Numerous businesses are in danger of dying out. The livelihoods of over half of the 3.3 billion workers worldwide are in jeopardy. Workers in the informal economy are particularly vulnerable because the majority do not have access to social safety, high-quality healthcare, or productive assets. Many people are unable to provide for themselves and their family during lockdowns because they lack the means of earning a living. Most people who lack funds cannot eat, or at best can only eat less food that is less nutritious.

The epidemic has been having an impact on the whole food system and exposed its vulnerability. Border closures, trade restrictions, and confinement measures have made it difficult for farmers to access markets, including to buy inputs and sell their produce, and for agricultural workers to harvest crops. As a result, domestic and global food supply chains have been disrupted, and the availability of a variety of safe, healthy diets has decreased. The pandemic has destroyed jobs and jeopardised the livelihoods of millions of people. Millions of women and men's food security and nutrition are at risk as breadwinners lose their jobs, get sick, or pass away; those in low-income nations, especially the most marginalised groups, such as small-scale farmers and indigenous peoples, are severely hurt.

3. Objective

• The project's objective is to provide a portable sanitization method that is secure for a variety of materials and sanitises bioburden concentrations over acceptable thresholds.
• This eliminates any germs present in the food goods and electronic items, including parasites, viruses, algae, and other contaminants. It operates by exposing these microbes to light at a wavelength that causes their DNA to change. They are incapable of reproducing due to this mutation. As a result, infections are prevented from growing and spreading.

4. Literature Review

The pandemic has been affecting the entire food system and has laid bare its fragility. Border closures, trade restrictions and confinement measures have been preventing farmers from accessing markets, including for buying inputs and selling their produce, and agricultural workers from harvesting crops, thus disrupting domestic and international food supply chains and reducing access to healthy, safe and diverse diets. The pandemic has decimated jobs and placed millions of livelihoods at risk. As breadwinners lose jobs, fall ill and die, the food security and nutrition of millions of women and men are under threat, with those in low-income countries, particularly the most marginalized populations, which include small-scale farmers and indigenous peoples, being hardest hit.

The design of the sterilization box is based on the ATmega2560 microcontroller which utilizes the concept of 254 nanometer UV-C shortwave radiation and disinfectant spray to increase the effectiveness of the sterilization box. In order to prevent transmission through touch from users through physical contact via sterilization box, researchers designed a system that can make users access sterilization box without the need to make physical contact with the device, namely by using IoT system with the help of applications that can be accessed through the user's smart device. Based on the results of the analysis and experiment that has been carried out, it is concluded that the sterilization box in this study can work optimally at a distance of less than 700 cm. This tool can operate using smartphone media via bluetooth HC-05 module, so it can minimize the process of spreading Covid-19 that occurs through physical contact.

Ultraviolet germicidal irradiation (UV-GI) UVGI modules are typically produced from low pressure mercury lamps that emit light from 100–290 nm, typically at a wavelength of 254 nm. This wavelength is close to the wavelength that can kill bacteria, which is 265 nm [1]. Mercury lamps produce ozone as a by-product which is reactive oxygen that can inactivate bacteria. Studies have found that the disinfection time required to inactivate MS2 bacteriophages is much shorter with light sources emitting UV-C and combined ozone than with UV-C alone. This system is limited due to restrictions related to ozone emissions and the toxic effects of ozone on human health [1].

A study of N95 FFR infected with influenza A H1N1 found a reduction of 3 log after a UVGI dose of 1 J/cm2 was administered for 60–70 seconds. This dose has been supported by additional studies, and higher doses (> 1 J/cm2) provide reduced benefit. UV-GI has also been shown to effectively inactivate coronaviruses including severe acute respiratory syndrome coronavirus (SARSCoV) and Middle East respiratory syndrome coronavirus (MERS-CoV). This could be one potential explanation for the UV-C dose variation reported in the literature [1]. E3S Web of Conferences 328, 0 (2021) ICST 2021 4034 https://doi.org/10.1051/e3sconf/202132804034 © The Authors, published by EDP Sciences. This is an open access article distributed under the terms of the Creative Co.

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5. Block Diagram

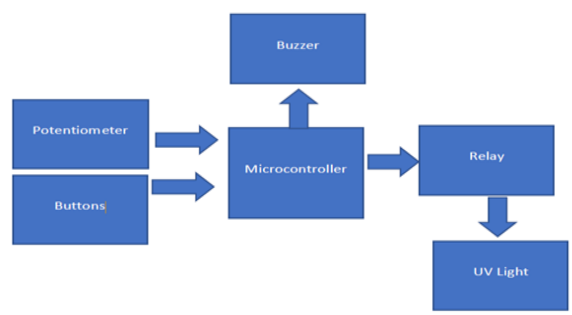

Fig 1. Block Diagram

6. Experimental working

UV Chamber works by the process of ultraviolet germicidal irradiation. It is a disinfection method that uses UV-C, the shortest wavelength having 254nm. UVC light produces electromagnetic energy that can kill microorganisms e.g. bacteria, viruses, fungi, etc. by photochemical reaction.

Ultra Violet radiation, Chlorination, washing with soap and heating are some methods of sterilizing. Ultra Violet light is the best sterilizing and disinfectant agent, used for domestic as well as clinical purpose. Food packets, books, stationery, medical equipment's, toys, electronic gadgets like mobile phones, laptops, wrist watches, etc can be sterilized with UV radiation whereas other methods of sterilization cannot be used. UV light does not release any waste and is eco-friendly, if used in a controlled manner. UV radiation is a range of electromagnetic waves with shorter wavelength (high frequency and energy). The wavelength from 100-280 nm known as UV-C is the best disinfectant used for purifying water, air, sterilizing vegetables and surgical equipment's. Research has shown that UV-C wavelength can kill harmful fungi, protozoa, bacteria and viruses like SARS-CoV-2 Virus. The article describes the construction of a low cost UV-C Sterilizer Box where UV radiation is taking place in a closed environment. Safety features are also incorporated to prevent humans from UV light exposure. It will having timer for various product elements to be sanitize as per desired conditions.

7. Design Analysis

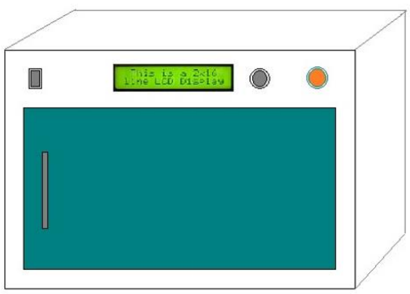

Fig. 2. Design of Model

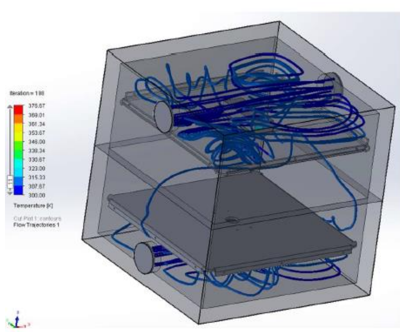

Fig. 3. LEDs heat sources simulated at steady state.

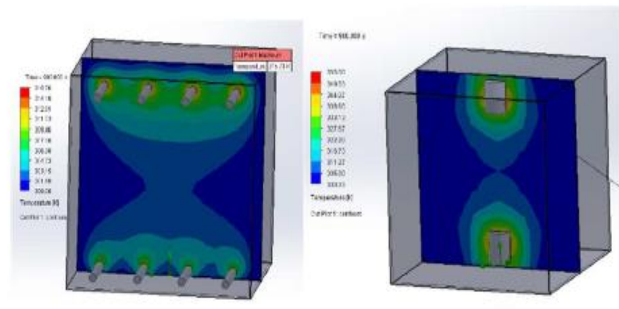

Fig. 4. Thermal simulation results using Solidworks Flow Sim Thermal compare mercury tube (Left) and LED (Right) UV sources to determine fan and air venting requirements.

8. Calculation of UV

- ***UVGI Disinfection***

Ultraviolet Germicidal Irradiation is a common method used for air, water, and surface sterilization. The UVGI process uses a 254 nm wavelength in order to inactivate microorganisms. To sanitize the surface of an object, it needs direct exposure from the lights for a given amount of time depending on the microorganism. In the case of *Bacillus atrophaeus*, to achieve a 2 log reduction, it would require a UV light exposure (dose) of 50 mW s/cm2 [Carlson]. In order to determine the amount of time it takes to achieve this reduction, the specifications of the bulb is needed.

Table 1: Ultraviolet bulb specification

Bulb Model	Life (hr)	Lamp Wattage (W)	UV-C Radiation (W)	Length (cm)	Diameter (cm)	Weight (g)
TUV PL-L 95W	9000	95	27	53.5	3.8/1.8	134
TUV 18W 1SL	9000	18	4.5	60.4	2.8	100
TUV 10W SLV	9000	10	2.5	34.5	2.8	62
G25T8 (GE-T8)	7500	25	7	45.7	2.8	N/A

Using these four bulb types, the time it takes to achieve a 2 log reduction using the known exposure of 50 mW s/cm2 [Carlson] can be found. The intensity can be found using Equation 1,

$$I = \frac{P}{A} \tag{1}$$

where P is the output power of the UVC radiation and A is the projected area of the light. The

area of each light is calculated using the length of the bulb times 0.3 m in the radial direction. The intensity of each light can be seen in Table 3.2. The Dosage can be found using Equation 2,

$$D = I * t(s) \quad (2)$$

Solving for time, the time it takes each bulb to achieve a 2 log reduction and 3-4 log reduction at an exposure of 4647 mWs/cm2 [Carlson] can be seen in Table 3.2. The time it takes for a 3-4 log

reduction shows how much longer it would take to achieve a greater state of sanitization.

Table 2: Effective application of each bulb

Bulb Model	Intensity (mW/cm^2)	Time For 2log (sec)	Time For 3-4log (sec)
TUV PL-L 95W	9.28	1.25	500.93
TUV 18W 1SL	1.56	7.45	2984.78
TUV 10W SLV	1.51	7.66	3068.78
G25T8 (GE-T8)	2.86	4.06	1626.01

Based off the time it takes to achieve a 2 log reduction, the TUV PL-L 95W bulb is the most effective for the design. The full specifications of the bulb can be seen in Appendix D. Since the bulb is now known, other components such as the ballast and base, can now be selected.

- ***Deep UV (UVC) Laser Disinfection***

UV lasers are similar to the effectiveness of UVC light as they both use the same mode of disinfection. Producing lasers in the UVC wavelength is a complex process and is cost prohibitive. At this point in time, the technology is still in the early stages of development.

A study by Sharp Laboratories of Europe, Ltd. [Carlson], demonstrated the effectiveness of the UVC laser in inactivating different bacteria and viruses, and decontaminating drinking water. They used a 205 nm through 230 nm wavelength lasers at 1 mW. In their experiments, they focused the laser to a 0.05 cm diameter dot. Assuming that they need a dosage of 50 mW s/cm2 to reduce *Bacillus atrophaeus* spores by 2-log and 100-4,000 mW s/cm2 to have 3-4-log reduction [Terra Universal], the required time to achieve the above dosage can be found by substituting Equation 1 into Equation 2 while rearranging to solve for time:

$$t(s) = \frac{DA}{P} \quad (2a)$$

Using Equation 2a and 1 mW laser would result:

$$t(s) = \frac{50\,\frac{mW\cdot s}{cm^2}\cdot 1.96x10^{-3}cm^2}{1mW} = 0.098\ s$$

for 2-log reduction and similarly 0.196 – 7.859 second pulse for 3-4-log reduction. This results in a required time for 2-log reduction over an area of size of 8.5” x 11” paper of 30,240 seconds or 8.4 hours.

At this time, the required time for just 2-log reduction is far too long to be acceptable. If the laser output could reach 100 mW for a continuous beam, the required time would be reduced to 5 minutes for 2-log reduction and 10 – 403 minutes (0.168 – 6.72 hrs) for 3-4-log reduction. This is far more acceptable for quick disinfection as it falls within the 20 minute goal.

Factoring in that the design to use a laser would require a mirror to scan the items, all above times would need to factor the reflectivity of the mirror. Using bare aluminum mirrors from Rocky Mountain Instrument Company, the expected reflectivity is between 90% and 93%. This means that an ideal 5 minute scan would be between a 5.4 – 5.6 minute real scan. The disinfection chamber will be made of aluminum, which will reflect and stop all laser beams from reaching the user when the system is running,

9. Application

UV light can safely be used for a variety of disinfection applications. Systems are available to disinfect rooms and high traffic areas with common touch points, ambulances and other emergency service vehicles, ductwork, tools or equipment inside a disinfection chamber, continuous pass-through conveyors, and many more. It has long been available for biological safety cabinet disinfection and home water treatment as well. It provides a chemical free method of disinfecting soundproofing materials and sensitive electronics that are traditionally chemically incompatible.

10. Benefits

While there are definite limitations to UV-C disinfection technologies, there are many benefits as well. Disinfection times are fast, with a typical disinfection cycle lasting about 15 minutes. This allows for extremely fast turnover times for rooms or other spaces being disinfected. Due to its simplicity, UV-C disinfection is extremely easy to understand.

11. Drawbacks

While UV is effective at inactivating a wide range of microorganisms, there are limitations for its use. As it involves light waves, UV operates in a “line-of-sight” fashion, only irradiating surfaces within its sightlines. Surfaces can be blocked from the light if objects are in the way, much like a beach umbrella offering protection from the sun. These areas that become blocked from the UV light are commonly referred to as shadow areas.

12. Conclusion

Considering the crisis created by COVID-19 pandemic, a sterilization box (prototype) was designed and fabricated for disinfecting the items of daily use such as face masks, wallets, belt and wristwatch. The box comprised 30 W incandescent lamps along with some electronic accessories. A study was conducted to study the effectiveness of the box chamber for sanitizing the items from bacteria and viruses.

The development of the appliances include safety factors to avoid any possible skin exposure to UV during assembly and testing. Improvements to the systems include decreasing the size and weight. There is difficulty in fitting electrical components within the limited space for an effective dose, however a more compact and lighter system can be useful in more applications. It is desirable to provide a cost effective solution while considering exposure time. For example, if longer exposure times can be afforded for an application, then radiation sources with lower intensity can be used, while decreasing system cost. Certain applications will benefit from shorter exposure times.

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