UV-C Sterilization
For Bacteria, Germs, and Viruses

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Ratification of Scientific Writing

1. **Title Essay**

   UV Sterilization Box for Bacteria, Germs, and Viruses

   (As a more practical and safer substitute for disinfectant spray)

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Foreword

Praise the presence of Allah SWT, the god of the universe, who always gives His grace and blessings to all of us until we can complete our research entitled "UV-C Sterilization For Bacteria, Germs, and Viruses". We do not forget to give prayers and greetings to the lord of the great prophet Muhammad SAW who has always brought mankind from the dark ages to the present which is full of truth.

Our paper is aimed at participating in the Indonesia Science Project Olympiad (ISPO) which is held every year. We do not forget to give our thanks as much as possible to all our teachers, school, friends, and parents for all our prayers and efforts that have helped to validate our scientific research.

We are very aware that our work is not completely perfect and that we could not have gone this far and succeeded without the help of various parties. Hopefully, with the completion of the ratification of this scientific paper, it can add to our knowledge and become our experience in the future, and hopefully, it can be useful for the world and life.

Depok, 10 February 2021

Contents

Abstract

Based on several research studies, some microbial infections can be caused by contaminated surface. Tuberculosis, covid-19, SARS-Cov influenza has affected more than million people worldwide. One method that can be used to inactivate microbes is UVC light. It is commonly believed that UVC light is extremely effective in damaging the DNA of microorganisms without leaving harmful chemical residuals. This research aims to make a low-cost UVC sterilizer box that can be used to sterilize baggage. The method of this research is observational- experimental study and literature study.

Based on several research, the usage of UVC light show very high effectiveness of this device to eliminate microbes. The sanitizing method employed by this device affects a very wide range of microorganisms and it has several advantages of respect to chemical based-sanitizing methods. The total cost to make this open-source device is below Rp 200.000 and it is easily customizable which is different from commercial devices available. This device represents an open-source, secure, fast and automatized equipment for room disinfecting. The device is configured in less than three minutes and it does not require continuous monitoring.

CHAPTER I

PREFACE

1.1 Backround

Microbial infection is one of the major challenges to worldwide public health. Some infection appears in seasonal, and pandemic forms. A common example of infection by viruses are influenza, SARS-Cov, MERS-COV, and COVID-19. COVID-19 that firstly emerged in 2019 has been infecting more than 219 countries with more than 107,115,221 cases worldwide. The death that has been reported is around 2,339,408. Other infections such as tuberculosis are still the main concern worldwide. In 2020, around 1.85 million people died due to Tuberculosis (WHO, 2020). In Indonesia, around 11,993 people died due to tuberculosis (Kemenkes, 2020).

Based on several kinds of research, some diseases often spread by direct contact with other people. a pathogen (disease-causing microorganism), finding a way out of an infected person is easy enough via sniffles, sneezes and coughs that produce droplets. People can be infected by breathing in the droplets during close contact with an infected person. Besides, the droplets containing bacteria can fall on certain surfaces, it infects the host when the contaminated surface is touched and finds its ways through the mouth, nose or eyes. The rapid spread of viral infections through contaminated surfaces is common particularly in crowded indoor establishments such as schools, day-care facilities, nursing homes, business offices, hospitals or transport systems (Barker et al. 2001). Viral agents that primarily infect the upper or lower respiratory tract include influenza and parainfluenza viruses, adenoviruses, respiratory syncytial virus (RSV), coronaviruses, human metapneumovirus, rhinoviruses and enteroviruses (Kesson 2007). It is generally accepted that respiratory viruses are spread from person to person by aerosol transmission due to sneezing or coughing (Goldmann 2000). Additionally, there is evidence to suggest that a significant proportion of flu viruses and other respiratory viruses are spread via contaminated hands and fomites (Winther et al. 2007). A recent review of the scientific literature found that the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), which causes COVID-19, can survive on different surfaces for different amounts of time. It is not certain how long the virus that causes COVID-19 survives on surfaces, but it seems likely to behave like other coronaviruses. A recent review of the survival of human coronaviruses on surfaces found large variability, ranging from 2 hours to 9 days (Kampf et. al, 2020).

The ultraviolet (UV) disinfection system is among one of the alternatives to conventional disinfection procedures for killing pathogenic microorganisms. At particular wavelengths such as 254 nm, UV-C light can destroy the molecular bonds and disrupt DNA or RNA, causing the death of a variety of environmental microorganisms. The UV-C device offers several advantages compared with disinfection using traditional disinfectants. These include germicidal activity

against broad-spectrum organisms, the shorter time required for vegetative bacteria, safety and eco-friendly without hazardous residual, saving costs such as labour and consumables, and relatively simple way to set up and operate in many institutions. Additionally, disinfection of the surfaces that are rarely cleaned such as food package, luggage, handphone, shoes, clothes and many more.

Based on those descriptions, we want to develop UVC sterilizer Box that can sterilizer rarely cleaned baggage such as bag, wallet, handphone, jacket and shoes. This tool is intended to be easily used and affordable for many people.

1.2 Questions Problem

1. How can humans sterilize their goods effectively and efficiently?
2. How to maximize the function of UVC lamps to sterilize items from microbes?
3. How to design the UVC sterilizer Box to be effective, but at low cost?

1.3 Research Objective

Based on the formulation of the problem above, we determine our research objectives, namely:

1. Determine an effective method for sterilizing the boundaries of microbes
2. Determine the effective UVC reflective material
3. Determine the tools and materials that are effective and efficient

CHAPTER II

LITERATURE REVIEW

2.1 Microbes

a. Bacteria

1. Definition of Bacteria

Bacteria are a group of organisms that do not have a nuclear cell membrane. These organisms are included in the prokaryotes and are very small and have a large role in life on earth. Some groups of bacteria are known as agents that cause infection and disease, while other groups can provide benefits in the fields of food, medicine and industry.

2. Structure of Bacterial Cells

Like prokaryotes (organisms that do not have a nuclear membrane) in general, all bacteria have a relatively simple cell structure. Due to the absence of a nuclear membrane, the genetic material (DNA and RNA) of bacteria hover in the cytoplasm called the nucleoid. One of the important bacterial structures is the cell wall. Bacteria can be classified into two major groups based on their cell wall structure, namely Gram-negative bacteria and Gram-positive bacteria. Gram-positive bacteria have a cell wall composed of a thick layer of peptidoglycan (a type of polysaccharide molecule) and teichoic acid, while Gram-negative bacteria have a thinner peptidoglycan layer and have a thick lipopolysaccharide structure.

Many bacteria have structures outside other cells such as flagella and fimbriae which are used for movement, attachment and conjugation. Some bacteria also have capsules that play a role in protecting bacterial cells from drying out and phagocytosis. The capsule structure is often a virulence factor that causes disease, such as that found in Escherichia coli and Streptococcus pneumoniae. Bacteria also have chromosomes, ribosomes, and several other species have food granules, gas vacuoles, and magnetosomes. Some bacteria can form themselves into endospores which enable them to survive in extreme environments.

b. Virus

1. Definition of a Virus

Viruses are pathogenic microorganisms that can only replicate in the cells of living things because they do not have the cellular equipment to reproduce on their

own. All forms of life can be infected by viruses, from animals and plants to bacteria and archaea. The term virus is usually used to refer to the types of viruses that infect eukaryotic cells, while viruses that infect prokaryotic cells (such as bacteria and archea) are known as bacteriophages. Until 2019, more than 6,000 virus species have been described in detail, out of a total of millions of viruses in the environment. Viruses are found in nearly every ecosystem on Earth and are the most abundant biological entity.

2. **Virus Structure**

The viral genome can be either DNA or RNA. The viral genome can consist of double-stranded DNA, single-stranded DNA, double-stranded RNA, or single-stranded RNA. Besides, the viral genome nucleic acid can be single linear or circular. The number of viral genes varies from four for the smallest to several hundred for the largest. The genetic material of most animal and human viruses is DNA, and in-plant viruses, it is mostly single-stranded RNA. Virus genetic material was covered by a protective layer. The protein that forms this protective layer is called the capsid. Depending on the virus type, the capsid can be round (spherical), helical, polyhedral, or a more complex shape and consists of proteins encoded by the viral genome.

2.2 Tools and Material

A. UV-C

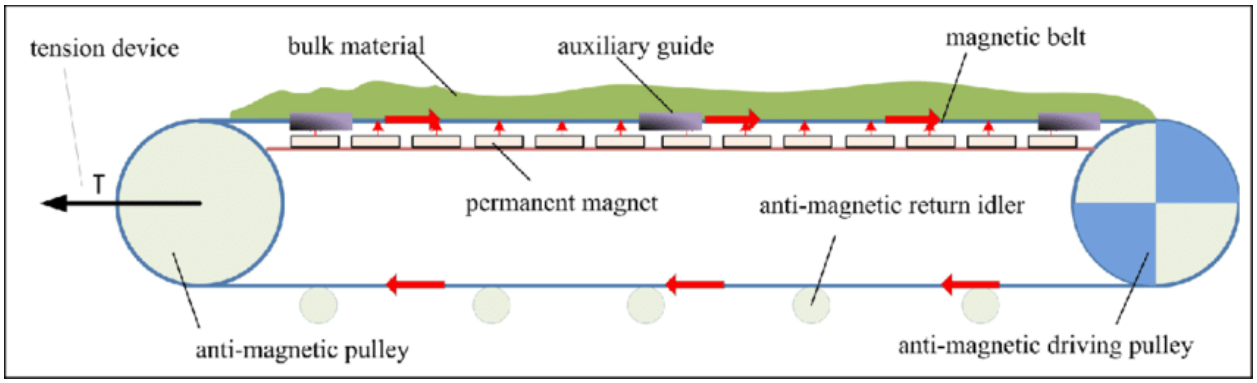
At present, there are many different designs for UV disinfection systems. Some systems consist of just a bare lightbulb and a timer, while others are mobile robots that can reach hard-to-access places. Two of the major design choices are the wavelength of light and the method of delivery. By far the most common wavelength for germicidal light is 254 nm, produced by low-pressure mercury lamps. These lamps are easy and cheap to manufacture because they use essentially the same technology as a fluorescent light bulb. A fluorescent bulb produces UV light inside the bulb. But the phosphor deposited on the glass surface of the bulb absorbs that light and re-emits it at longer wavelengths that humans can see. To make a UV lamp, the glass is replaced with a material transparent to UV light, such as fused quartz.

Experts believe that different wavelengths disable viruses in different ways. The 254 nm light damages the viral deoxyribonucleic acid (DNA) or ribonucleic acid (RNA) so that the virus cannot reproduce. Shorter wavelengths, like 207–222 nm (sometimes called “far UVC”) are believed to damage the proteins on the surface of the virus that it needs to attach to human cells. Thus, the curve that describes the viral killing ability of UVC light has a double-humped shape, with a peak at shorter wavelengths and another around 265 nm.

Disinfection with far-UVC lamps remains largely experimental but could have an intrinsic advantage. Initial evidence suggests that far-UVC light does not penetrate beyond the outer dead layer of skin cells or the liquid film on eyes in healthy people. Thus, it cannot cause skin cancer or cataracts, like UVA and UVB. It also seems not to cause temporary skin burns and eye damage (“welder’s flash”) like standard UVC. This presumably depends on the intensity of exposure; whether intense exposure to destroy pathogens on the hands, for example, would be safe is unknown.

The popularity of UVC 1980s, when drug-resistant bacteria emerged, particularly tuberculosis (TB). Nardell said that a partial solution to disrupt hospital transmission of TB, an airborne pathogen, used louvred UVC lamps to disinfect the air near the ceiling, which was then circulated to the rest of the room. But that strategy did not affect pathogens that depend on surface-based transmission. Hospital-acquired infections remain a major problem globally, affecting an estimated seven to ten of every 100 hospitalized patients. Many of the pathogens that cause these infections are multi-drug resistant and difficult or impossible to cure with drugs, so it makes sense to try to kill them before they can enter the body. Thus, before 2020, hospitals were the main customers for whole-room UV disinfection.

2.3 Conveyor Belt Structure



1. Conveyor Belt Idea

The idea of the sterilizer box mainly comes from a conveyor belt in an airport. A conveyor belt is a type of conveyor that can move by a pulley. We change a few things in the conveyor belt. The first thing that we change is the pulley. We don't use a pulley to make it move but we use a bearing. The second thing that we change is the motor. In our project, we don't use an automatic motor, but we use a manual motor, for example, human motor. At the end of the line, there is a box, the sterilization will occur inside the box. Our conveyor belt is made from a PVC pipe. We use PVC pipe material because it is affordable, reachable, and it has lightweight.

2. How it Works

Things from outside that have not been sterilized will enter through the roller. After that, the goods will enter the box. then the switch will be turned on and the UV lamp will sterilize the object by emitting light. The UVC lamp will work effectively by turning it on for approximately 1 minute. The UVC lamp will emit light to all sides of the room because in the room there is cardboard covered with aluminium foil where when the UVC lamp emits light, the light will reflect. After finishing the item can be taken. How to pick it up is also easy, we only need to open number 9 in the same way as opening a small door and then we can take the object by hand. Now the object has been sterilized and is free from viruses or bacteria.

2.4 UVC Reflector

Improving UV Reflectance in the Reactor System designers can optimize the field of uniformity by using materials with highly reflective properties for UVC light in reactors where the light source footprint is at a premium or there is a need to increase efficiency. This maximizes internal reflection to take full advantage of the UV energy or photons emitted from the light source.

A common material used in commercial UV disinfection systems is stainless steel. While this surface is highly resistive to microbial growth, it only has 20 - 28% reflectance of UV light. Flow cells that contain e-PTFE (expanded PolyTetraFluor Ethylene) provide more than 95% reflectance of the UVC light—making systems constructed of these materials more than three times effective than traditional reactors.

Aluminium Foil can also serve as a reflection of light from UVC rays. With aluminium, light can radiate off all sides so that items that are being sterilized can be exposed to UVC light effectively.

2.5 Other tools

A switch is an electrical component that can disconnect or connect a conduction path in an electrical circuit, interrupt an electric current or divert it from one conductor to another. The most common type of switch is an electromechanical device consisting of one or more circuits of mobile electrical contacts connected to an external circuit. When a pair

of contacts touch current can pass between them, whereas when the contacts are separated no current can flow.

Switches are made in a variety of configurations; they may have multiple sets of contacts controlled by the same knob or actuator, and the contacts can operate simultaneously, sequentially, or alternately. The switch can be operated manually, for example, a light switch or a keyboard button, or it can serve as a sensing element for sensing engine part position, fluid level, pressure, or temperature, such as a thermostat. A common use is lighting control, in which several switches can be connected to a single circuit to allow convenient control of the light fixture. Switches in high-powered circuits must be of special construction to prevent damaging arcs when opened.

a. PVC pipe

PVC pipe functions as a frame and also as a roller so that items coming from outside can enter easily. This pipe is one of the most important components because it is the framework for the entire body of the box.

b. Carton

This carton functions as a holder so that items that are put in the box do not fall. Also, this carton functions as a protector for our bodies. This is because exposure to UVC rays can irritate our skin and can damage the retina of the eye.

c. ON / OFF switch

This switch will be used as a trigger so that the UVC lamp can light up properly. And when it's finished using the UVC lamp, you can turn it off to reduce excessive electricity consumption.

d. Bearing 6000ZZ

This bearing will be used as a support for rollers. These bearings help the rollers run smoothly.

CHAPTER III

METHODOLOGY

3.1 Type of Research

This research is a type of experimental-observational research conducted with a series of experiments on the product under study and calculations and direct observation on the design of the tool.

3.2 Data Collection Method

Data collection was carried out to complement this paper by research

3.2.1 Literature Study

A literature study is carried out by reviewing the literature, books, and seminar papers relevant to the problem discussed in the study.

3.2.2 Observation Method

Observations are made by direct observation as well as with record the symptoms that occur in the object of research as a whole with facts that exist in society.

3.2.3 Documentation Method

Documentation is done by collecting data from various sources comes from documents which are secondary data such as the internet.

3.2.4 Experimental Method

Experiments were carried out with the manufacturing process and design testing UV sterilizer Box.

3.3 Time and Place of Research

This research was started on December 7, 2020, until January 10, 2021, which includes searching for ingredients, manufacturing products, experiments, direct product testing, and preparation of research reports.

3.4 Tools and Materials

1. Lampu UVC 270-nm

2. Pipa PVC

3. Aluminium Foil

4. Bearing 6000ZZ

5. Switch ON/OFF

6. Carton

7. Bubble Wrap

3.5 Manufacturing Steps

Outline creation

1. Before starting manufacture, we make a frame and measure the dimensions of the box that will be made so that it can be used effectively.
2. The next step after measuring everything, we started cutting the PVC pipe into several parts according to the predetermined size
3. After that, we put the PVC pipe into the sketched shape.
4. After everything was installed, we started modifying the PVC pipe so that the bearings that function as rollers could be installed.
5. After that, we glue between the sides of all the joints.

Aluminium foil installation

1. After the frame is finished, we start cutting the aluminium foil to the size of the box.
2. After that, we attached the aluminium foil to all sides of the box and attached it with string and duct tape
3. After everything is installed, we coat the outside with cardboard

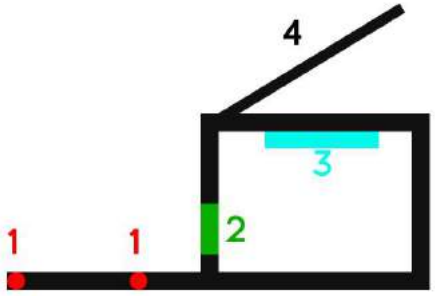
Lamp Installation

1. We attach the lights inside the top of the box
2. After the lights were installed, we proceeded to install the switches to the right of the box

CHAPTER IV

DISCUSSION

4.1 UVC Sterilizer Design



Based on the picture above, number 1 is a roller whose function is to beautify the items you want to sterilize in the box. Number 2 is a switch whose function is to turn on / off the light. Number 3 is a UVC lamp and lastly, number 4 is a small door whose function is to take items that have been sterilized.

4.2 Tools and materials used

4.2.1 Far-UVC lamp (222 nm wavelength)

In this section, we will explain how to kill bacteria that come from outside using a UVC lamp. UVC lamps serve as a tool to kill bacteria and germs. The UVC lamps will be combined into one with the box frame at the top. After joining, the UVC lamp is turned on, after which the UVC lamp can kill bacteria and germs found on goods or packages from outside.

4.2.2 PVC pipe

PVC pipe functions as a frame and also as a roller so that items coming from outside can enter easily. This pipe is one of the most important components because it is the framework for the entire body of the box.

4.2.3 Aluminum Foil

This aluminium foil is used as a light reflector from UVC lamps. Aluminium foil was chosen because it is easy to obtain and very affordable. Aluminium foil also has a fairly good reflectance rate of 73%. This aims to evenly eradicate bacteria and germs so that all bacteria and germs contained on the item can be lost without anything left.

4.2.4 Carton

This carton functions as a holder so that items that are put in the box do not fall. Besides, this carton also functions as a protector for our bodies. This is because exposure to UVC rays can irritate our skin and can damage the retina of the eye.

4.2.5 ON / OFF Switch

This switch will be used as a trigger so that the UVC lamp can light up properly. And when it's finished using the UVC lamp, you can turn it off to reduce excessive electricity consumption.

4.2.6 Bearing 6000ZZ

This bearing will be used as a support for rollers. These bearings help the rollers run smoothly.

4.3 Cost Production

The proprietary market offers disinfecting units based in UV-C lamps that use mercury or xenon. The first ones are the most common and less expensive, and this kind of lamp is used in the device here presented. Effect of exposure to the disinfectant device on plates inoculated with 200 mL of a liquid culture of E. coli K12 W3110 (1,2 E3 CFU/mL) placed at 1 m and 2 m from the device and exposed for one hour. Duplicates of the experiment are shown. Effect of different times of UV-C exposure over plates inoculated with 200 mL of E. coli K12 W3110 liquid culture (1,9 E3 CFU/mL) placed at one meter from the UV-C device. Triplicates of the experiment are shown. M. Bentancor, S. Vidal / HardwareX 4 (2018) e00046 9 to make this open-source device are easily available locally and its cost, below USD 180, turns this into a very competitive device because it represents a more than 80% save compared with proprietary commercial devices with similar functions. If xenon lamps-based devices are considered, the saved amount is even higher. These savings are in the order of other reported savings for other kinds of open-source hardware. In this cost analysis the labour cost for the assembly of the device is not considered, however, and in the same way that for other open-source hardware after being developed the prototype unit, this device can be replicated by any person with basic knowledge about electronics. So, this device is not only easily accessible to many laboratories that require room UV-C disinfection but also can be used for training purposes on the use of this kind of microcontroller or the assembly of open source hardware

4.4 The Effectiveness of Using UVC Sterilizer Box

This discussion will discuss the effectiveness of the UVC sterilizer box for goods that come from outside. UVC radiation has been shown to destroy the outer protein layer of SARS-Coronavirus, which is a different virus from the current SARS-CoV-2 virus. Destruction ultimately leads to virus inactivation. UVC radiation is also effective in preventing the SARS-CoV-2 virus, which is the virus that causes Coronavirus disease 2019 (COVID-19). However, currently,

published data are limited on the wavelength, dose and duration of UVC radiation needed to kill the SARS-CoV-2 virus.

According to research UVC can kill bacteria, germs, and viruses in a period of between 2 to 30 minutes. Within 25 minutes, bacteria, germs, and viruses have been lost as much as 95%. In times like this, health and hygiene are taken care of. There are several ways to get rid of bacteria and germs. However, several. of these methods harm our bodies. As an example; hand sanitiser. According to research, hand sanitisers can irritate the skin in excess. Besides, hand sanitisers contain synthetic chemicals that can increase various allergic disorders, asthma, and cancer. Therefore, it was decided to make a UVC Sterilizer box. The UVC Sterilizer Box has several advantages. These advantages are easy, practical, and effective. Besides, sterilizing goods can be done side by side by doing other activities such as washing, cooking, and making coffee. UVC Sterilizer boxes can be placed in various places such as offices, schools and supermarkets. The price of the UVC Sterilizer box is very affordable, this is because it only takes about 7 items to make it.

CHAPTER V

CONCLUSION AND SUGGESTION

5.1 Conclusion

UV-C box sterilization devices are made with functions similar to commercial proprietary systems. The presented model can be easily upgraded, modifying its structure (adding more UV-C lamps) and programming (editing open-source Arduino boards and/or Android applications), achieving savings of more than 80%. at the same price as proprietary commercial equipment. This low cost, open-source hardware development extends access to this kind of equipment for use in health facilities, schools, offices, cultural spaces. Besides, this tool is useful for training human resources in building this device, making it easier to repair the equipment.

5.2 Suggestions

There is an opportunity for the user to upgrade this equipment or upgrade it to build a higher power model if needed. Possible improvements might add a timer and increase the dimensions.

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Attachment

UV-C Sterilizer Box Manufacturing Process

Prices For UV-C Sterilizer Box

No.	Materials	Prices
1.	UV-C Light 222nm	Rp100.000,-
2.	PVC Pipe	-
3.	PVC Pipe Connection	Rp85.000,-
4.	Bearing 6000zz	Rp10.000,-
5.	Cartoon	-
6.	Alumunium Foil	Rp12.500,-
7.	On/Off Switch	-
8.	Glue	-
Total		Rp207.500,-

*notes (-) = Reused Materials