E-ISSN 2581 –7957
P-ISSN 2277 – 3916
CVR Journal of Science and Technology, Volume 21, December 2021
DOI: 10.32377/cvrjst2110

Touch-less Disinfecting Contraption using UV-C Light

Cholleti Mahathi[1] and Dhruva R Rinku[2]
[1]PG Scholar, CVR College of Engineering/ECE Department, Hyderabad, India
Email: mahathicholleti@gmail.com
[2]Assoc. Professor, CVR College of Engineering/ECE Department, Hyderabad, India
Email: dhruva.rinku@cvr.ac.in

Abstract: **An electro-mechanical disinfecting device is designed and implemented using UV-C (Ultraviolet-C Radiation light). This device is made completely touchless in an effort to avoid viruses from being contacted to the device. The outbreak of SARS-COV-2 has led to serious public health emergencies. The vital step for preventing the spread of coronavirus is sanitizing, disinfecting. Ultraviolet radiation as a disinfecting unit is preferable to chemical-based sanitation, with research studies proving its effectiveness in deactivating viruses when exposed to the radiation. The things to be disinfected are exposed to UV radiation in this closed chamber and the device is operated using sensors.**

The main objective is to design a cost-effective device that can be availed at any public place by anyone.

Index Terms: **SARS-COV-2, Covid 19, UV-C radiation, UVC lamp, Covid vaccine, Disinfecting, sanitizing.**

I. Introduction

The novel coronavirus has been a chaotic pandemic all over the world since Dec 2019. It left the world in a state of crisis in many areas, including the economy, health, education, and others. SARS-COV-2 (Severe Acute Respiratory Syndrome Coronavirus 2) is accountable for the emergence of COVID 19 (Coronavirus disease 2019). As a result, the world has been witnessing traumatic scenarios involving lakhs of deaths. Airborne, direct contact, indirect contact are the different transmission modes of coronavirus. Therefore, the most important thing people can do is to avoid transmission. People have been advised by the WHO (World Health Organization) to avoid the spreading of the coronavirus by wearing masks, regularly washing their hands, avoiding groups, sanitizing and disinfecting. There were no other precautions we could take. Although covid vaccination is on the rise, these precautions must be part of our daily activities without any negligence. During the early stage of the pandemic, the world was in dire straits that vaccines seemed to be out of the question. Developing a vaccine for the SARS-COV-2 was viewed as a challenge around the world. Scientists across the world collaborated to develop vaccines, treatments to save people and end this pandemic [6]. In order to develop a vaccine, five stages must be completed, involving numerous trials and time-consuming processes. After tremendous research, finally vaccines are available after almost one year since the outbreak of COVID-19. The majority of them are largely successful [6]. Initially, vaccine dosage was low as people were terrified by its side effects. However, these side effects are out of note compared to its nature of fighting against coronavirus. Ultimately, the WHO and the government are successful in bringing vaccines to the public's attention. Vaccines are to provide immunization against serious illness and death. Boosting the immune system by providing the highest level of immunity is what vaccines do. Getting vaccinated doesn't mean that people can cast away the precautions completely. Studies are being conducted to ascertain whether these vaccines can provide long-term protection [10]. Hence, the WHO guidelines should be followed on a regular basis.

Disinfecting and cleaning the often-used items are the requisite steps among the precautions conferred by WHO [1]. There are physical methods as well as chemical methods of disinfection. Physical methods include ultraviolet radiation, heat, sunlight exposure and chemical methods involve liquid sanitizers, bleaching and other chemical solutions. As chemical sanitizers leave residue behind, most of the materials can't resist them. Hence, physical disinfection methods are preferable to chemical-based methods. UV radiation is one of the physical disinfection methods and is considered to be the most effective. In the early 19^{th} century, UV was first used for water treatment and sterilization. With the evolution of UV technology, Ultraviolet Germicidal Lamps (UVGI) are acknowledged as air and surface disinfectors. Moreover, it has been shown to kill 99.9% of viruses in studies. Mainly there are two drawbacks to using UV radiation,

- A significant health risk is posed by UV exposure such as skin cancer, skin burn. It not only effects the outer layer of the skin but also penetrates into deeper layers causing DNA damage.
- While using UV disinfectant, part of the item in the shadow region doesn't get disinfected, so this must be spotted.

Scientists have ascertained the effectiveness of UV radiation in deactivating corona virus and different designs of UV disinfection units are being implemented. Some are mobile units, some are open which condition the open rooms, some are closed chambers.

Received on 17-05-2021, Revised on 03-07-2021, Accepted on 19-08-2021.

II. Related Work

A. UV Radiation

Ultraviolet radiation, an electromagnetic radiation form with the wavelength ranging from 10nm to 400 nm (corresponding frequency around 30PHz to 750THz) shorter than visible light and longer than X-rays [14]. UV is contained in sunlight and adds up to 10% of electromagnetic radiation from the sun. There are several sub-ranges in the range of the UV i.e., 10 nm to 400 nm, mainly UVA, UVB, UVC, N-UV, F-UV, H Lyman-α, E-UV, V-UV. UVA, UVB, UVC ranges are considered mostly [14].

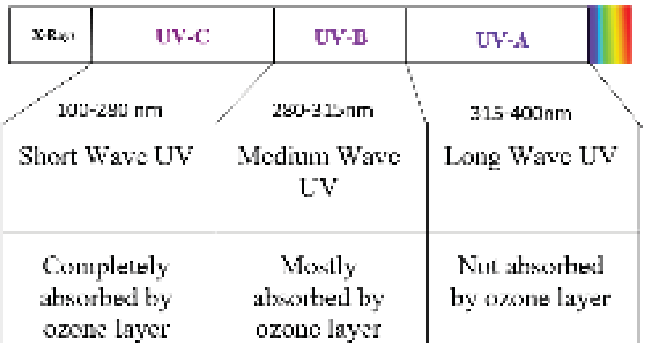

Figure 1. UV ranges in the electromagnetic spectrum

In the figure 1, the different types of UV radiation are grouped based on their wavelength range. In addition, their characteristics towards the ozone layer are described.

Thus, the majority of UV radiation reaching the surface of the earth is UV-A, with some UV-B showing up in portions [14]. Due to the ozone layer, UV-C light is not able to reach the Earth's surface and biological life on earth has not been exposed to this energy. But UV-C is more prominent as a disinfecting unit than others. Finally, researchers successfully invented lamps that can produce radiation in the range of UV-C. In the year 1901, the Germicidal lamp (Low-Pressure Mercury Lamp) that produces 254 nm wavelength radiation was invented. This is proven to deactivate bacteria, viruses and protozoa.

How does UV-C work? Despite being used for disinfection since the 19th century, the answer to this was recently found. UV-C deeply assimilates RNA and DNA heading to the structural havoc of the virus in a process called photodimerization [8]. DNA has nucleotides containing nitrogen base, deoxyribose sugar and phosphate group as elementary units. The nitrogen bases in DNA are Adenine(A), Thymine(T), Guanine(G) and Cytosine(C) whereas in RNA Uracil (U) is present instead of Thymine. A - T and G - C are the pairs that form DNA strands [2].

exposure to UV radiation DNA can be damaged in several ways. i) can break double-strand ii) can change the structure of the base, for example, G could look like A iii) can make either two T molecules or two C molecules to bond together [9]. DNA is thus disrupted in such a way that it becomes inactive to perform its cellular functions. While RNA makes up the Coronavirus, the effect is the same when exposed to UV radiation. UV radiation has a higher impact on C, T [2].

UV dose and UV intensity are commonly used terms to describe the amount of UV radiation penetrates. The former measures the amount of energy that penetrates through the surface multiplied by exposure time, while the latter measures the amount of UV energy penetration through the treated surface.

UV dose determines log reduction of pathogens.

- 1 log reduction = 90% reduction
- 2 log reduction = 99% reduction
- 3 log reduction = 99.9% reduction
- 4 log reduction = 99.99% reduction and so on.

The relation between percentage reduction and log reduction is given in [12] as

$$P = (1 - 10^{-L}) \times 100 \tag{1}$$

Where P is the Percentage in reduction and L is the log reduction.

According to [11] UV Dose is expressed in terms of UV irradiance and Time

$$UV_{dose}\left(\frac{J}{cm^2}\right) = UV_{irradiance}\left(\frac{W}{cm^2}\right) \times Time\ (s) \tag{2}$$

Where UV_{dose} is the radiation dose required in Joules per centimeter square, is the radiation emitted by th e source in Watts per centimeter square and is the time required to eliminate a virus in seconds.

UV LEDs have finally been found to kill 99.9% of the SARS-COV-2 virus in 30 seconds [3]. It is also demonstrated that UVC is more effective in inactivating SARS-COV-2 than UVA in [4]. SARS-COV-2 can be inactivated by UV-B, but it is less effective for other SARS viruses. Humans are more vulnerable to the harmful effects of UVB than UVC. It can penetrate through the skin and damage DNA. As such, it poses a risk [5]. It is widely recognized that UVC can disinfect the air, water, and surfaces and that it has been used for decades. Thus, it is called a germicidal lamp [5].

III. Proposed Model

The proposed system provides flexibility to the user to get their things physically sanitized. This system shows following new features from existing models,

- It is made touchless
- It has an interactive display
- It has adjustable disinfection timer features
- A curtain is fixed so that there is no chance for humans to get exposed to UV light.
- Items can be disinfected individually.
- This device can be availed at anywhere without any installation.
- It only needs a simple power source.

A. Design of the system.

This system includes both input and output devices. Input devices give input signals to Arduino boards and output devices take signals from Arduino boards. A motor driver, LCD display, buzzer, relay module, and ultrasonic sensor are the output components. An ultrasonic sensor, IR sensor modules and limit switches are the inputs. The input and output devices used to implement the device are:

- Arduino Mega 2560
- LCD display
- DC motors
- IR sensor modules
- L298N motor driver
- UV lamp
- Ultrasonic sensor
- Limit Switches
- Buzzer
- Relay Module

B. Block Diagram of The Designed Model

As UVC is showing its efficacy in inactivating SARS-COV-2 different designs and technologies using UVC as disinfecting units are being implemented. Block diagram of design model is shown in Fig. 2. This model is an electromechanical device that can disinfect handheld items with a UV lamp as a disinfectant unit. A touch-free, closed chamber is designed to disinfect items within it. It is made touchless with the help of IR sensor modules. It has a user-interactive display (16x2 LCD display), ultrasonic sensor, relay module, UV lamp, two DC motors, limit switches and all components are controlled by Arduino mega 2560.

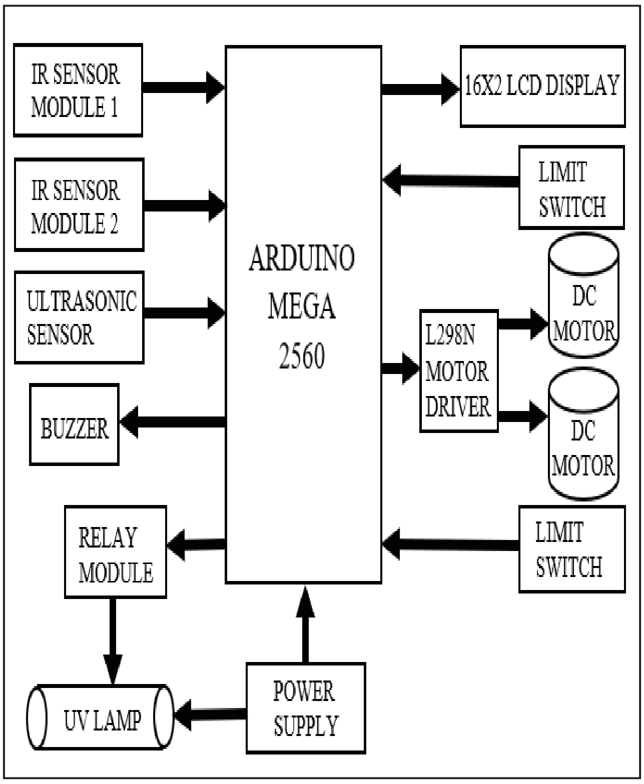

Figure 2. Block diagram of the designed model.

The closed chamber contains some mechanical parts like the main tray (which can be opened and closed by moving in and out of it), flipping tray (fixed on the main tray gets which can get flipped). Arduino is powered by 9 volts and UV lamp by 230 volts.

Arduino upon receiving signals from IR sensor modules triggers the events. Arduino sends signals to the L298N motor drive to drive DC motors when an opening or closing or flipping event is triggered. The movement of DC motors is stopped by limit switches where these limit switches send signals to Arduino when motors touch them.

IR sensor module is a sensor that detects the presence of an object in its proximity range. IR sensor modules are used in this design to operate the device. Two IR sensor modules are used IR1 and IR2. IR1 is for opening the tray and to set disinfecting time, IR2 is for closing the tray and for selecting different disinfecting times. The user interaction with the device is provided through a 16x2 LCD which has 2 lines each having the ability to print 16 characters. The default time for disinfection is 1 minute. It can be changed in accordance with the distance of the user's hand from the ultrasonic sensor. This device provides 4 different times for disinfection (1min, 3min, 5min, 6min) along with default time. For each time, the distance range is as follows

- 1cm < Distance < 5cm = 3 min
- 5cm < Distance < 10cm = 5 min
- 10cm < Distance < 15cm = 6 min

Ultrasonic sensor containing a transmitter and receiver measures the distance of the obstacle by transmitting ultrasonic waves and receiving the echo signals (reflected signals). It calculates the distance by measuring the time span between emitting the signal and receiving the echo signal. The formula that converts time-span to distance is

$$Distance\ (m) = \frac{Time\ span}{2 \times speed\ of\ the\ sound} \quad (3)$$

$$= \frac{Time\ span}{2 \times 29.1} \quad (4)$$

Two DC motors are used, one for opening and closing the main tray and the other to lift the mini tray. As DC motors require a large amount of current approximately 1A where Arduino can provide only 30-40 mA so a motor driver is required to drive the motors. One L298N motor driver can drive two DC motors at a time. An Arduino operates at 5V, far less than the 230V operating voltage of UV lamps, thus a relay module is used to handle that voltage. The Arduino turns on a relay that switches the UV lamp ON and OFF when an event occurs.

C. Circuit Diagram of the Proposed Model

The schematic layout of the implemented model is designed in Fritzing software and is presented below as a circuit diagram. Developers can use the Fritzing software to develop CAD software for the electronics industry. The Fig. 3 shows the circuit diagram for the model.

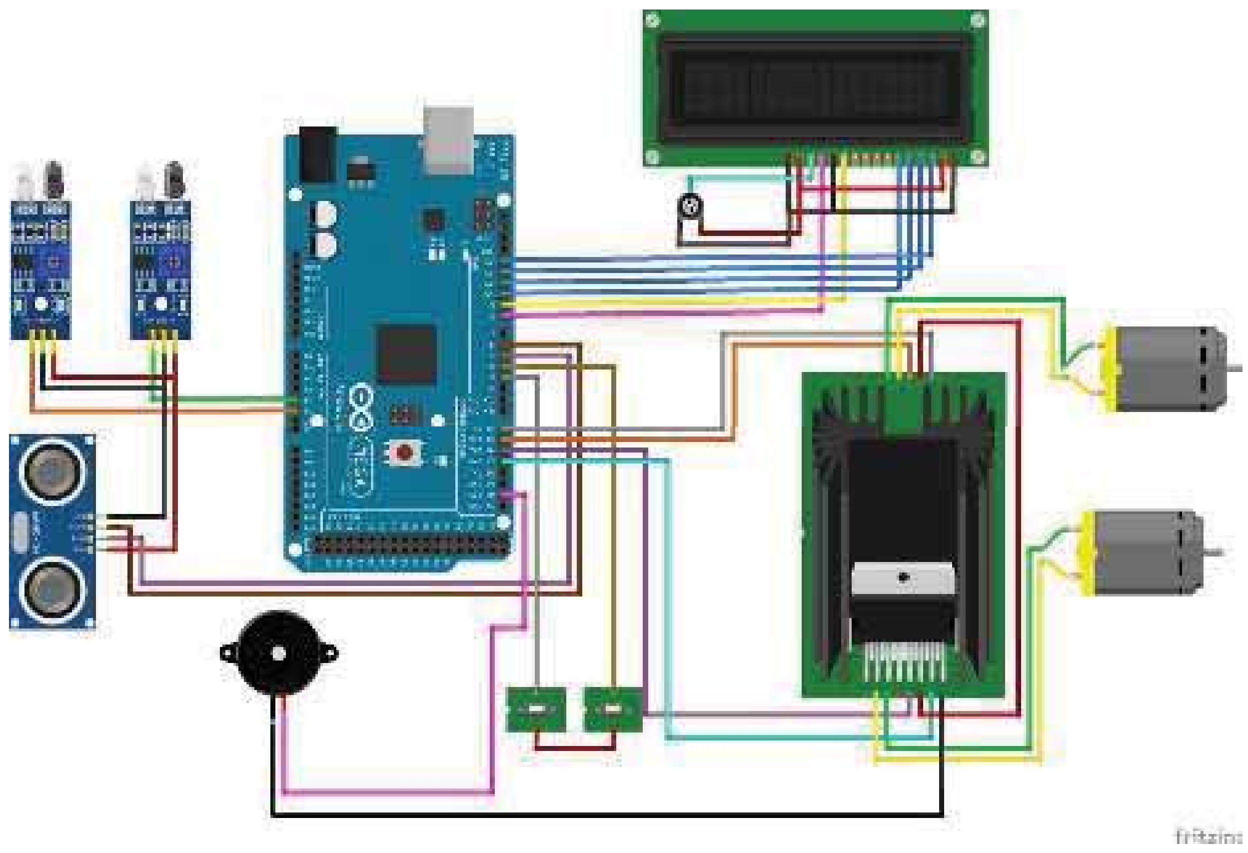

Figure 3. Circuit Diagram of the Touch-less disinfecting contraption implemented in Fritzing software.

D. Working of the Design

Upon turning ON the power supply, all the I/O devices will be initialized. The first message LCD displays is “UVC Based Disinfector” and “1 to open Tray”. It's time for the user to trigger the event at IR1 by placing his/her hand in the proximity of IR sensor 1 then the tray gets opened. After the tray is opened, the item to be disinfected must be placed on the mini tray (flipping), which is mounted on the main tray (open/closed). “2 to close the tray” on the display indicates an event to close the tray to be triggered at IR2 by placing the hand in the proximity of IR sensor 2. The user now needs to select a disinfecting time. When the tray gets closed, the user has an option to select disinfection time. LCD displays “1 to Default time 2 to change time”. Then IR1 to be triggered to select default time or IR2 to select different disinfection times. If IR2 is triggered, the user can select the given disinfection times by varying his hand from the ultrasonic sensor and the time in accordance to the distance range is displayed on LCD then the user can stop varying distance when desired time displays on LCD. Keeping the hand at that position, the user needs to trigger IR1 to select the time. Then the LCD displays the selected time, and the relay gets switched and the UV light is ON. The mini tray gets flipped after halftime has passed. Upon flipping the item falls on the main tray from the mini tray and disinfection continues. This helps the item to get exposed to the UV radiation on all sides. As soon as the disinfection gets completed the buzzer beeps and the UV lamp turns OFF simultaneously. Then the user can collect the item as per the instructions shown on the LCD display.

IV. RESULTS

In this section, the real-time images demonstrate the messages displayed on LCD while the device is in use. It also includes the appearance of the device. The following images were taken in one through of the disinfection process.

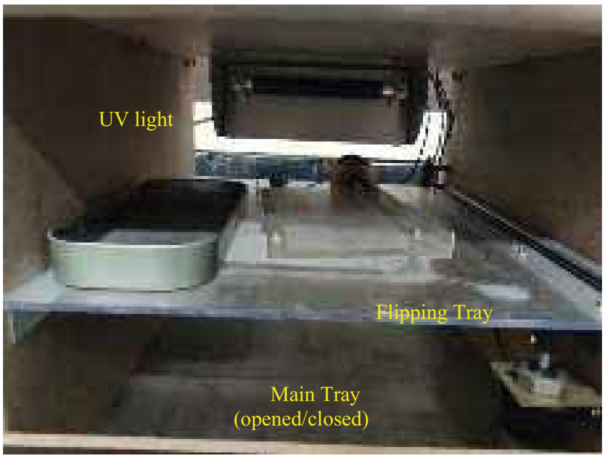

Figure 4. The interior mechanical parts of the implemented device

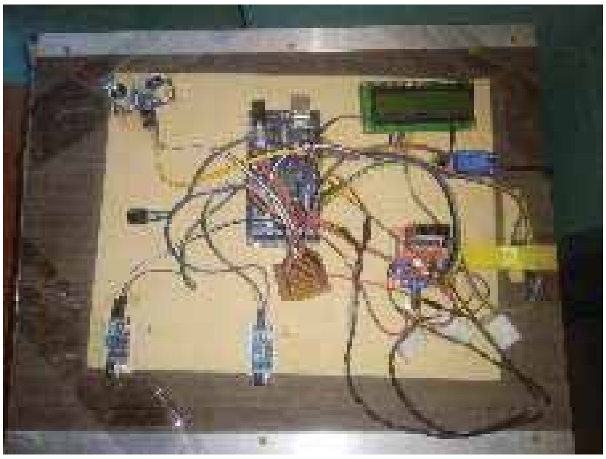

Figure 5. The top view of the device containing components.

Figure 6. Display as soon as all devices initialize

Figure 7. 1 in the display indicates IR1 to open the tray.

Figure 8. The front view of the implemented device

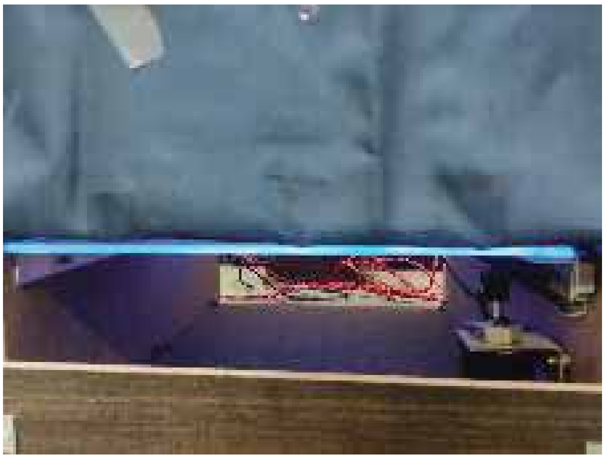

Figure 9. Blue light is observed when UV light is ON

Figure 10. Message on LCD during the opening of the tray

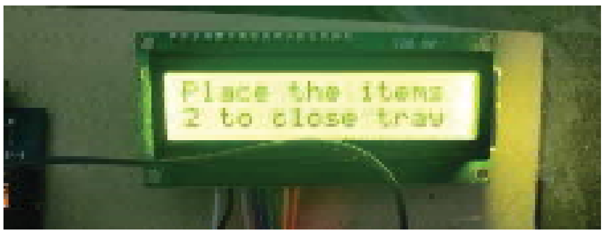

Figure 11. User need to place items on tray and 2 indicates IR 2

E-ISSN 2581 –7957
P-ISSN 2277 – 3916

DOI: 10.32377/cvrjst2110

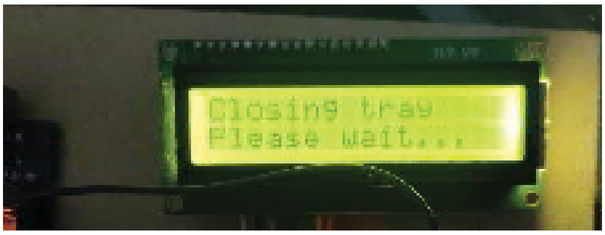

Figure 12. Instruction to user to wait during the closing of the tray

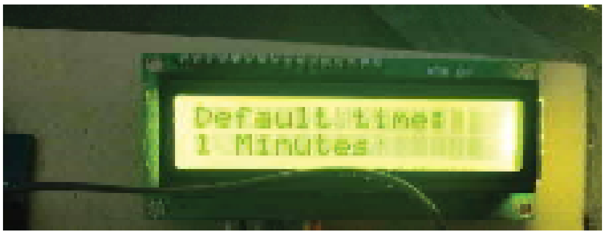

Figure 13. Displays the default time set as 1 minute.

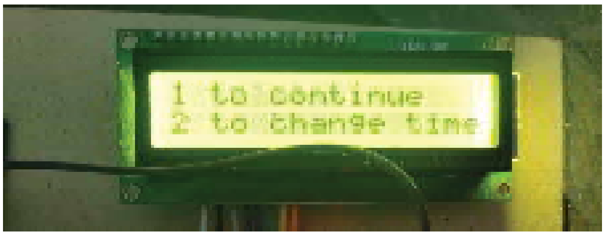

Figure 14. IR1 to continue with default time else IR2 to change time

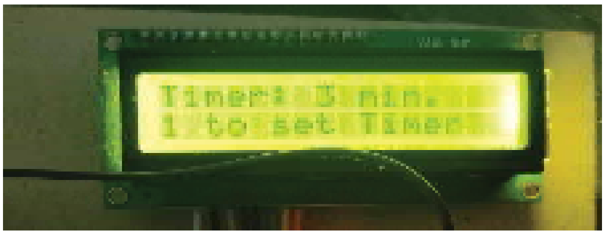

Figure 15. Displays time according to the varying distance from Ultrasonic sensor and desired time is chosen with IR1.

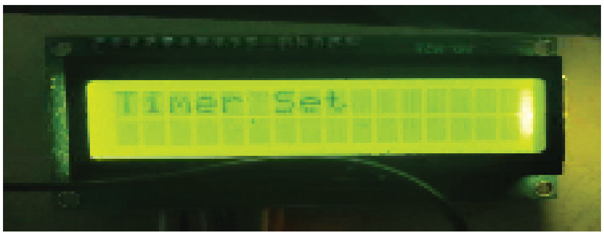

Figure 16. After time is set, displays it on the LCD as timer set.

Figure 17. For first half of the time, time set is shown in milliseconds.

Figure 18. After half time passed, flipping is done & it is displayed.

Figure 19. Disinfecting is displayed during disinfection after flipping.

Figure 20. After disinfection time is passed, message as disinfection Completed is shown and Buzzer is ON and tray gets open.

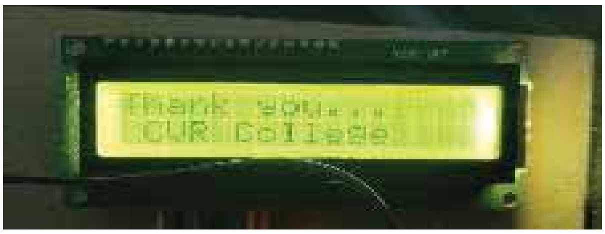

Figure 21. Last message shown after tray is closed by collecting the Disinfected items.

CVR Journal of Science and Technology, Volume 21, December 2021
DOI: 10.32377/cvrjst2110

Figures 4 to 21 are the images that illustrate the general appearance of the device. The interior mechanical parts are shown in Fig. 4, top view of the device in Fig. 5, front view in Fig. 8 and observation of UV light during disinfection is shown in Fig. 9. Immediately after powering ON, users can see messages on Fig. 6 and Fig. 7. Figures from images labelled Fig. 10 to Fig. 21 show the messages displayed on LCD during the workflow of the device. Once the disinfection process has been completed, the buzzer blows, and the LCD displays "opening tray". When the tray is opened LCD displays "2 to close the tray" then the user has to collect the item and place his hand near IR 2 for the tray to close. When the tray is being closed, the LCD displays "closing tray, please wait". A final message "Thank you, CVR college" is displayed after one through of the disinfection process. To continue, the RESET button on the Arduino board is to be pressed.

V. Conclusions

In this paper, a physical disinfecting system is recommended to eradicate the spread of the devastating coronavirus from handheld devices. A completely touch-less contraption is designed successfully using economically available components. The Arduino mega 2560 is programmed using Arduino IDE software. Fortunately, it is working without any time lag. The LCD display provides comfortable interaction by displaying essential data without any uncertainties in time. As the device contains UV light which is extremely harmful to humans, the user must use the device with caution. The device is implemented with an idea to provide accessibility at any public place with an affordable cost of installation. It can be installed directly with a power supply and no peripheral devices are required. There is a large scope for the application of this device. The insistence on UV-C disinfecting gadgets has increased with the outbreak of coronavirus.

References

[1] WHO (WORLD HEALTH ORGANIZATION). (2020). Retrieved from COVID-19 transmission and protective measures
[2] ANDERSON, M. (2020). The ultraviolet offense: Germicidal UV lamps destroy vicious viruses. New tech might put them many more places without harming humans. IEEE Spectrum, 50-55.
[3] Berezow, A. (2020). COVID-19: UV LED Can Kill 99.9% Of Coronavirus In 30 Seconds. AMERICAN COUNCIL ON SCIENCE AND HEALTH.
[4] Christiane SilkeHeilingloh, Ulrich Wilhelm Aufderhorst, Leonie Schipper, Ulf Dittmer, Oliver Witzke, Dongliang Yang, Adalbert Krawczyk. (2020). Susceptibility of SARS-CoV-2 to UV irradiation. American Journal of Infection Control, 1273-1275
[5] UV Lights and Lamps: Ultraviolet-C Radiation, Disinfection, and Coronavirus. (2021, 01 02). Retrieved from U.S Food & Drug Administration: https://www.fda.gov/medical-devices/coronavirus-covid-19-and-medical-devices/uv-lights-and-lamps-ultraviolet-c-radiation-disinfection-and-coronavirus.
[6] COVID-19 Vaccines. (n.d.). Retrieved from WHO (WORLD HEALTH ORGANIZATION): https://www.who.int/emergencies/diseases/novel-coronavirus-2019/covid-19-vaccines.
[7] Derraik, J. &. (April, 2020). Rapid evidence summary on SARS-CoV-2 survivorship and disinfection, and a reusable PPE protocol using a double-hit process. ResearchGate.
[8] Understanding Genetics. (2011, March 30). Retrieved from The Tech Interactive: https://genetics.thetech.org/ask/ask402#:~:text=UV%20radiation%20in%20sunlight%20can.
[9] Coronavirus disease (COVID-19). (2020, OCT 12). Retrieved from WHO (WORLD HEALTH ORGANIZATION): https://www.who.int/news-room/q-a-detail/coronavirus-disease-covid-19.
[10] The History of Water Treatment. (n.d.). Retrieved from UV03 Ltd. The UV Disinfection Specialists: https://www.uvo3.co.uk/the-history-of-uv-disinfection-uvo3/#:~:text=The%20History%20of%20Water%20Treatment&text=UV%20light%20has%20long%20been,of%20water%20treatment%20and%20sterilisation.&text=The%20first%2C%20full%2Dscale%2C,disinfection%20was%20used%20.
[11] F. A. Juarez-Leon, A. G. Soriano-Sánchez, M. A. Rodríguez-Licea, & F. J. Perez-Pinal. (2020). Design and Implementation of a Germicidal UVC-LED Lamp, IEEE Access, 196951-196962.
[12] Log and Percent Reductions in Microbiology and Antimicrobial Testing. (n.d.). Retrieved from MICROCHEM Laboratory: https://microchemlab.com/information/log-and-percent-reductions-microbiology-and-antimicrobial-testing China, 2020, pp.1-4, doi: 10.1109/ICEPT50128.2020.9202924.
[13] Ultraviolet. (2021, May 5) In Wikipedia https://en.wikipedia.org/wiki/Ultraviolet.
[14] D.J. Weber, H. Kanamori, W.A. Rutala, 'No touch' technologies for environmental decontamination: focus on ultraviolet devices and hydrogen peroxide systems, Curr. Opin. Infect. Dis. 29 (4) (2016) 424–431.
[15] N. Mahida, N. Vaughan, T. Boswell, First UK evaluation of an automated ultraviolet-C room decontamination device (Tru-DTM), J. Hosp. Infect. 84 (4) (2013) 332–335.
[16] A. Beal, N. Mahida, K. Staniforth, N. Vaughan, M. Clarke, T. Boswell, First UK trial of Xenex PX-UV, an automated ultraviolet room decontamination device in a clinical haematology and bone marrow transplantation unit, J. Hospital Infect. 93 (2) (2016) 164–168.
[17] Y. Cao, W. Chen, M. Li, B. Xu, J. Fan and G. Zhang, "Simulation Based Design of Deep Ultraviolet LED Array Module Used in Virus Disinfection," 2020 21st International Conference on Electronic Packaging Technology (ICEPT).
[18] Reed N. G. (2010). The history of ultraviolet germicidal irradiation for air disinfection. Public health reports (Washington, D.C.: 1974), 125(1), 15–27. https://doi.org/10.1177/003335491012500105.