UVC Sanitizing Smart Kit

Marwa Tharwat
Department of Electrical and Computer Engineering
King Abdulaziz University
Jeddah, Saudi Arabia
mmzahran1@kau.edu.sa

Maram Alsofiani
Department of Electrical and Computer Engineering
King Abdulaziz University
Jeddah, Saudi Arabia
malsofiani0006@stu.kau.edu.sa

Sereen Bahdad
Department of Electrical and Computer Engineering
King Abdulaziz University
Jeddah, Saudi Arabia
SBAHDAD0001@stu.kau.edu.sa

Ghaida Alyousfi
Department of Electrical and Computer Engineering
King Abdulaziz University
Jeddah, Saudi Arabia
galyousfi0001@stu.kau.edu.sa

Heba Alebbie 1808555
Department of Electrical and Computer Engineering
King Abdulaziz University
Jeddah, Saudi Arabia
Halabi@stu.kau.edu.sa

2022 5th International Conference on Computing and Informatics (ICCI) | 978-1-6654-9973-6/22/$31.00 ©2022 IEEE | DOI: 10.1109/ICCI54321.2022.9756125

***Abstract*— During the Coronavirus pandemic, the world counted on conventional sanitizing products that involved unsafe toxic chemicals. Ultraviolet Germicidal Irradiation or ultraviolet disinfection is introduced in many sanitizing applications, as it splits the DNA/RNA, forcing microorganisms unable to spread. For that, ultraviolet disinfection technology is presented in this project to replace the old nonenvironmental practices. Far-ultraviolet type C is a small part of the ultraviolet spectrum, with wavelengths from 207 nm to 222 nm proven effective against micrograms. This project aims to apply far-ultraviolet technology to design an easily used, reliable, and optimized system to control and monitor the sanitizing operation. Moreover, this project design combines two different sanitizing modes intended to serve the need of a dental clinic's daily sanitizing technique. The first mode is intended to sanitize the dentist's tools connected to a monitoring system that shows the ultraviolet type C intensity and the received dosage. The second mode is for the surfaces and handlers in the clinic; the sanitizing handheld will be attached to a distance identification system that guides the user to apply the sanitizing operation at the proper distance. Furthermore, this project will determine the disinfection parameters (dosage, intensity, exposure time, wavelength, and distance) according to the used far-ultraviolet source and the prototype design.**

I. INTRODUCTION

The world is suffering from the COVID-19 pandemic along with other new viruses. This pandemic had affected humans' lives on many levels, mainly their health. However, with the rise of COVID-19, people relied on conventional sanitizing methods, especially medical clinics that require frequent disinfecting of touched surfaces and objects, including portable medical equipment which causes infection. Sanitizing surgical equipment is a routine practice in medical clinics, and it often involves the use of chemicals and high-pressure, high-temperature steam sanitizing techniques. Most of these sanitizing techniques require expensive, cumbersome machines and are unsuitable for sanitizing equipment that does not need a sterile field. In addition, introducing a chemical material into a device containing electrical components has the potential to damage the device's internal systems [1]. The use of chemical products has increased massively, in a way that affects human health by causing irritation of eyes and throat and developing severe headaches and cancer. Some products release toxic chemicals, including Volatile Organic Compounds (VOCs) and other hazardous materials [2-3]. Furthermore, some traditional antimicrobial agents and disinfectants increase antibiotic-resistant bacteria, a significant problem in the medical community [4].

Unlike traditional disinfection methods, ultraviolet (UVC) light disinfection is a physical method for killing bacteria, as the bacteria in question cannot build immunity to it [5]. In addition, UVC disinfection does not generate any toxic or hazardous materials [6]. Ultraviolet (UV) rays are a beam ofelectromagnetic radiation emitted by the sun or any other artificial source (arc welding torches, mercury vapor lamps, etc.) with a wavelength varying from 100 nm to 400 nm. Moreover, the UV rays can be classified as invisible short- wave light [7]. However, the most effective germicidal region of the UV light spectrum is UV type C which has a wavelength that ranges from 100 nm to 280 nm. Still, UVC radiation does not reach the earth's surface because the ozone layer blocks it in the atmosphere [8].

Moreover, UVC light is a robust UV purification as the spectrum 200-280 nm can damage the bacterial DNA by preventing it from breeding. This technique can be used to contain the disease and stop it from spreading [6]. Furthermore, Ultraviolet Germicidal Irradiation (UVGI) is a sanitizing approach that uses short-wavelength UVC light to eliminate microorganisms by destroying nucleic acids. One of the UVC radiation limitations is that it can only deactivate viruses through direct exposure because of its low penetration depth. Accordingly, the exposed area must be clean, as any blocking particles such as dust or fluids must beremoved to ensure the effectiveness of the sanitizing operation. Certain levels of UVC radiation can cause severe skin burns and eye damage if humans are directly exposed for extended periods. Skin cancer, cataracts, or a risk of permanent blindness is shallow because the penetration depth is minimal for the far-UVC [9].

II. RELATED WORK

Germicidal ultraviolet light is adequate in deactivating airborne viruses quickly; however, direct exposure can damage human skin and eyes. By contrast, many global studies have established the safe UVC light range known by far-UVC light (207-222 nm). Hence this range of UVC light does not cause any human health issues even under direct exposure to conventionalgermicidal UV light, as these rays cannot reach living humancells in the skin or eyes [10]. In contrast the small size of theviruses and bacteria made the far-UVC light a destroyable approach that can kill them.

Furthermore, an exploratory clinical trial on the safety and bactericidal effect of 222 nm UVC irradiation in healthy humans were conducted on 20 volunteers exposed to 22nm. The induced erythema was evaluated. Moreover, theresult of this trial indicates that the 222 nm UVC at 500 mJ/cm^2 is a safe irradiation dose and can be used in sanitizing [11]. The ability of UVC light to kill micrograms is already proven and tested on many viruses and germs. The studies have indicated the most important factor to ensure the disinfection results, which is the applied UVC intensity. The UV radiation intensity is the energy received on a given area that is measured in W/cm^2 or J/cm^2.

Furthermore, the University of Nevada, Reno, published a study that provides test result evidence of the effectiveness of UVC sanitizing on the HCoV-NL63 (Family of Alpha Coronavirus) sample. The human coronavirus HCoV-NL63 was exposed to UVC germicidal lamps to measure the efficiency of the UVC disinfection against COVID-19. After that, the HCoV-NL63 sample was exposed to a UVC light intensity of 2.9 mW/cm^2, and the results were analyzed by measuring the number of intact viral genomic. Finally, this study stated that UVC light exposure affects the virus resistance and can destroy it [12]. Another study was established to investigate the far-UVC range effectiveness against human coronavirus. The source of far-UVC was generated from an excimer lamp with wavelength 222 nm and intensity of 0.0009 mJ/cm^2. Furthermore, the results of this trial shown in Figure 12 display viral distribution from the single pulse of SARS- COV-2 at 10, 50, and 100 s before UVC exposer and after [13].

Fig. 1. *The Test Result in Viral Distribution on Two Samples with and without Far-UVC [13].*

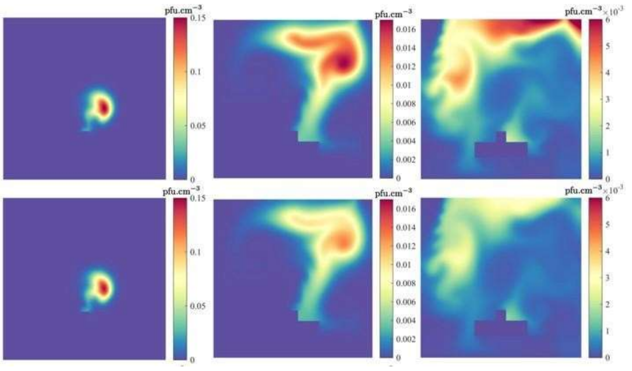


Figure 1 shows the test results of this study; sample B was exposed to far-UVC light while sample A was used for comparison. Accordingly, sample B showed the disinfection of the viruses. This study had stated that far-UVC can reduce the viability of human coronaviruses [44].

To sum up, the efficiency of a UVC sanitizing system can be verified by measuring the radiation intensity. However, the UVC radiation intensity of the UVC lamp is measured using the following techniques:

- UVC Card: it is a UVGI analysis card used to indicate essential factors in the UVGI disinfection process, including its intensity, accumulative dose, and optimal UVC wavelength. There are different types of test cards; each type can be used to test a specific parameter of the UVGI disinfection. However, the data collected by this approach is not accurate [14].

- UVC radiation intensity electrical sensors detect the intensity of the ultraviolet radiation that wavelength ranges from 100 nm to 400 nm and gives numerical results which can be used in data analysis.

This paper discusses the circuit schematic, input/output specification, block diagram, mathematical modeling, box design, health impact, social impact, and economic impact.

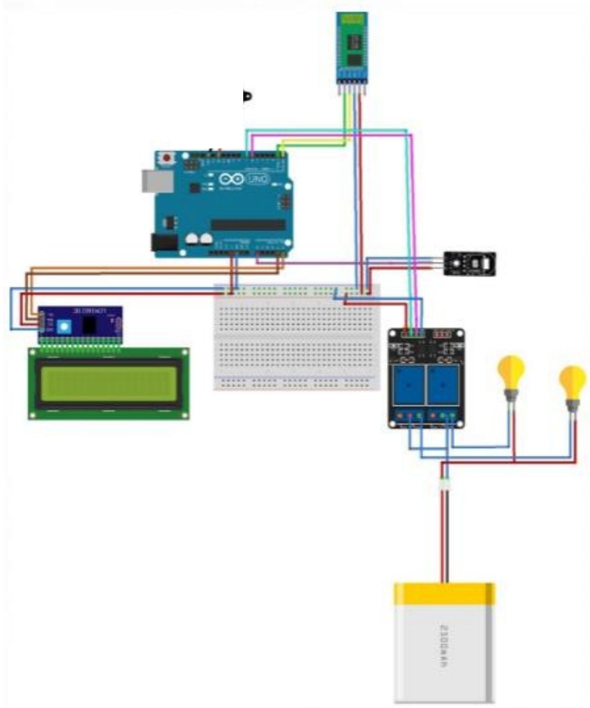
III. SYSTEM DESCRIPTION

The UVC smart sanitizing kit monitors and controls the disinfection of germs process by applying the far-UVC technology. Furthermore, the system consists of hardware and an application connected to the microcontroller chip via Bluetooth. The system contains a control panel that allows the user to set the sanitizing mode and control the process. However, UVC light intensity sensor is implemented to monitor the UVC source effectiveness.

A. *Circuit Schematic*

Any electrical circuit can be presented using a graphical representation that is called circuit schematic or circuit diagram. Figure 2 displays a pictorial circuit diagram that uses simple images of components and shows the external connections between the circuit components; however, this circuit diagram was implemented using Fritzing software.

Fig. 2. *UVC Smart Sanitizing Kit Circuit Schematic.*



In Figure 2, the essential component is the microcontroller chip (Arduino UNO), which connects the hardware components such as sensors with the software code to process and collect data. Furthermore, the system uses two far-UVC lamps associated with relays. Relays control high-voltage electronics such as lamps and protect the Arduino UNO, which cannot handle high voltage. Moreover, the two lamps are connected to the relay, which is attached directly to a 2500 mA battery and consists of four ports VCC, GND, input lamp 1, and input of lamp 2.

Moreover, the UVC light intensity sensor is connected to the microcontroller to monitor, read the sanitizing variable intensity, and export the data to an application in the database. The sensor reading is processed in the Arduino to calculate the applied dose; the sensor has three ports, VCC, GND, and the data connected to the Arduino analog as an input. Finally, an HC-05 Bluetooth module allows the Arduino UNO board to send wireless data to a smartphone application via Bluetooth, and it contains a VCC, GND, RX, and TX.

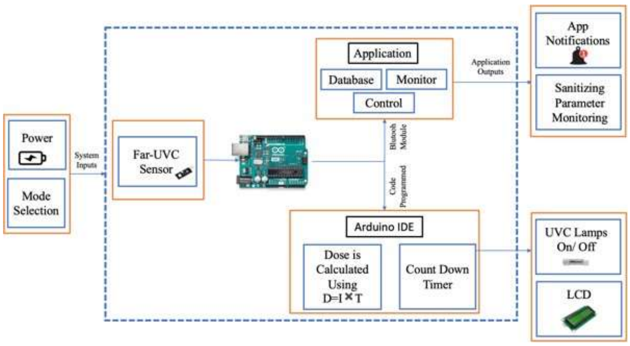
B. *Input/output specification*

UVC Sanitizing Smart Kit system has two inputs: the power supply and the mode selection. The system uses Arduino Uno to convert the system's input to the output using sensors to calculate and measure the project's parameters, then process these data and send it to the application via Bluetooth module. Moreover, the system hastwo outputs, one for the application and the other is for the box. The application output will be sending notifications, readings of the sensors, and monitoring the parameters to theuser. For the box, the outputs will be turning on/off the UVC-Lamp, the information of sanitizing process displayed on LCD, and the buzzer sound.

C. *Block Diagram*

The functional block diagram can be used to describe the functions and operations of a system. Moreover, the block diagram of the system displayed in Figure 3 is consisted of blocks inputs, outputs, and process with lines connecting them.

Fig. 3. System Block Diagram.



For the UVC Sanitizing Smart Kit's system, first, the power is supplied by rechargeable batteries as an input to the entire system. Furthermore, mode selection is an input set by the user, this feature allows the user to choose the sanitizing mode, and either object sanitizing or surface sanitizing. A microcontroller chip is used, which is the system's core that takes the inputs and converts them into outputs. However, the microcontroller chip is associated with the Far-UVC light intensity sensor.After that, the data is processed and sent to the applicationon a smartphone via a Bluetooth module. Moreover, the Arduino Uno is also used to count down the elapsed time of the system. The following bolt points explain the system significant main features:

- Far-UVC Lamps is used as a UVC light sourceirradiated can kill micrograms considered a system's output.
- Far-UVC Sensor is used to monitor the UVC light intensity, and the output reading of the sensor is connected to the microcontroller to calculate the applied UVC dose.
- Bluetooth Module: is used to connect the microcontroller to an application that enables sending the user selections, monitoring the system parameters, sending notification messages to the user, and saving the sanitizing operation data.

D. *Mathmatical Modeling*

To fully deactivate the targeted microbes, a correct UVC dose is critically determined by Equation (1) [11]:

$$\boldsymbol{D} = \boldsymbol{I} \times \boldsymbol{T} \quad (1)$$

Where:
D: UVC received dose ($mJ/cm2$)
I: Irradiance light (mW/cm^2)
T: Time (s)

UVC radiation functions best at short distances because it has a short wavelength and high energy compared to other UV radiation. UVC light is restricted by the inverse square law because the UVC radiation has high energy. The law states that increasing the distance from the light source, will decrease the propagation of light intensity radically [15].

The time for the decontamination processes is closely related to the distance from the UVC light to the surface in which it is intended to be sanitized.

All types of UVC light are proven to be effective in the decontamination processes, thus, the important matter to be considered regarding wavelength is safety. The conventional germicidal UVC type with 254 nm wavelength is known for its human health safety issues. However, the far-UVC, with wavelengths ranging from 207 nm to 222 nm, does notthreaten human health at all, as it is proven that it is not a cytotoxic to exposed human cells and tissues [16].

E. *Box Design*

This part will discuss the project's initial design, which was done using SolidWorks software to visuals the overall design. Figure 4 shows the main part of the project which is the box body. The second part is shown in the Figure 5, representing the handler part containing the UVC-Lamp and the project circuit. The assembly part illustrates the combined parts together as shown in Figure 6.

Fig. 4. Main Part (Box Body)

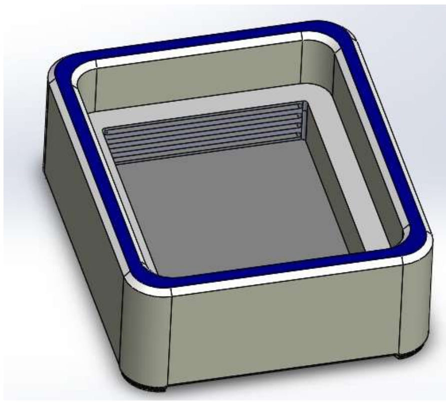


Fig. 5. Part 2 (Handler)

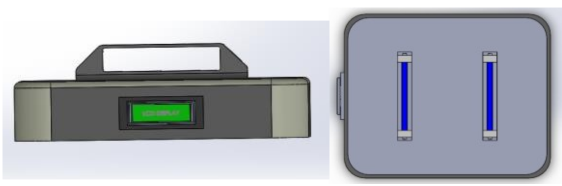
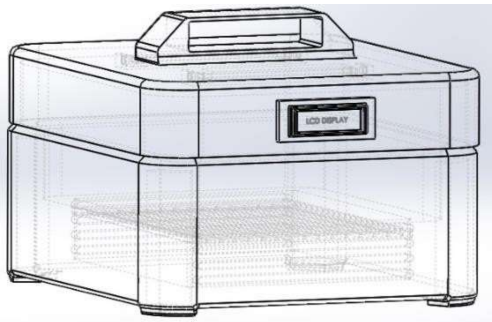


Fig. 6. Assembly Part for the Initial Design



IV. IMPACTS OF ENGINEERING SOLUTION

A. Health impact:

Accidental consumption, absorption through dermal contact, and suicidal ingestion are all possible causes of toxicity from frequent and increased hand sanitizer usage. The American Association of Poison Control Centers recorded 7593 incidents of children under 12 years old exposed to alcoholic hand sanitizer. According to prior research, excessive use of alcohol-based hand sanitizer leads to antimicrobial resistance, which can add to the difficulties already faced by healthcare providers. Whenmicroorganisms are repeatedly exposed to disinfectants, antibiotics, or other genotoxic compounds, they develop mutations that render them resistant to survival from repeated hand sanitizer usage. Furthermore, the far-UVCtechnique will reduce the exposure of alcohol-based techniques and the health issues that comes with it.

Moreover, inactivating viruses within a short time after their production is a direct way to minimize viral transmissions in the air. In this context, germicidal ultraviolet radiation, typically at 254nm, is helpful, but it can be harmful to the skin and eyes when used directly. On the other hand, Far- UVC light from 207nm to 222nm effectively kills pathogens without causing any harm to exposed human tissues [17].

B. Social impact:

The COVID-19 pandemic has resulted in a significant loss of human life worldwide, and it poses an unprecedented threat to public health, food systems, and the workplace. The pandemic has caused severe economic and social devastation. People recognized how important it is to sanitize the surrounding objects and surfaces regularly, especially hospitals environment. This UVC-sanitizing kit will help doctors in the dental clinics to sanitize efficientlyin a very short time and to sanitize objects and surfaces that cannot be sanitized using conventional methods.

C. Economic impact:

Environmental cleaning is an essential element of an infection-control program. Pathogens responsible for HAIs survive on surfaces for many months; due to that, dental clinics need to use sterilizers regularly and in largequantities. These sterilizers lead to an increase in the overall cost of sterilization in the long term. The UVC-sanitizing kitwill help reduce this cost because it has a longer life span and can cover more various objects and surfaces than the sanitizer.

V. CONCLUSION

The COVID-19 Pandemic has put significant strain on the worldwide healthcare system. Chemical sanitizers can cause hazardous health problems on the skin, eyes, and throat. This risk factor may eventually cause rashes, dry skin, streaming eyes, and a cough. People relied on chemical sanitizing agents during the COVID-19 pandemic, particularly in hospitals and healthcare clinics. Chemical cleaning products are one of the most common causes of eye and throat irritation. Furthermore, they may contribute to headaches and breast cancer in persons who use these items regularly, such as hospital cleaners. One sanitizing smart kit will speed and improve the sanitizing process through sanitizing different types of objects which cannot be sanitized using conventional methods and combining both object and surface sanitizing using safe and efficient far-UVC.

REFERENCES

[1] J. Roberts, "Flexible ultraviolet LED sanitizing apparatus", U.S. Patent 8 662 705, Mar. 03, 2010.

[2] W. Kanchongkittiphon, M. J. Mendell, J. M. Gaffin, G. Wang, and W. Phipatanakul, (2015, Jan). "Indoor Environmental Exposures and Exacerbation of Asthma: An Update to the 2000 Review by the Institute of Medicine." Environmental Health Perspectives. [On-line]. 123(1), pp. 6-20. Available: https://ehp.niehs.nih.gov/doi/full/10.1289/ehp.1307922 [Sep. 15, 2021].

[3] T. Schettler. "Cleaners and Disinfectants, Health Care without Harm." Internet: https://noharm-uscanada.org/issues/us- canada/cleaners-and-disinfectants, Apr. 28, 2013 [Sep. 10, 2021].

[4] Guridi et al., (2019, Nov). "Disinfectant Activity of a Portable Ultraviolet C Equipment." International Journal of Environmental Research and Public Health. [On-line]. 16(1), pp.1-6. Available: https://www.mdpi.com/1660-4601/16/23/4747/htm [Sep. 15, 2021].

[5] V. Defense et al., "Violet Defense Technology." Internet: https://www.violetdefense.com/blog/2017/8/31/6-benefits-of-using-uv-light-for-disinfection, Sep. 07, 2017 [Sep. 10, 2021].

[6] T. Wyant et al., "Ultraviolet (UV) Radiation." Internet: https://www.cancer.org/cancer/cancer-causes/radiation-exposure/uv-radiation.html, Jul. 10, 2019 [Sep. 12, 2021].

[7] T. Mathebula, F. W. Leuschner, and S. P. Chowdhury, "The Use of UVC-LEDs for the Disinfection of Mycobacterium Tuberculosis." Internet: https://ieeexplore.ieee.org/abstract/document/8521172, Jun. 01, 2018 [Sep. 13, 2021].

[8] A. Georgakilas, A. A. Konsta, E. G. Sideris, and L. Sakelliou, (2001, Jun). "Dielectric and UV spectrophotometric study of physicochemical effects of ionizing radiation on mammalian macromolecular DNA," IEEE Transactions on Dielectrics and Electrical Insulation. [On-line]. 8(3), pp. 549–554. Available: https://ieeexplore.ieee.org/abstract/document/933382 [Sep. 20, 2021].

[9] U.S. Food and Drug Administration, "Ultraviolet (UV) Radiation." Internet: https://www.fda.gov/radiation-emitting-products/tanning/ultraviolet-uv-radiation, Oct. 19, 2020 [Sep. 21, 2021].

[10] M. Buonanno, D. Welch, I. Shuryak, and D. J. Brenner, (2020, Jun). "Far-UVC light (222 nm) efficiently and safely inactivates airborne human coronaviruses," Scientific Reports. [On-line]. 10(1), pp. 1–8. Available: https://www.nature.com/atricles/ s41598- 020- 67211-2?pm-nl-16012020 [Sep. 23, 2021].

[11] "UVC LEDs for Disinfection." Internet: https://www.klaran.com/images/kb/application-notes/UVC-LEDsfor-Disinfection---Application-Note---AN002.pdf [Oct. 4, 2021].

[12] S. Khaiboullina, T. Uppal, N. Dhabarde, V. R. Subramanian, and S. C. Verma. (2020, Dec). "Inactivation of Human Coronavirus by Titania Nanoparticle Coatings and UVC Radiation: Throwing Light on SARS-CoV-2," Viruses. [Online]. Vol. (13), no. 1, p. 19. Available: https://www.mdpi.com/1999-4915/13/1/19 [Sep. 01, 2021]

[13] A. G. Buchan, L. Yang, and K. D. Atkinson. [2020, Nov]. "Predicting airborne coronavirus inactivation by far-UVC in populated rooms using a high-fidelity coupled radiation-CFD model," Scientific Reports. [Online]. vol. (10), PP. 1-7. Available: https://www.nature.com/articles/s41598-020-76597-y.pdf [Sep. 08, 2021].

[14] admin, "What is the difference between UVC Dosimeter Test Cards vs UVC Intensity Test Cards vs UVC Indicator Test Cards," Internet: https://www.quantadose.com/what-is-the-difference-between-uvc-dosimeter-test-cards-vs-uvc-intensity-test-cards-vs-uvc-indicator-test-cards/ , Aug. 21, 2020, [Sep. 13, 2021].

[15] M. Lindblad, E. Tano, C. Lindahl, and F. Huss. (2020, Jun.). "Ultraviolet-C decontamination of a hospital room: Amount of UV

light needed." Burns. [On-line]. 46(4), pp. 842–849. Available: https://reader.elsevier.com/reader/sd/pii/S0305417919300920?token=0EEFDF76705CD58580205BCA3D5E8AB09535D8783E6EC6A4C F646E8623D5D2131AD0458B38657ED21BC93A402689CE8E&originRe gion=eu-west-1&originCreation=20211007210442

[16] J. Molinet. (2021, Jan.). "U 97.7% of Hospital Pathogens Eliminated by UV Light Disinfection."[Online]. Available: https://www.technologynetworks.com/appliedsciences/news/977-of- hospital-pathogens-eliminated-by-uv-lightdisinfection-314199 [Accessed: 11- Sep- 2021].

[17] A. Mahmood et al., "COVID-19 and frequent use of hand sanitizers; human health and environmental hazards by exposure pathways," Science of The Total Environment, vol. 742, p. 140561, Nov. 2020, doi: 10.1016/j.scitotenv.2020.14056