Pakistan Journal of Engineering and Technology, PakJET
Multidisciplinary & Peer Reviewed
Volume: 04, Number: 01, Pages: 159- 162, Year: 2021

Androidbased UV-C Disinfecting Mobile Unit

Sana Hassan*, Abdul Hannan, Shazray Khan and Syed Abbas

Institute of Quality and Technology and Management, University of the Punjab, Lahore, 54000, Pakistan

*Corresponding author: Sana Hassan (sana.iqtm@pu.edu.pk)

***Abstract*-With the development in advance automation, the use of service robots is increasingly becoming popular in every field of life. A simple and cost-effective mobile unit for surface disinfection using ultraviolet C radiation (UV-C) is presented in this study. Contaminated surfaces are one of the main reasons of disease transmission, through the spread of the pathogen. Ultraviolet-C radiation mobile unit is designed to disinfect and sterilize such areas. The physical disinfecting unit developed has four 30W UV-C lamps mounted on a mobile frame. A solar panel is used to charge the battery in the robot's circuit, which power up Arduino kit, sensors, and lamps. The prototype can work as a line following unit as well as steered by an android system via Bluetooth module. The system can generate a dose of 9.6mWsec/cm^2 in 14sec, which could disinfect 120 ft^2 rooms in 288sec (4.8min).**

***Keywords*—Advance automation, Arduino, UV (Ultraviolet)-C light, Disinfection, Mobile unit**

I. INTRODUCTION

Contaminated surfaces with viruses, bacteria and fungi are main sources of disease transmission. Well-developed physical and chemical disinfectant techniques have been widely used to kill or inactivate pathogenic microorganism in the environment[1]. Commonly harsh chemicals and bleaching agents are used for decontamination; but the efficacy of manual cleaning by mopping and spraying depends on labor skill, cleaning time and frequency. Often inaccessible areas and high touch surfaces become the hotspots for super bug growth and spread[2].Ultraviolet light is one of the novel technologies which could provide solution for periodic sanitization problem. UV light has germicidal effects that were discovered in 1903 by Niels Finsen[3]. Since the 1930s, UV light has been used in hospitals for air and water treatment. According to the World Health Organization Global Solar UV index, UV light is divided into three classes UVA (315-400nm), UVB (280-315nm) and UVC (200-280nm)[4]. Both UVA and UVB are present in sunlight and their long exposure is considered dangerous for humans. However, they both have the limited germ-killing ability. On contrary to this, irradiation with ultra violet C wavelength (200-280nm) effectively inactivates a wide spectrum of microbial pathogens[5]. UVC induces changes in deoxyribonucleic acid (DNA) or ribonucleic acid (RNA) of microbes that results in their inability to replicate [6].

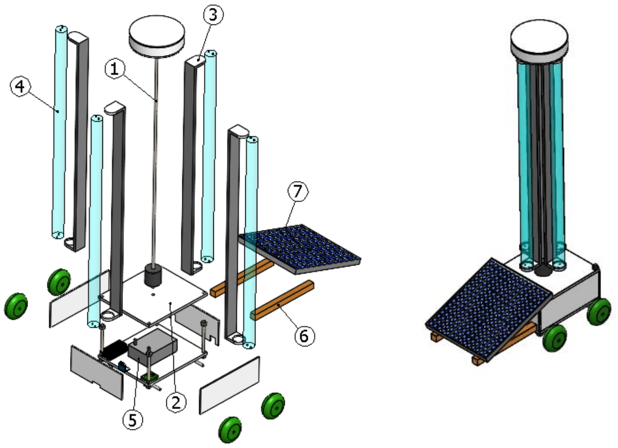
Since the past few years, improvement in advance automation has led to the development of service robots and their applications in the medical field are increasing immensely. In developed countries, many modern health care facilities are equipped with ultraviolet disinfecting robots. Hospitals finds them very attractive compared to traditional cleaning because: a) UVC has germicidal activity against broad-spectrum organisms, b) it has shorter inactivation time for gram positive and negative bacteria, c) UVC robots are safe and eco-friendly without hazardous residual, e) they offer saving on labor and consumables cost, f) equipment are relatively simple to set up and operate in different facilities[7]. There are more than 30 companies throughout the world which are making UVC robots[8]. Undoubtedly these commercial systems are not only smart in operational technology, but their germ-killing ability is also phenomenal. Some of the famous UVC systems are provided by Xenex, Dimer, Omron, UVD by blue ocean robotics and IRIS3200m by infection prevention technologies have proprietary technology and are very costly[9]. Many studies have reported the supremacy of the above-mentioned germ-killing devices in comparison to manual cleaning[10–14]. It has been claimed that UVC systems have eliminated 99% of bacteria, fungi and viruses like Clostridioides difficile, Escherichia coli O157, salmonella enterica serovar typhimurium, Listeria monocytogenes, Staphylococcus aureus, Aspergillus flavus, Alternaria japonica, MHV-A59, MERS-CoV, and SARS-CoV[15–19].

But, in developing countries due to limited resources and technical facilities, the use of ethanol, alcohols, and biguanides like chlorhexidine are common to prevent infections. They are not only harsh on the workers who use them, but also a threat for ecology. Recently, after the emergence of the new Corona Virus, the need for surface decontamination has increased[20]. These days' sanitary measures are enforced everywhere to reduce the spread of the virus. Now not only the medical facilities but commercial areas like malls, airports, banks, restaurants and educational institutes need effective and frequent cleaning to make sure the safety of the consumer[21]. To avoid human exposure, robots are recommended for frequent cleaning[22].This has led a need to explore simple and cost-effective disinfecting systems which could assist workers in periodic sanitizing and are free from harsh chemicals. With the availability of UVC light-generating lamps and LEDs in the market at a reasonable cost, it is possible to develop low-cost open-source systems. At the local level, such devices can be scaled up according to consumer requirements and used as a service robot for periodic contactless surface disinfecting. Many researchers have explored the efficacy of UVC mobile disinfecting units by developing small units[23–26].

The aim of the present work is to develop a cost-efficient ultraviolet C radiation prototype utilizing locally available components, to contribute to chemical free disinfection. The article is arranged as follow: section 2 presents the design details of the mobile unit, while section 3 gives the numerical calculation to find UVC dose and irradiating time; finally, section 4 outlines the concluding remarks.

II. UV MOBILE FRAME DESIGNING

Construction of the device involved three stages: 1) structural building, 2) electronic assembling and 3) programming of the micro controller and the mobile application. Four UV-C lamps were connected in a circular pattern on a fixed column. The central fixed column was placed on a mobile frame, and in its lower end a box was attached to house the control unit. Solar panel was supported by a wooden frame. A schematic view of the assembled model is shown in Fig.1.



a b

Figure 1: Schematic view of the UV-C disinfecting mobile unit. a) Assembling guide, (b) Isometric view

a) Assembling guide. A lightweight steel column (1) was fixed using mechanical fasteners. (2). In the lower part of this base, four rotating wheels were placed (3). Four lamp holders were attached around the central column using ties. (4). Four 30W T8 GL UV-C lights were attached in the holder. (5) Control unit was installed in an acrylic box at the bottom. (6) A wooden frame was attached at the bottom to support the (7) Solar panel. (b) Isometric view of the device.

The essential electronic components of the developed unit are: 1) a mobile platform 2) four 30W UV lamps mounted in a circular configuration 3) Arduino UNO 4) a 12V battery 5) 10V solar panel 6) UV detection sensor 7)PIR sensor and 8) ultrasonic sensor. The height of the unit is 4ft.with an approximate weight of 3kg, as shown in Fig. 2.
The full bill of material is shown in Table 1. Construction of the whole system was below $200 (approx.PKR 27000), which is a supportive signal for the local production of such units. Clinical trials of the prototype are also under process at department of microbiology and molecular genetics.

The 12V battery is charged by a solar panel which powers up controller. Arduino is the main controller; this gives order to switch on the Bluetooth module, UV lamps and drives the frame. The frame can be steered via an android system from more than 20 ft using Bluetooth module. To safeguard the device from obstacles two ultrasonic sensors have been installed. A PIR sensor was also added as a security measure to turn off the lamps when a user is near.

Figure 2: UVC surface disinfecting device

Table 1: Full bill of materials used to make the ultraviolet C radiation device.

Sr. #	Item Name	Quantity	Per Unit Cost (PKR)
1	Arduino board	1	650
2	UVM 30A sensor	1	2400
3	Ultrasonic sensor	2	200
4	PIR sensor	1	200
5	12V (7A) battery	1	2100
6	Phillips UVC lamps TUV T8 (3 ft)	4	2500
7	Gear motor	2	1200
8	180W Inverter	1	450
9	Electronic accessories set	1	3000
10	Bluetooth module HC05	1	800
11	Transparent sheet plates	2	900
12	Single channel relay module 5V	1	180
13	Mechanical fasteners set	1	150
14	Wheels	4	150
15	L298 Motor driver	1	250
16	Solar panel	1	1500
17	Jumper wire set	1	500
Total cost			27000

The electrical diagram of the connections is shown in Fig.3. A mobile application was developed to steer the mobile frame. This app was designed using the MIT app inventor 2 tool. The interface of this application is used to control disinfecting mobile frame and make connection to the device via Bluetooth.

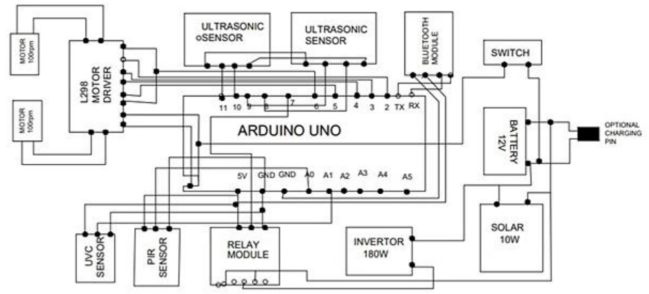


Figure 3: Circuit diagram

III. UV-C EXPOSURE DOSE AND IRRADIATION TIME CALCULATIONS

The developed disinfecting system utilized four UVC lamps mounted in a circular pattern. Each lamp has a 30watt output as per manufacturer's specifications. The dose received by surface unity at a given distance from the robot depends upon the power P(μW) and irradiation time t(sec) of the lamps used according to the following equation[27]:

$$D = \frac{Pt}{2\pi\, Lr} \qquad (1)$$

Where L is lamp length (91cm) and r (76cm) is the distance from the source.

$$D = \frac{30e^{7} X\ 14}{2\ X\ 3.1416\ X\ 91\ X\ 76}$$

$$= 9.670\ mWsec/cm^{2}$$

The energy per area in a given time is the brightness ($\mu W/cm^{2}$). The brightness produced by the lamp at a distance of 76cm (2.5ft) can be calculated below as[24]:

$$Brightness = \frac{Luminosity}{4\pi\ X\ Distance^{2}} \qquad (2)$$

$$= \frac{30\ X\ 4}{4\ X\ 3.1416\ X\ 76^{2}}$$

$$= 1.645\ \mathrm{mW/cm^{2}}$$

The UVC dose required for sterilization of 90% virus and bacteria range from 2000 to 12000μW/cm^2[2-12 mW/cm^2] so using a value of 10.6mWsec/cm^{2}the irradiation time can be expressed as:

$$Time = \frac{\mathrm{UV\ dose\ (mW.\frac{sec}{cm^{2}})}}{\mathrm{Brightness\ (mW/cm^{2})}} \qquad (3)$$

$$= \frac{10.6}{1.645}$$

= 6.44 sec

In this study, the developed solar-powered UVC mobile unit can produce a dose of 9.670mJ/cm^2 at a distance of 2.5ft in 14sec. According to the calculated brightness of 1.645mW/cm^2, this system can disinfect the surface at 2.5 ft^2 from pathogens in 6 sec. Hence, the mobile unit can disinfect a 120 ft^2 room in 288 sec (4.8min) without any hindrance; otherwise, the time will elapse. Android-based motion control can be used to keep time within the given range.

IV. CONCLUSION

In this paper, the design and development of an android based mobile disinfecting unit is presented. The developed prototype could disinfect surfaces in a reasonable time without human intervention. With four lamps of 30W power, this system could disinfect a 120 ft^2 room in just 4.8min without the use of harmful chemicals and bleaching agents. The system can produce a dose of 9.670mWsec/cm^2 at a distance of 2.5ft within 14sec. This value is approximately near to 10.5mWsec/cm^2 as per intensity of 0.75mW/cm^2 in a second, measured by UVM 30A sensor. The mobile unit is equipped with a PIR sensor to safeguard the intruders from UV. The robot can be easily steered from a safe distance via the Bluetooth module.

The presented design can be easily scaled up, by structure modification (adding more UVC lamps), programming improvements (editing the open-source code of the Arduino board) and addition of more safety features according to consumer requirements, budget, and viral load. Such open-source disinfecting devices could offer significant savings in comparison to similar proprietary commercial equipment.

ACKNOWLEDGMENT

The authors acknowledge to Institute of Quality and Technology Management for providing the financial support.

REFERENCES

[1] J. M. Boyce, "Modern technologies for improving cleaning and disinfection of environmental surfaces in hospitals," *Antimicrob. Resist. Infect. Control*, vol. 5, no. 1, p. 10, Apr. 2016, doi: 10.1186/s13756-016-0111-x.

[2] A. Guridi, E. Sevillano, I. de la Fuente, E. Mateo, E. Eraso, and G. Quindós, "Disinfectant activity of a portable ultraviolet C equipment," *Int. J. Environ. Res. Public. Health*, vol. 16, no. 23, p. 4747, 2019.

[3] "The Nobel Prize in Physiology or Medicine 1903," *NobelPrize.org*. https://www.nobelprize.org/prizes/medicine/1903/summary/ (accessed Mar. 19, 2021).

[4] W. Bahnfleth, B. Levin, and O. Sylvania, "IUVA Draft Guideline IUVA-G02A-2005 International Ultraviolet Association," 2005.

[5] K. Narita *et al.*, "Ultraviolet C light with wavelength of 222 nm inactivates a wide spectrum of microbial pathogens," *J. Hosp. Infect.*, vol. 105, no. 3, pp. 459–467, 2020.

[6] M. Lindblad, E. Tano, C. Lindahl, and F. Huss, "Ultraviolet-C decontamination of a hospital room: Amount of UV light needed," *Burns*, vol. 46, no. 4, pp. 842–849, 2020.

[7] J.-H. Yang, U.-I. Wu, H.-M. Tai, and W.-H. Sheng, "Effectiveness of an ultraviolet-C disinfection system for reduction of healthcare-associated pathogens," *J. Microbiol. Immunol. Infect.*, vol. 52, no. 3, pp. 487–493, 2019.

[8] D. Mackenzie, "Ultraviolet Light Fights New Virus," *Eng. Beijing China*, 2020.

[9] E. Ackerman, "Autonomous robots are helping kill coronavirus in hospitals," *IEEE Spectr.*, vol. 11, 2020.

[10] B. Casini *et al.*, “Evaluation of an ultraviolet C (UVC) light-emitting device for disinfection of high touch surfaces in hospital critical areas,” *Int. J. Environ. Res. Public. Health*, vol. 16, no. 19, p. 3572, 2019.

[11] M. Diab-El Schahawi *et al.*, “Ultraviolet disinfection robots to improve hospital cleaning: Real promise or just a gimmick?,” *Antimicrob. Resist. Infect. Control*, vol. 10, no. 1, pp. 1–3, 2021.

[12] J. E. Villacís *et al.*, “Efficacy of pulsed-xenon ultraviolet light for disinfection of high-touch surfaces in an Ecuadorian hospital,” *BMC Infect. Dis.*, vol. 19, no. 1, pp. 1–6, 2019.

[13] D. J. Anderson *et al.*, “Implementation lessons learned from the benefits of enhanced terminal room (BETR) disinfection study: process and perceptions of enhanced disinfection with ultraviolet disinfection devices,” *Infect. Control Hosp. Epidemiol.*, vol. 39, no. 2, p. 157, 2018.

[14] A. E. Martínez de Alba, M. B. Rubio, M. E. Morán-Diez, C. Bernabéu, R. Hermosa, and E. Monte, “Microbiological Evaluation of the Disinfecting Potential of UV-C and UV-C Plus Ozone Generating Robots,” *Microorganisms*, vol. 9, no. 1, p. 172, 2021.

[15] P. Sampathkumar *et al.*, “A trial of pulsed xenon ultraviolet disinfection to reduce Clostridioides difficile infection,” *Am. J. Infect. Control*, vol. 47, no. 4, pp. 406–408, 2019.

[16] K. Bedell, A. H. Buchaklian, and S. Perlman, “Efficacy of an automated multiple emitter whole-room ultraviolet-C disinfection system against coronaviruses MHV and MERS-CoV,” *Infect. Control Hosp. Epidemiol.*, vol. 37, no. 5, pp. 598–599, 2016.

[17] J. L. Cadnum, D. F. Li, S. N. Redmond, A. R. John, B. Pearlmutter, and C. J. Donskey, “Effectiveness of ultraviolet-C light and a high-level disinfection cabinet for decontamination of N95 respirators,” *Pathog. Immun.*, vol. 5, no. 1, p. 52, 2020.

[18] D.-K. Kim and D.-H. Kang, “UVC LED irradiation effectively inactivates aerosolized viruses, bacteria, and fungi in a chamber-type air disinfection system,” *Appl. Environ. Microbiol.*, vol. 84, no. 17, 2018.

[19] P. O. Nyangaresi, Y. Qin, G. Chen, B. Zhang, Y. Lu, and L. Shen, “Comparison of the performance of pulsed and continuous UVC-LED irradiation in the inactivation of bacteria,” *Water Res.*, vol. 157, pp. 218–227, 2019.

[20] “Coronavirus disease (COVID-19) – World Health Organization.” https://www.who.int/emergencies/diseases/novel-coronavirus-2019 (accessed Mar. 19, 2021).

[21] Z. Zeng, P.-J. Chen, and A. A. Lew, “From high-touch to high-tech: COVID-19 drives robotics adoption,” *Tour. Geogr.*, vol. 22, no. 3, pp. 724–734, 2020.

[22] X. V. Wang and L. Wang, “A literature survey of the robotic technologies during the COVID-19 pandemic,” *J. Manuf. Syst.*, 2021.

[23] M. Bentancor and S. Vidal, “Programmable and low-cost ultraviolet room disinfection device,” *HardwareX*, vol. 4, p. e00046, 2018.

[24] P. Chanprakon, T. Sae-Oung, T. Treebupachatsakul, P. Hannanta-Anan, and W. Piyawattanametha, “An ultra-violet sterilization robot for disinfection,” in *2019 5th International Conference on Engineering, Applied Sciences and Technology (ICEAST)*, 2019, pp. 1–4.

[25] M. Guettari, I. Gharbi, and S. Hamza, “UVC disinfection robot,” *Environ. Sci. Pollut. Res.*, pp. 1–6, 2020.

[26] A. Vyshnavi, A. Manasa, C. Hamsika, S. Sai, and P. Shalini, “UV Disinfection Robot with Automatic Switching on Human Detection,” *EAI Endorsed Trans. Internet Things*, vol. 6, no. 23, 2020.

[27] M. U. Owens, D. R. Deal, M. O. Shoemaker, G. B. Knudson, J. E. Meszaros, and J. L. Deal, “High-dose ultraviolet C light inactivates spores of Bacillus atrophaeus and Bacillus anthracis sterne on nonreflective surfaces,” *Appl. Biosaf.*, vol. 10, no. 4, pp. 240–247, 2005.