EasyChair Preprint

№ 9196

Studying the Effect of a Disinfection Robot Using UVC Lights, on Fungi and Microbes in the Hospital Environment

Mojtaba Sedaghat, Pedram Madani, Yazdan Alvari and Ali Jahangiri

EasyChair preprints are intended for rapid dissemination of research results and are integrated with the rest of EasyChair.

October 31, 2022

Studying the effect of a disinfection robot using UVC lights, on fungi and microbes in the hospital environment

1st M.Sedaghat
Faculty of Mechanical and Energy Engineering,
Shahid Beheshti University,
Tehran, Iran
mo.sedaghat@mail.sbu.ac.ir

2nd P. Madani
School of Mechanical Engineering,
Iran University of Science and Technology
Tehran, Iran
teralistat@yahoo.com

3rd Y. Alvari
Faculty of Mechanical and Energy Engineering,
Shahid Beheshti University,
Tehran, Iran
Yazdan.alvari.a@gmail.com

4th* A. Jahangiri
Faculty of Mechanical and Energy Engineering,
Shahid Beheshti University,
Tehran, Iran
a_Jahangiri@sbu.ac.ir

Abstract-

The high prevalence rate of covid-19 is the most prominent feature making this deadly virus known in the world. One of the efficient ways to bridle this spread is disinfecting furniture in public places. Since there are demerits in utilizing chemical sanitizers, like imperfect disinfection processes, developed countries have turned to use modern cleaning methods. In this paper, the design, manufacturing, and experimental test of a UVC[1] multipurpose robot are presented. Containing 8 UVC lights, the portable system is capable of disinfecting a whole sphere around its working area. Consider the Ozone gas produced by the lights, this robot can sanitize covered places that UVC rays cannot reach. As UVC rays are dangerous, this system is remotely controllable in a range of two km. An atmega128 microcontroller is utilized to navigate the robot and send the operator's commands to the system. Corona group viruses like SARS and Ebola besides E. coli bacteria have been studied during an experiment. 39 sample points of a surgery room in a hospital were disinfected by three types of mentioned microbes. Cultivating the microorganisms before and after a 20 minutes UVC disinfection process, almost 80% of the microbes were deactivated.

Keywords- Robot, Disinfection, Covid-19, UVC, Ozone, Corona, fungi, E. coli, Hospital microbes

I. INTRODUCTION

The first known infections from Covid19 were discovered in Wuhan, China in December 2019. About 200 million Infections in the worldwide population are the result of this Epidemic. More than 210 countries are involved in this problem [1]. To prevent the spread of this virus, developed countries are utilizing UVC radiation and ozone gas as alternative methods of disinfection. Due to variant virus lifetime in different conditions, like humidity, temperature, the material of the surface, and biological features [2], it is arduous to cope with it. Worldwide countries have suggested Quarantine [3], vaccination [4], and using Smart disinfection devices in public sites [5] to handle corona pandemic. The necessity of Utilizing a variety of disinfection methods in medical centers, public crowded places, and public transportation systems, is the priority [6]. Unfortunately, in developing countries, using Disinfectants is still the most common method to clear the area infected with the covid virus [7].

Based on radiology science, ultraviolet radiations with 200 to 290 nm wavelength, can deactivate some viruses and bacteria. Manufacturing disinfection devices for air, water and surfaces is a consequence of recent researches on microorganisms [8]. Therefore, the substitution of new disinfection methods, helped the asepsis process be done without chemical material. It made this process possible while it must have been performed in special conditions like high temperatures. Today, UVC radiation as a cleaning procedure is effective while it is utilized as a supplementary method besides other disinfection ways [9]. Casini et al [10], studied the rate of disinfection due to the intensity of UVC radiation on surfaces in the hospital. They observed considerable positions (345 cases). Comparing the effect of UVC lights on the infected area before and after the disinfection process, they realized that only 18% of the cases were active after the process. The lights they used had 254 nm wavelength. The result of cleaning the hospital rooms with old methods was 63% active cases after the process.

[1] Ultra violet C

Fleming et al [11], investigated the effect of using UVC lights in public places. The experiment took 25 months to increase the absorption of radiation from 20% to 100% which affected decreasing C difficile in the area. Alba et al [12], compared UVC lights with ozone gas and without it. The study's aim was their effect on the disinfection amount. They had two sample units; a UVC robot with 256 nm wavelength without ozone and another UVC robot with 185 nm wavelength producing ozone gas. Studying their effect on bacteria, they figured out sufficient radiation intensity. The adequate intensity of ozone-based lights was 3.62 mJ/cm2 and 2.28 mJ/cm2 for the other robot to disinfect the air and surfaces. Ruan, Wu and Xu, [13], designed and manufactured a UVC robot to disinfect corona contamination. Cultivation of microbes before and after the robot operation verified the UVC disinfection action. 84% of the air bacteria were eliminated using the device.

Schaffzin et al [14], studied using UV robots in sanitizing isolated sites in Hospitals. Their target areas were waiting rooms and isolated environments. The experiment was done in 6 months. The consequences of this test were 86% disinfection in the waiting room and 88% disinfection in an isolated area.

The increasing mortality due to the prevalence of Covid disease was the main importance of constructing a disinfectant system. The novelty of this paper is based on reducing disinfection time, supreme technology, and economical system. In detail, energy consumption was optimized and the remote controller range increased. In this paper, Designing and manufacturing of this UVC robot are presented. The UVC system is experimented within hospitals to verify its disinfectant effect on air and surfaces. The purpose of the article is a Feasibility study of the ability of remote disinfection robots to deal with a variety of diseases, including corona in public places.

II. DESINGING AND MANUFACTURING EXPERIMENTAL DEVICE

The experimental tests were done using a distinction UVC robot with the features presented in Table 1.

TABLE 1. Geometric dimensions of Equipment

Parameter	Description
Robot length (L)	110 cm
Robot width (W)	70 cm
Robot height (H)	180 cm
Lights	UVC, 254 nm, 36-watt
Number of lights	8
Weight	40 kg
Wheels	number of Wheels =4, diameter =12cm
Operational temperature	0-50 ^{o}c

Based on Table 1, the robot contains 8 UV lights with a power of 36 watts and a wavelength of 254 nm. There is a camera installed on top of the robot to navigate manually the system. The components of the designed system are illustrated in Fig 1.

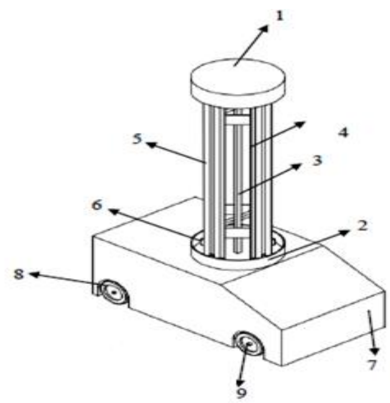


Fig. 1. The designed UVC robot components:

(1) Camera mount, (2) connector of the main body and lights, (3) iron foundation, (4) lights reflectors, (5) UVC lights, (6) lights circuit, (7) Main body, (8) Wheels, (9) shafts

According to Fig 1, the main components of the system are shown. The body of robot (part 7) and lamp foundation (part 3) made of iron, 4 coupled lamp with bright reflector (part 4) inserted in every 90 degree, on the top part of robot a camera (part 1) installed to observe the spaces. (part 2) manufactured to connect the body and lights, furthermore keep lamps safe. Designing the structure of the robot is based on the optimal operation while it is radiating UVC waves in the infected area. The manufactured robot shown in Fig 1, is controlled remotely. The controller has 4 main functions; turning on/off the system, moving the robot rotational and transitional, activating the UVC lights (part 6), and the command to turn the camera on or off. The robot has eight UVC lights fixed on the amount in the middle of the system. It supports a full spherical area around the system. It can be guided using an online camera synced to a programmed application. The operating current of the moving actuators is up to 30A.

The main electronic circuit has three units; processor, camera and light controller, and moving controller unit. The main processor of this system is a microcontroller called atmega128. Analog pins are used to receive remote controller signals. Battery charge is measured by other analog pins. The liquid crystal display on the body shows these measures. The received data from the remote controller is processed in the microcontroller which determines the velocity and direction of the system. The main circuit detail parts are ordered in Table 2.

TABLE 2. Electronic components of the main circuit

electronic main units	Unit details
Power supply unit	48 v battery
	12 v battery
	Volt divider 48:4 and 12:4
	DC2AC inverter 700watt
Processor unit	atmega128 microcontroller
	Six channel radio receivers
Controller unit	VNH5019 dc motor driver (rotational actuator)
	L298 dc motor driver (transitional actuator)
	2 relay modules 5v-24v (lights pre-command-camera command)
	One relay module 24v-220v (lights main commands)
Other components	LCD (supply charge display)
	Online camera
	8 lights with 254nm wavelength

As mentioned in Table 2, the power supply of this system is a compound of two batteries; 48v and 12 DC. Although it is possible to use one battery besides Step-Down Voltage Regulators or increasing regulators, it will be power loss in the circuit. Since the battery life in every charging cycle is vital in this process, the power loss should be below. The main application of this robot is disinfection in the surgery room, so the necessity of this lifetime is tangible. According to the importance of UVC lights in this system, the power supply was divided in order to keep the system active in unsuitable situations. Briefly, the disinfection unit always is charged while the moving controller unit forces the operator to plug in the robot.

There are two relays connected in series in the circuit. The first one activates the command pin of the second relay in order to magnetize the core of this relay which connects 220v AC to the lights. There is a third one that needs 5v to magnetize the core to power on/off the camera. An LCD is attached to the body that displays the battery charge level. Three motor drivers are used to control the translational and rotational motion of the system. Since there are five DC motors as an actuator to move the robot, one motor driver is utilized to control the motor determining robot direction, and two drivers, with two outputs for each, control the transitional move of the system. Direction controller works in 30A current and others need a current up to 10A.

The Supply unit of this robot has two batteries with 48v and 12v DC outputs. There is a 700watt inverter, converting 48v DC to 220v AC to power UVC lights. There are two Volt dividers with a scale of 12:4 and

8:4 that makes observing the battery charge level possible. Fig 2 summarizes all of these explanations.

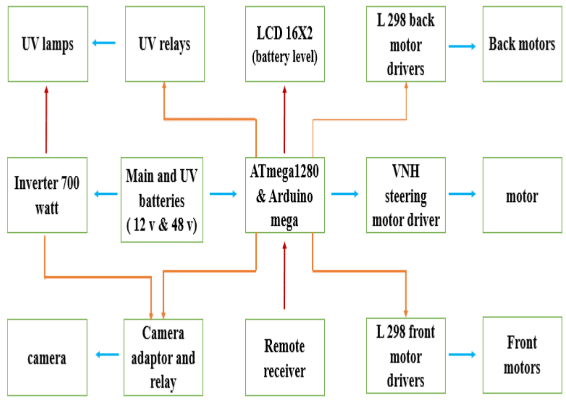


Fig.2. system function is details

The main considerable features of the disinfectant robot are stated:

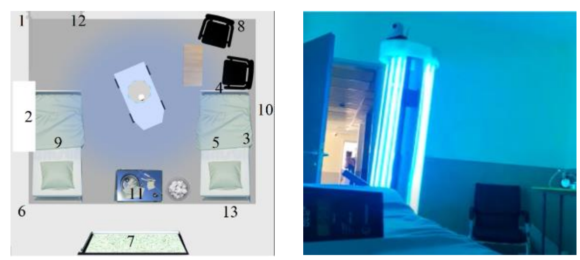
- Reducing sterilization process Due to the possibility of the robot approaching the surfaces.
- Up to a 2000-meter range of remote controlling
- Activating the lights remotely
- The ability to navigate the system using windows/android application while the operator accesses spherical view around the robot.
- Two hours continuous operation time after 5 hours plugged.
- Displaying system information on the monitor.

3 Results and discussion

In June 2020, the UVC robot experimented in a hospital. Three kinds of bacteria and viruses were cultivated in 13 sections located in a hospital room. The microbes were E. coli, SARS and Ebola some of which were Corona kind viruses. 39 samples were being observed during the disinfectant process. The microbe cultivation took an hour then the UVC robot was sent into the room. The performance process lasts 20 minutes for a typical room to be disinfected. The cases were sent to the hospital laboratory for the second cultivation. Almost 80% of the case studies microbes were deactivated after the procedure.

Fig.3. Bacterial culture sampling

The cultivation of bacteria in normal conditions is demonstrated in Fig 3. Strong UVC lights demolish the remarkable number of microbes by deactivating them due to the high-power lights shining closely to the surfaces.



(A) (B)

Fig. 4. disinfection process in hospital room

(A) simulated process ; (B)Actual robot performance

Sterilization shown in Fig 4, was performed in a surgery room containing 13 case study locations. The cases from 1 to 13 in order are behind the main door, above the cooling system, between the bed and the wall, bed's leg, beneath bed's cover, south wall corner, a glass of the window (under the curtain), behind the chair, beneath the bed, on the wall, above the Table, door handle and top margin of the patient's bed. The UVC rays in this process were 240 to 255 nm wavelength. The consequences based on this experiment are presented in Tables 3 and 4.

TABLE 3. Disinfectant effect on three kinds of microbes

Microbe type / Case study location	Ebola (5.1 e6 $\frac{cfu}{ml}$)	E. coli (1.65 e9 $\frac{cfu}{ml}$)	SARS (8.2 e7 $\frac{cfu}{ml}$)
1	4.3	7.8	6.4
2	4.1	6.4	5.7
3	5.3	5.7	6.2
4	4.7	8.1	7.4
5	4	6.3	6.1
6	5.2	7.2	6.3
7	5.6	7.4	5.7
8	5.1	7.7	6.4
9	4.3	7.1	6.7
10	4.2	8.4	6.9
11	5.7	8.7	7.3
12	5.1	8.4	6.9
13	3.9	7.5	7

In Table 3, the numbers assigned to the microorganisms specifies the number of that microbe in 1 milliliter of sampled volume. Due to these results, the best efficiency of this process was on the wall and the ground. The worst outcome was beneath the curtain. E. coli elimination was the best disinfection effect while Ebola had the highest resistance against the UVC robot. This system was experimented with in another surgery room infected with air fungi and bacteria. The case study room had 4.7m width, 4.9m length, and 3.2m height. The experimental data of this test is organized in Table 4.

TABLE 4. UVC robot effect on infected air

Experimental conditions / microbe types	Before the Operation	After the Operation
Number of air bacteria	195 CFU/m^3	39 CFU/m^3
Number of air fungi	312 CFU/m^3	46 CFU/m^3

According to the reported data in Table 4, this system could deactivate around 83% of the air infection in the room. These admissible outcomes are the effects of Ozone gas produced by UVC lights during the process. Produces Ozone gas via UVC lights is measured in a time period of one hour, shown in Fig 5.

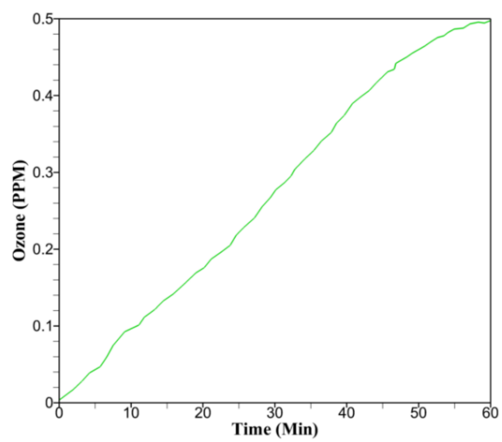


Fig. 5. generated Ozone gas by UVC robot in an hour

According to Fig 5, the UVC robot produced less than 0.5 ppm of ozone gas in 60 minutes. This amount of gas is appropriate for air disinfection and has negligible detriment on the environment.

4. Conclusion

Corona pandemic, affected many countries' economies, society, culture and, other aspects of a nation. Disinfection is the most operational method to cope with this issue. The proposed design and manufactured robot have lots of smart features while it is economical.

- Smart disinfection is based on distance of UVC rays to the object.
- Deactivation of 80% of the microbes during 20 minutes disinfection
- Simplified remotely controllable system for Hospital rooms.
- Producing Ozone gas for air microbes and inaccessible parts.

Studying three types of microorganisms, UVC robot deactivated almost 80% 0f them. In details E. coli had the lowest resistance while Ebola was the strongest microbe against this system. In front of air fungi and bacteria it could disinfectant 83% of the microbes while the UVC lights produced less than 0.5 ppm Ozone gas in an hour.

REFERENCES

[1] "www.worldometers.info," covid-19 corona virus pandemic, 2020. [Online]. Available: https://www.worldometers.info/coronavirus.

[2] A. Saghazadeh and N. Rezaei, "Immune-epidemiological parameters of the novel coronavirus – a perspective," *Expert Rev. Clin. Immunol.*, vol. 16, no. 5, pp. 465–470, 2020.

[3] Z. Memon, S. Qureshi, and B. R. Memon, "Assessing the role of quarantine and isolation as control strategies for COVID-19 outbreak: A case study," *Chaos, Solitons & Fractals*, vol. 144, p. 110655, 2021.

[4] R. M. Kaplan and A. Milstein, "Influence of a COVID-19 vaccine's effectiveness and safety profile on vaccination acceptance," *Proc. Natl. Acad. Sci.*, vol. 118, no. 10, p. e2021726118, 2021.

[5] C. Pironti *et al.*, "The influence of microclimate conditions on ozone disinfection efficacy in working places," *Environ. Sci. Pollut. Res.*, vol. 28, no. 45, pp. 64687–64692, 2021.

[6] D. Ghernaout and N. Elboughdiri, "On the Disinfection Chain as a New Technique for Economic and Chemical Free Disinfection of Public Places from Viruses," *Saudi J Eng Technol*, vol. 6, no. 6, pp. 130–138, 2021.

[7] G. Zhang, W. Li, S. Chen, W. Zhou, and J. Chen, "Problems of conventional disinfection and new sterilization methods for antibiotic resistance control," *Chemosphere*, vol. 254, p. 126831, 2020.

[8] W. Szeto, W. C. Yam, H. Huang, and D. Y. C. Leung, "The efficacy of vacuum-ultraviolet light disinfection of some common environmental pathogens," *BMC Infect. Dis.*, vol. 20, no. 1, pp. 1–9, 2020.

[9] Y. J. Jung, B. S. Oh, and J.-W. Kang, "Synergistic effect of sequential or combined use of ozone and UV radiation for the disinfection of Bacillus subtilis spores," *Water Res.*, vol. 42, no. 6–7, pp. 1613–1621, 2008.

[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. Fleming *et al.*, "Deployment of a touchless ultraviolet light robot for terminal room disinfection: The importance of audit and feedback," *Am. J. Infect. Control*, vol. 46, no. 2, pp. 241–243, 2018.

[12] 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.

[13] K. Ruan, Z. Wu, and Q. Xu, "Smart cleaner: A new autonomous indoor disinfection robot for combating the covid-19 pandemic," *Robotics*, vol. 10, no. 3, p. 87, 2021.

[14] J. K. Schaffzin, A. W. Wilhite, Z. Li, D. Finney, A. L. Ankrum, and R. Moore, "Maximizing efficiency in a high occupancy setting to utilize ultraviolet disinfection for isolation rooms," *Am. J. Infect. Control*, vol. 48, no. 8, pp. 903–909, 2020.