American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-13, Issue-12, pp-154-162
www.ajer.org
Research Paper Open Access

Constructing An UV-A Floor Disinfecting Robot: A Wi-Fi-Controlled Solution for Safer Environment

Shuvon Roy[1], Rubiat Mustak[2]*, Mohammad Ozayer Bin Rafique[3], Deboprio Biswas[4]

[1,2,4] *Department of Mechanical Engineering, Khulna University of Engineering & Technology, Khulna - 9203, Bangladesh.*

[3] *Department of Biomedical Engineering, Khulna University of Engineering & Technology, Khulna - 9203, Bangladesh.*

Corresponding Author: Rubiat Mustak

ABSTRACT :*In response to the critical need for improving surface decontamination, particularly the ongoing challenges after the COVID-19 pandemic, this project introduces an innovative solution—a Wi-Fi controlled floor disinfecting robot powered by UV-A radiation. Thinking outside of the fluid-based sanitization system, this robot used the proven germicidal properties of UV-A light (wavelength range: 315-400 nm). The robot is designed with human touch where an ESP-32 platform and a camera module is used for real time monitoring of the sanitization process. Utilizing a Wi-Fi network, it provides a flexible and considerable solution which is best suited for infectious environment, including hospitals, food manufacturing plants, medical service stations, ambulances, and food trucks. The L298N Motor Driver Module, which ensures accurate control of four DC Motors attached to the wheels, powers the robot's movement to apply its UV-A functions. Two comprehensive tests are done named the Lawn Culture Method and Pour Plate Method to analyze the robot's eye-catching contributions to surface decontamination. The Lawn Culture Method showed better performance at the time of preventing the growth of pathogen of uncovered area where ultraviolet radiation was exposed for a certain time. In this type of testing, Lactobacillus bacteria showed high sensitivity of UV light compared to E-Coli bacteria. In contrast, the Pour Plate Method was not giving satisfactory result in minimizing bacterial growth in exposed areas. The bacterial growth in this testing method was found normal. An effective advancement in surface cleaning technology, the robot transforms into an intelligent defender against bacterial strains, including Lactobacillus, with wide-ranging effects to provide a safe and healthy environment.*

KEYWORDS *Disinfecting Robot, Ultraviolet Radiation, Bacteria, Lawn Culture, Pour Plate Method.*

Date of Submission: 13-12-2024 Date of acceptance: 28-12-2024

I. INTRODUCTION

The process Disinfection refers to eliminating all microorganisms like bacteria, fungi, virus etc. from any surface of an object. Due to the fact that contaminated surfaces operate as carriers, everyone who touches or comes into contact with them may contract an infection. Bacteria and virus are two most common over spreading microorganism responsible for contamination and the spread of infectious diseases. The world gives a high priority on disinfection due to its critical role on public health after the time of COVID 19 pandemic which highlighted the importance of safety from virus [1]. Infectious diseases caused by viruses, bacteria, and other pathogens spread rapidly in environments where disinfection practices are insufficient. These diseases can range from mild to life-threatening, and some—like COVID-19, influenza, or MRSA etc. can have severe with long time impact on health. As advised by the Centers for Disease Control and the World Health Organization (CDC & WHO), there are numerous disinfection techniques available today. Bleach, hydrogen peroxide, and isopropyl alcohol (>70%) are the most often used disinfectants [2]. Manual cleaning and sanitation methods are not always sufficient to stop the spread of germs and viruses produced by infected surfaces. A significant advancement in sanitization technology, the fluid-less floor disinfection robot that uses UV light combines robotics and ultraviolet germicidal irradiation (UVGI) in a seamless manner. This inventive device uses UV-C radiation, a powerful wavelength known to destroy bacteria by damaging their DNA, in contrast to conventional

disinfection techniques that depend on liquid solutions [3]. Millions of people have died and been infected globally as a result of the COVID-19 pandemic. It pushes us to reconsider how communities can function with little to no physical interaction [4]. The prevention of the transmission of infectious diseases is largely dependent on cleaning and disinfection. Due to a lack of time and training, manual cleaning and disinfection requires a lot of labor and time. The use of robotics reduces contamination risk, traditional cleaning and disinfection costs, and—most importantly—improves safety. Mainly the frontliners are at high risk of contamination and at the same time the vector of transmitting the virus into the others. Because they remain in total contact with the affected patients [5]. Mobile robots are therefore giving a durable solution to the problem faced at the tie of traditional cleaning using fluid-based system. Autonomous robotic systems are becoming more and more common in many industries for a variety of activities, such as cleaning and sterilizing huge areas, detecting plant diseases, and taking inventory in warehouses. Autonomy has two main benefits. First, robots are capable of using stronger disinfectants that are hazardous to people. Second, when the area they must sanitize grows, their efficacy does not diminish. These robots have the potential to replace people, who are currently employed in hazardous environments [6]. The robot will supplement the current cleaning cycle with UV light, preventing the spread of bacteria, viruses, HAIs, infectious diseases, and other dangerous organic microorganisms. By lowering the danger of infectious diseases and secure cleaner environments for everybody, its inclusion into numerous industries can improve community's general well-being.

Table-1: Wavelength of different Radiation.

Name of the Radiation:		Wavelength (nm)
Infrared		>780
Visible Light		400-780
Ultraviolet	UV-A	315-400
	UV-B	280-315
	UV-C	200-280
	Vacuum UV	100-200
X-rays		<100

A UV radiation method for disinfecting a surgical or hospital space has been devised by Pacharawam et al. Three 19.3 W UV radiation LEDs are installed on the radiation bot platform of their UV radiation larva, which covers a 360° field of view. Tests conducted for identifying obstacles by static figuring show that the developed identification gadget greatly enhances cleaning robotics perception of its surroundings and path search capability [7]. Tuangzhi et al. designed a synthesis detection system based on sensor array finding method technology in accordance with algorithm characteristics [8]. Amrita et al. proposed that Robots that use UV light to kill germs eliminate the need of conventional sanitization. This patent integrates restrictive calculations that regulate UVC measurement and treatment time as the robot operates, ensuring feasible, effective treatment despite factors such as space dimensions, layout, furnishings, and beneficial to the environment features [9]. According to Adhirath et al, by effectively cleaning confined spaces, the Corner Disinfection Robot overcomes conventional approaches and covers 80% of targeted regions, solving problems with sanitation. In response to the COVID-19 epidemic, it represents an innovative move toward advanced autonomous hygiene solutions by improving resource optimization, cost-effectiveness, and future sanitation technologies [10]. Gerchman et al. examined the sensitivity of human coronavirus to UV LED and found that coronavirus is wavelength dependent and the peak of the effectiveness occur under 286 nm [11]. Antonio et al. established a key strategy against infectious diseases, which is UV disinfection and frequently employed in public areas like hospitals. It means exposing surfaces to the most powerful germicidal wavelength, UV-C light (200–280 nm). For this, UV robots

are utilized, which are equipped with 360° lamp arrays on a movable platform [12]. The efficiency of UVC against SARS-CoV-2 was investigated in a study by Heilingloh et al. which found that after nine minutes of exposure, the virus was completely inactivated, whereas UVA had little effect and the effectiveness against the spreading of virus is minimal [13]. In a comprehensive study conducted by Yang Shen et al. explained that in a distance of 1 meter, UV-C light eject 20 joules per square meter with a wavelength of 254 nm and this will destroy 99.99% of the germ of virus and bacteria [14]. According to the experiment of Yagi et al. 100% destroy of bacteria occurred for 60 minutes of UV radiation and 80% and 50% damage occur for 30 and 15 minutes respectively. Here the consumed energy will also differ [15].

II. Construction and Methodology

The driving process of the robotic car by L298N motor driver:

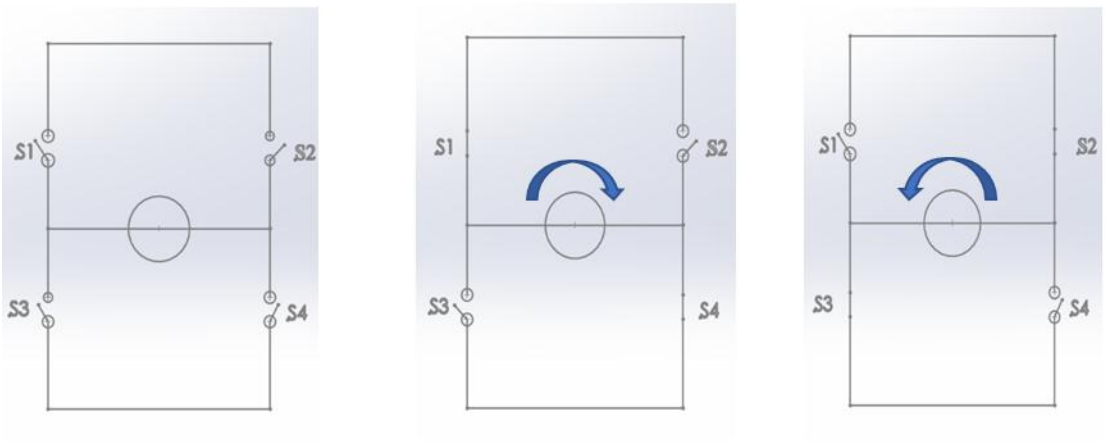

Fig 1. Inner L298N Driver Module circuits regarding to wheel rotation.

The main part in charge of managing the four DC motors that drive the robot's motion is the L298N Motor Driver Module. It can control motor rotation and change the path of the electricity by using an H-Bridge circuit. The pins on the module (IN1, IN2, IN3, and IN4) regulate these switches to control motor direction, allowing the robot to steer forward, backward, and sideways.

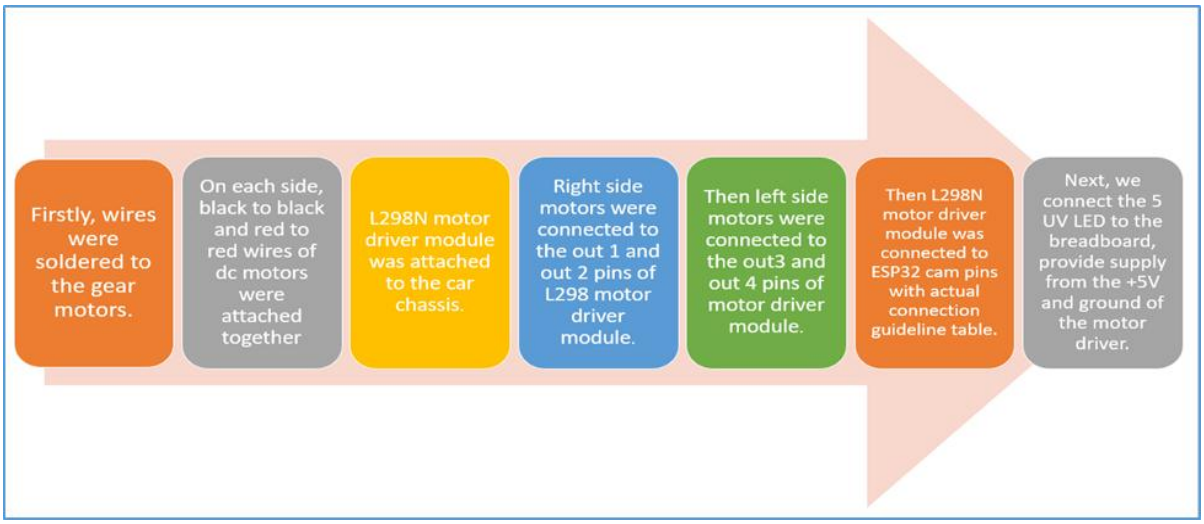

Fig 2. The robotic car driving mechanism.

All of the robot's wheels rotate clockwise when it is moving forward and counterclockwise when it is moving backward. For turning the robot in right side, one sides wheels rotate in clockwise direction and the other side in counter clockwise and for a left turn, opposite of the right turn will done. Control signals was passed to the microcontroller by a mobile device, which instructs the motor driver to carry out the intended movement.

The process of killing bacteria by using UV ray:

Ultraviolet light is a type of electromagnetic radiation that has wavelengths greater than X-rays but smaller than visible light. It is known as "germicidal UV" because it can stop mycobacterial development. This wavelength of UV light is absorbed by nucleic acids, causing defects on pyrimidine chain of the pathogen that restrict the function of DNA and RNA. UV light generates reactive oxygen through photoexcitation of cellular porphyrins, which are toxic to bacterial cells. UV light makes microorganisms inactive by causing mutations or cell death, which stops them from reproducing and producing antigens. The electromagnetic energy produced by UV light can destroy the bacteria and virus and ultimately ensure the proper disinfection [16]. The process of killing bacteria is given below:

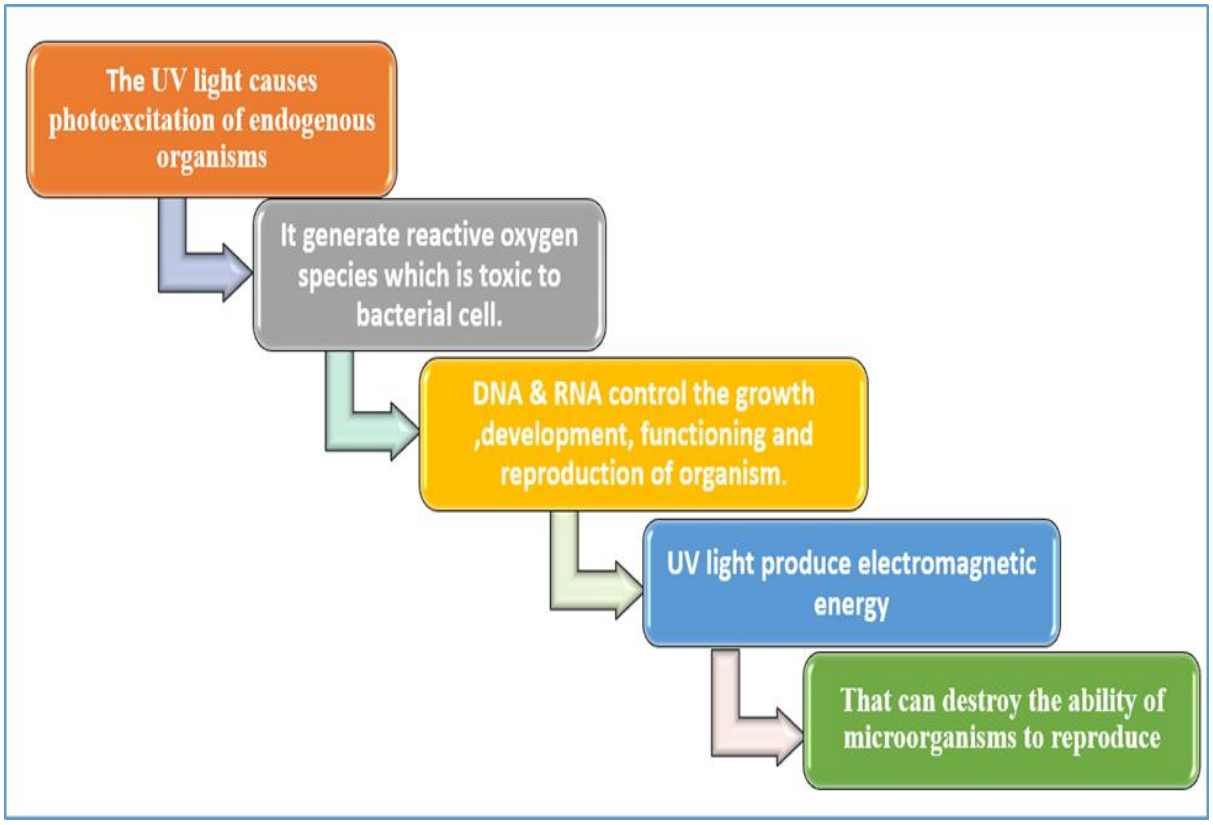

Fig 3. Bacteria destruction process.

Hardware requirements:

The total disinfecting Robot is developed with the help of assembling some parts. Here the ESP32 camera module serve as the brain of the system and the UV lights are powered by a battery with the help of an inverter which convert the DC voltage to Ac. Additionally ESP 32 module control the movement of the four motors using Pulse Width Modulation (PWM) as well as the speed of the motors. The hardware components used to construct the robot and the main purpose of using those components are given below:

Table 2: List of the components and their purpose.

Serial no.	Name of the component	Quantity	Purpose
1	ESP 32 camera module	1	Receiving feedback from the camera module and controlling through the Wi-Fi
2	L298N motor driver.	1	For controlling the driving of motors
3	UV LED	5	Emitting light for the purpose of disinfecting.
4	DC motor	4	Gear motor for moving base with 300 rpm.
5	Wheel	4	For transferring the robot from one place to another.
6	Battery	3	Perform as the main power source of the robot.
7	Inverter	1	Converting the DC voltage of the battery into AC to run the UV lights
8	Switch	1	For controlling the power transfer.
9	Connecting Wire	As required	Giving connection between the power source and the circuits.
10	Chassis	1	To hold the full Robot structure
11	Nut and bolt	As required	For building the structure.

UVA disinfection system's development:

The suggested method, which is made up of several parts and modules, assembled together to get the complete model. The brain of our proposed construction was an Arduino based ESP32 cam module which is the center of the system. The UV lights are powered by a battery using a customized sine wave inverter that is controlled by a relay. Additionally, the ESP32 unit manages two L298 motor drivers, which use PWM (pulse width modulation) speed control to manage four motors. To add object avoidance, a distance sensor is optionally installed.

To assemble a motorized car chassis controlled by an ESP32 CAM, first solder wires to the gear motors and securely mount them on the chassis, ensuring all parts are firmly attached. Connect the motors' wires by color for polarity consistency, linking right-side motors to OUT1 and OUT2 pins, and left-side motors to OUT3 and OUT4 pins on the L298N motor driver. For providing the power to the motor drivers +12V pin and the ground pit, it was attached with a battery. According to the circuit diagram, the driver module was connected to the ESP32 Camera module for establishing control upon the motor's operation. Next, the ESP32 CAM's IO12 pin was connected to the enable A and enable B pins. This setup enables synchronized control and dependable power distribution by allowing the ESP32 CAM to guide the chassis' movement through the motor driver. The circuit diagram and final construction is given below:

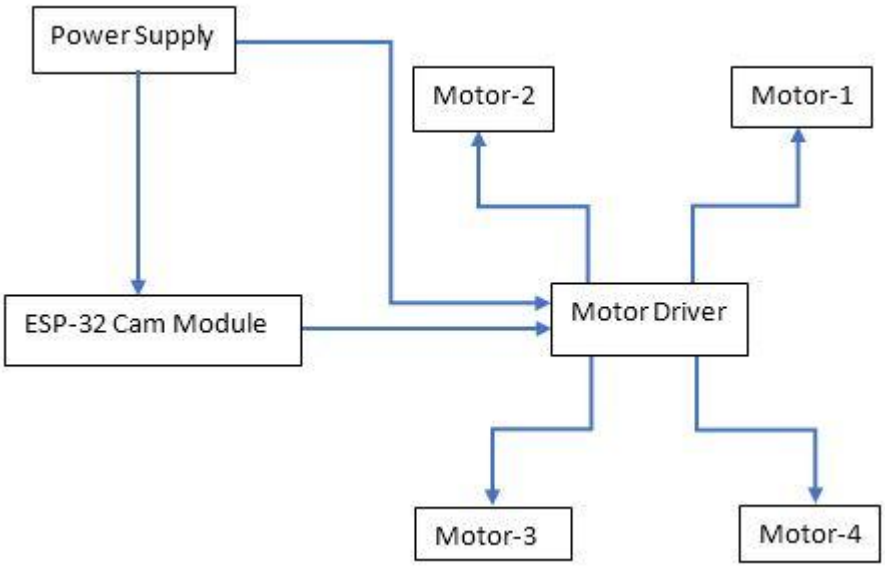

Fig 4. The circuit diagram for disinfecting robot.

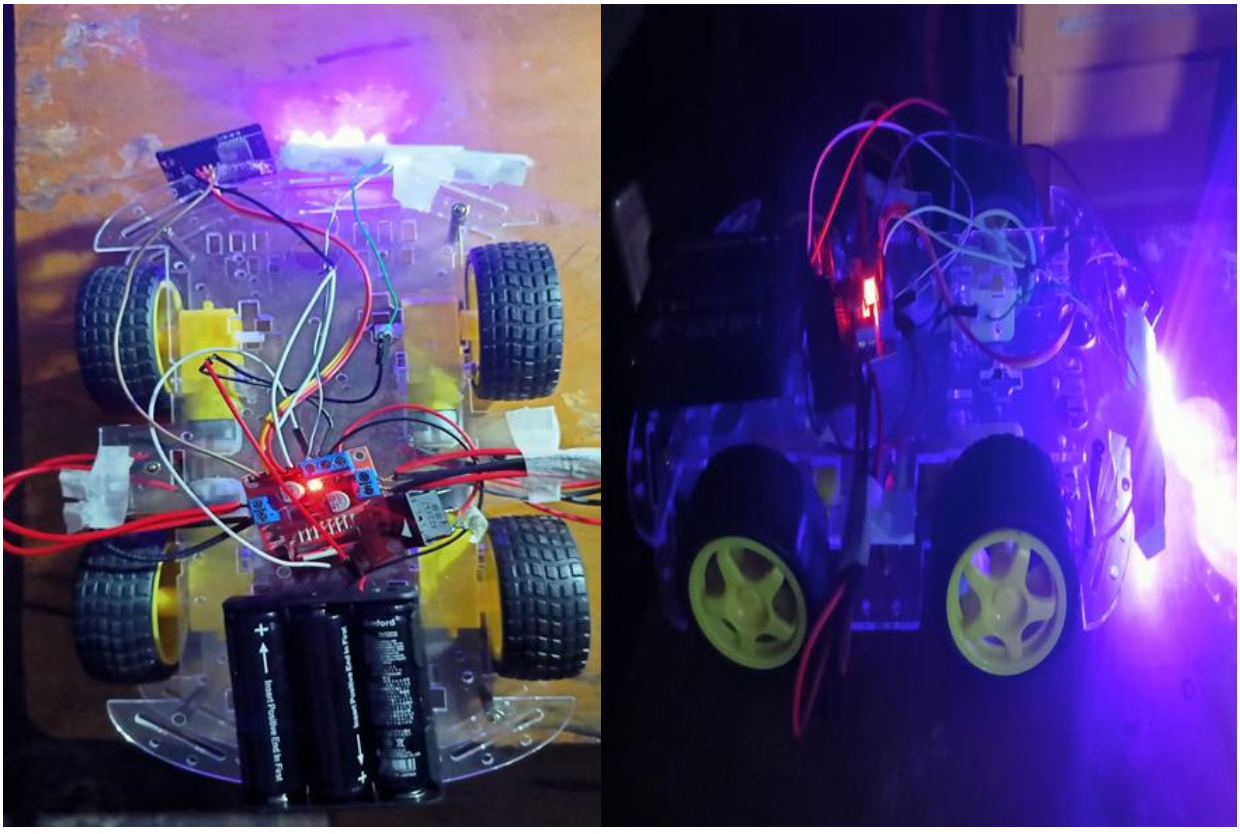

Fig 5. Construction of disinfecting robot by using UV light.

III. TESTING AND RESULTS

For testing the effectiveness of the disinfecting robot, two types of pathogens were taken. The first was E. coli (Escherichia coli) and the other is Lactobacillus bacteria- a kind of good bacteria that is present in the gut, fermented foods, and dairy products which enhances immunity, facilitates digestion, and promotes digestive health by producing lactic acid.

Two comprehensive tests are done named the Lawn Culture Method and Pour Plate Method to analyze the robot's eye-catching contributions to surface decontamination. In both types of testing, the UV light was exposure to the petri dish. At the time of exposure of light, half of the round petri dish was covered by a metal sheet and the other half was totally free. By making this setup, the UV radiation was given to the open half for 2 minutes. After applying the radiation upon the Escherichia Coli and Lactobacillus bacteria, the full petri dish was taken 48 hours of incubation.After successfully passing the incubation period, all of the dishes were taken out and observed for the performance.

Test by Lawn culture method:

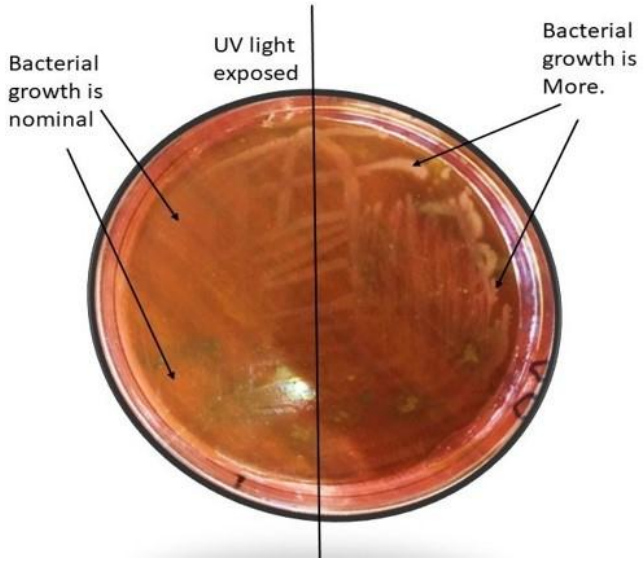

Fig 6. Results of cell culture using Lawn method for *E.coli*bacteria after exposure to UV radiation for 2 min and incubating for 48 hours.

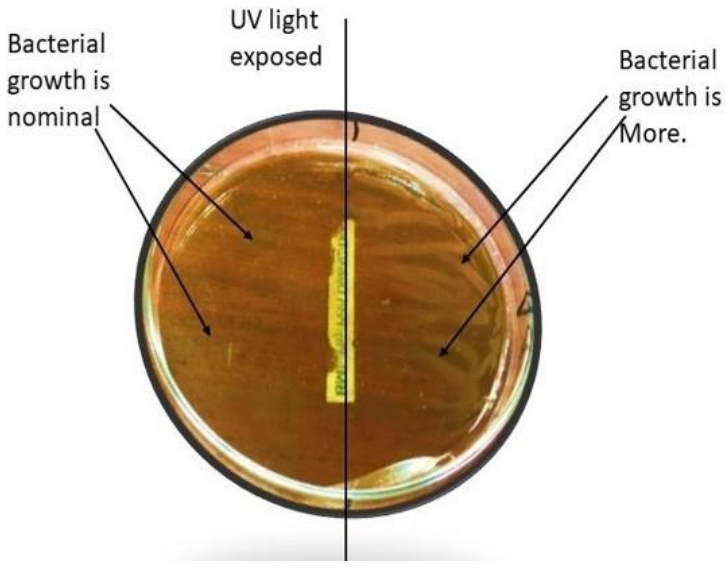

Fig 7. Results of cell culture using Lawn method for *Lactobacillus* bacteria afterexposure to UV radiation for 2 min and incubating for 48 hours.

Test by Pour plate method:

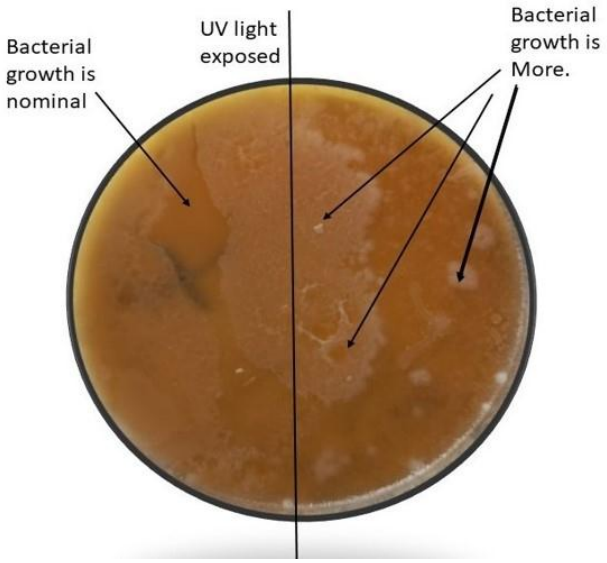

Fig 8. Results of cell culture using Pour Plate method for *E. coli* bacteria after exposure to UV radiation for 2 min and incubating for 48 hours.

Result Analysis:

The UV ray module's usefulness as a disinfection tool has been proven by its capability to effectively kill microorganisms. In case of Lawn Culture method, it is seen that, both in figure 6 and 7, in the left side, bacterial growth is nominal compared to the right side. In right side which was covered by the metal plate, the bacterial growth is normal. In comparison between these two figures, a decision can be taken that the process is successful in its operation and proved its efficiency by preventing the growth of the bacteria. So, the testing process is effective.

Now, in comparison between E-Coli and Lactobacillus bacteria, different microorganisms have different sensitivity levels to UV radiation, as showcased by the fact that Lactobacillus was more sensitive to the UV rays than E. coli among the tested bacteria. In the figure 7, the reproduction of lactobacillus bacteria is totally stopped. In contrast, growth of E-Coli was not totally obstructed by the UV radiation. So, Lactobacillus bacteria is more sensitive to UV light.

For evaluating the disinfection effectiveness, two comprehensive tests were conducted out named the Lawn Culture Method and the Pour plate method. Between this two-testing method, the most reliable and consistent results for evaluating bacterial inhibition were obtained using the lawn method. Furthermore, the Pour Plate Method underscores the robot's efficacy in preventing bacterial growth in exposed areas because in pour plate method in figure 8, the result was not satisfactory and some visible growth of the bacteria was observed.
So, a significant advance in surface cleaning technology, the robot turns into an understanding defender against bacterial strains, including Lactobacillus, with wide-ranging effects to provide a safe and healthy environment.

IV. CONCLUSION

Wi-Fi controlled floor disinfecting robot has been designed and constructed for pausing the over spreading of any virus or bacteria moreover all harmful pathogen. The robot was successfully constructed and tested for proving its duty and effectiveness. From the output of testing, it looks clear that the radiation from ultra violet LED is capable of destroying the spreading of pathogen.

Due to some limitation and safety issues, UVC radiation was not used for the safety of the people. By taking proper safety, in future UVC radiation will be applied. Future studies will examine the ideal robotic disinfection parameters, such as robot speed and distance to the target surface. Again, a sensor for detecting human will be implemented for proper safety. Besides, the robot will identify the location where highest human attachment are involved. Added, obstacle avoiding sensor will be implemented in future. Fully automation of the robotic car will also be installed.

Conflict of Interest

The authors declare that they do not have any conflict of interest.

Authors Contributions

S. Roy: Conceptualization, construction, testing, formal analysis, data curation, writing original draft.

R. Mustak: Review, editing, supervision.

M. Rafique: Review, editing.

D. Biswas: Review, editing.

Acknowledgement

The authors gratefully acknowledge the support of the Department of Mechanical Engineering, Khulna University of Engineering and Technology, Khulna, Bangladesh, in completing this project successfully.

REFERENCES

[1]. J. S. Abrahãoet al., 'Detection of SARS-CoV-2 RNA on public surfaces in a densely populated urban area of Brazil: A potential tool for monitoring the circulation of infected patients', Science of the Total Environment, vol. 766, Apr. 2021, doi: 10.1016/j.scitotenv.2020.142645.

[2]. M. M. R. Saad and M. A. Razzak, 'A Cost effective UV Robot for Disinfecting Hospital and Factory Spaces for Covid-19 and Other Communicable Diseases', in 2021 IEEE World AI IoT Congress, AIIoT 2021, Institute of Electrical and Electronics Engineers Inc., May 2021, pp. 373–378. doi: 10.1109/AIIoT52608.2021.9454191.

[3]. S. Perminovet al., 'UltraBot: Autonomous Mobile Robot for Indoor UV-C Disinfection', IEEE International Conference on Automation Science and Engineering, IEEE Computer Society, Aug. 2021, pp. 2147–2152. doi: 10.1109/CASE49439.2021.9551413.

[4]. V. Sivanantham, A. Vu Le, Y. Shi, M. R. Elara, and B. J. Sheu, 'Adaptive floor cleaning strategy by human density surveillance mapping with a reconfigurable multi-purpose service robot', Sensors, vol. 21, no. 9, May 2021, doi: 10.3390/s21092965.

[5]. Y. Abu-Zidan, K. Nguyen, P. Mendis, S. Setunge, and H. Adeli, 'Design of a smart prefabricated sanitising chamber for COVID-19 using computational fluid dynamics', Journal of Civil Engineering and Management, vol. 27, no. 2, pp. 139–148, Feb. 2021, doi: 10.3846/jcem.2021.14348.

[6]. Antonio Di Lallo, Robin R. Murphy, Axel Krieger, Junxi Zhu, Russell H. Taylor, and Hao Su ,'Medical Robots for Infectious Diseases: Lessons and Challenges from the COVID-19 Pandemic'Robotics and Automation (ICRA), 2015 IEEE International Conference on : date, 26-30 May 2015. IEEE, 2015.

[7]. P. Chanprakon, T. Sae-Oung, T. Treebupachatsakul, P. Hannanta-Anan and W. Piyawattanametha, 'An Ultra-violet sterilization robot for disinfection', 2019 5th International Conference on Engineering, Applied Sciences and Technology (ICEAST), Luang Prabang, Laos, 2019, pp. 1-4, doi: 10.1109/ICEAST.2019.8802528.

[8]. G Tuangzhi Dai and Tiequn Chen, 'Design on measurement and control system of cleaning robot based on sensor array detection', IEEE International conference on control automation, Guangzhou, 2007, China.

[9]. A. Rai, C. Shylaja, T. Singh, and S. Trivedi, 'Design and Development of Ultra-Violet Light Disinfectant Robot', 2021 9th International Conference on Reliability, Infocom Technologies and Optimization (Trends and Future Directions), ICRITO 2021, Institute of Electrical and Electronics Engineers Inc., 2021. doi: 10.1109/ICRITO51393.2021.9596288.

[10]. A. P. Kakade, A. Vibhute, S. Chavan, P. M. Nagrare, and Y. M. Bawankar, 'Corner Disinfection Robot', 2024 IEEE International Students' Conference on Electrical, Electronics and Computer Science, SCEECS 2024, Institute of Electrical and Electronics Engineers Inc., 2024. doi: 10.1109/SCEECS61402.2024.10482229.

[11]. Y. Gerchman, H. Mamane, N. Friedman, and M. Mandelboim, 'UV-LED disinfection of Coronavirus: Wavelength effect', J PhotochemPhotobiol B, vol. 212, Nov. 2020, doi: 10.1016/j.jphotobiol.2020.112044.

[12]. A. Di Lallo, R. Murphy, A. Krieger, J. Zhu, R. H. Taylor, and H. Su, 'Medical Robots for Infectious Diseases: Lessons and Challenges from the COVID-19 Pandemic', IEEE Robot Autom Mag, vol. 28, no. 1, pp. 18–27, Mar. 2021, doi: 10.1109/MRA.2020.3045671.

[13]. C. S. Heilingloh, Aufderhorst., 'Susceptibility of SARS-CoV-2 to UV irradiation', Am J Infect Control, vol. 48, no. 10, pp. 1273–1275, Oct. 2020, doi: 10.1016/j.ajic.2020.07.031.

[14]. Y. Shen et al., 'Robots under COVID-19 Pandemic: A Comprehensive Survey', IEEE Access, vol. 9, pp. 1590–1615, 2021, doi: 10.1109/ACCESS.2020.3045792.

[15]. Noriyuki Yagi et al. 'Sterilization using 365nm UV_LED', Proceedings of the 29th Annual International Conference of the IEEE EMBS cite International, Lyon, France, August 23-26 ,2007.

[16]. S. Parmar and H. Bhatt, 'A DESIGN OF HYBRID FLOOR UV-C STERILIZER ROBOT', International Research Journal of Engineering and Technology, Vol. 07, Issue. 12, pp. 1985-1989, 2020.