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Far -Ultraviolet C Light for Hospital Room Disinfection: A Novel Approach to Infection Control

S. Preethi[1], M. Bhuvaneswari[2], S. Poorani[3] and R. Suganya[4]
[1-4]Nandha Engineering College/Biomedical Engineering, Erode, Tamil Nadu
Email: {preethisaravanan03, bhuvaneswarimarimuthu20, pooraniselvaraj47, suganya.r0852}@gmail.com

***Abstract*—An effective and automatic disinfection is provided by the IoT-Controlled UVC Sterilization System. It is essential to keep labs, and healthcare facilities hygienic. This system makes use of IoT technology to monitor and manage UVC sterilization procedures, guaranteeing maximum disinfection with the least amount of human involvement. Automated scheduling and real-time monitoring improve accuracy and productivity while lowering the chance of contamination. Through the integration of smart sensors and remote accessibility, the system offers a dependable, intelligent, and user-friendly method of sterilizing. This innovative approach transforms disinfection procedures, enhancing hygienic environment maintenance in terms of safety, efficacy, and simplicity.**

***Index Terms*—Hospital-acquired infections (HAIs), Surface contamination, UV-C radiation, Ultraviolet germicidal irradiation (UVGI), Automated sterilization, Infection control, Healthcare disinfection, Patient safety, Smart sterilization technologies.**

I. INTRODUCTION

Chemical disinfectants, while commonly used, are often inadequate in completely eliminating harmful bacteria and viruses present in hospitals and other environments prone to contamination [1]. These microorganisms can survive on various surfaces for extended periods, posing a significant risk of infection to patients, healthcare workers, and visitors [2]. Traditional chemical-based disinfection methods may not always provide thorough coverage [3], leaving behind residual pathogens that can contribute to hospital-acquired infections (HAIs) [4]. Given the critical nature of healthcare settings, ensuring rapid and effective decontamination of patient-care beds and hospital rooms is of utmost importance [5]. This need becomes even more pressing due to the limited availability of hospital beds, as high patient turnover requires swift yet thorough sterilization [6]. Any delay in the disinfection process can lead to inefficiencies inpatient admissions and increased exposure to infectious agents [5].

Proper sterilization of hospital spaces before admitting new patients is essential in reducing infection risks and maintaining a safe healthcare environment [7]. By thoroughly disinfecting beds, furniture, and other frequently touched surfaces, healthcare facilities can significantly lower the chances of cross-contamination [8]. This proactive approach enhances patient safety, promotes better health outcomes, and ensures a more effective infection control strategy within medical institutions.[9]

To effectively combat the presence of harmful microorganisms in healthcare environments, various disinfection methods have been explored [10] [11], including both air purification and surface cleaning techniques [12] [13]. These methods play a crucial role in ensuring a sterile environment by eliminating bacteria, viruses, and other

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pathogens that pose a risk to patients and medical personnel [14] [15]. Among the widely recognized disinfection techniques are non-thermal plasma (NTP), thermal treatment, antimicrobial material-embedded filters, ultraviolet (UV) light, and photocatalysis [16]. These approaches have proven effective in reducing contamination and preventing the spread of infections in hospital settings. One of the most effective and cost-efficient disinfection technologies is ultraviolet germicidal irradiation (UVGI) [17] [18]. This method is commonly used to disinfect air, water, and various surfaces due to its high efficiency and relatively low operational cost [17]. UVGI utilizes short-wave ultraviolet C (UV-C) radiation, which falls within the 100-280 nanometer (nm) range, to inactivate bacteria and viruses [19]. UV-C light is particularly effective because its wavelengths are strongly absorbed by bioaerosols, leading to structural damage in the DNA and RNA of microorganisms. [20, 21].

UV-C radiation emitted by germicidal lamps penetrates microbial cells [19], rendering them inactive and preventing their ability to reproduce or cause infections [22] [3]. This disruption prevents their replication and ultimately results in their deactivation, making UV-C radiation a powerful tool for infection control. [22]

Over the past few decades, numerous studies have highlighted the germicidal capabilities of UV-C light and its growing applications in healthcare settings [23]. It has been successfully implemented in ambulances, operating rooms, and hospital patient rooms, where maintaining a sterile environment is essential [24]. The increasing adoption of UV-C technology in medical facilities underscores its effectiveness in reducing infection rates and enhancing overall hygiene standards [25] [26]. By integrating UV-C sterilization with modern automation technologies, healthcare institutions can significantly improve the efficiency and reliability [27] of their disinfection processes, ensuring a safer environment for both patients and medical staff. [2] [19].

By exploring existing disinfection methods, challenges, and emerging advancements, this paper aims to highlight the role of automated UV-C sterilization in enhancing infection control, minimizing human intervention, and improving healthcare efficiency. This research contributes to the advancement of smart sterilization technologies, paving the way for safer and more effective disinfection solutions.

II. EXISTING METHOD

The existing method involves designing a cost-effective UVC disinfection robot to sanitize hospital and factory spaces against COVID-19 and other communicable diseases. The robot is equipped with three UVC lamps arranged for 360-degree coverage and mounted on a mobile base with motors, controllers, and sensors. The system is controlled remotely via Wi-Fi using a mobile transceiver, ensuring safe operation. It incorporates an ESP32-CAM module as its main control unit, along with a relay-controlled inverter for powering the UV lamps.[28]

III. PROPOSED METHOD

This system proposes a sophisticated system aimed at effectively eliminating pathogens on hospital floors and providing protection against respiratory diseases. It uses a PIC 16f887 microcontroller as its brain, which receives instructions from connected modules and then tells other parts of the system what to do. It starts with a power supply that converts battery power into a usable form for all the components. The microcontroller is the heart of the system, receiving information from various modules and sending commands to other devices. It includes a Bluetooth module for wireless control using smartphones or computers. This lets users turn on the UV lamp or operate the motor remotely. Additionally, an IoT module allows internet-based control, enabling remote access, real-time monitoring, and updates through the internet.

The system has a Liquid Crystal Display (LCD) that shows information like device status, messages, and alerts. The microcontroller talks to the LCD to provide real-time feedback. Relays are used to control the UV lamp and motor safely. They act like switches, allowing the microcontroller to control high-power devices without being directly exposed to dangerous currents. The UV lamp is used for sterilization, while the motor can be used for moving the UV lamp or performing other tasks. The microcontroller controls both devices, ensuring safe operation and responding to commands received from Bluetooth, IoT, or programmed conditions.

The system’s communication is key to its functionality. The microcontroller acts as the central control unit, receiving inputs, processing information, and sending signals to other components. The Bluetooth module handles close-range communication, while the IoT module extends control to anywhere with internet access. It offers efficient, automated control of devices with flexibility for remote operation. It uses wireless communication modules for convenience and relays for safe high-power device control. The LCD provides immediate feedback, making the system easy to monitor and manage. The PIC 16f887 microcontroller is the core component, coordinating all operations and ensuring a seamless system.

IV. WORKING

This system starts with a power supply setup that includes a battery providing power to the entire system. The power is regulated and distributed to ensure that each component receives the required voltage and current. This stable power supply is crucial as it powers the microcontroller (PIC16F887) and its peripherals, which include the Bluetooth module (HC-05), the IoT module, LCD, and relays connected to the UV lamp and motor.
At the center of this system is the PIC16F887 microcontroller, which acts as the main control unit. When the system is powered on, the microcontroller initializes its various input and output pins and establishes communication protocols with the Bluetooth and IoT modules. It prepares to receive commands from either of these sources to control the connected devices (UV lamp and motor) through relays.

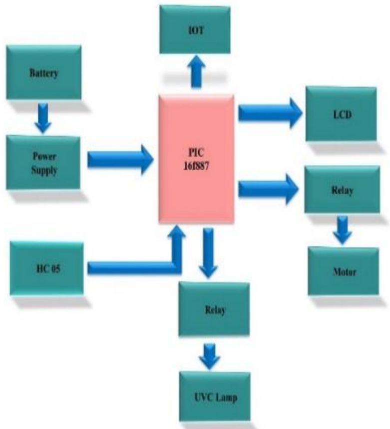

Figure 1. Block Diagram for Ultraviolet C Disinfection Kit

The HC-05 Bluetooth module enables communication between the microcontroller and a nearby Bluetooth-enabled device, such as a smartphone. The user can connect to the system via a mobile app or other Bluetooth interface. Once paired, the user can send commands directly to the PIC16F887. For instance, commands might include turning on the UV lamp, starting the motor, or stopping both. When a command is received, the microcontroller processes it and sends an appropriate output signal to control the relay connected to the respective device (UV lamp or motor). This mechanism allows the user to control the devices within Bluetooth range, typically up to around 10 meters, making it ideal for close-range applications.
In addition to Bluetooth control, the system is also equipped with an IoT module, which allows remote access to the device over the internet. This expands the control range far beyond Bluetooth limitations, as the user can access and control the system from anywhere with internet connectivity. Through an IoT platform or web application, the user can send commands to the microcontroller just like with the Bluetooth module. The PIC16F887 microcontroller receives these commands from the IoT module, processes them, and then controls the UV lamp or motor via the connected relays. This dual functionality (Bluetooth and IoT) enhances the system’s versatility, allowing the user to operate the device remotely or locally based on convenience.
The LCD display connected to the PIC16F887 provides real-time feedback to the user, showing the current status of the system. For example, it might display messages indicating whether the UV lamp is on or off, whether the motor is active, battery level, and connectivity status (Bluetooth or IoT connected). This feedback is useful as it informs the user of the device's operational state, helping them ensure that the commands have been executed successfully. Additionally, if any errors or status changes occur, the LCD can display messages to alert the user.

V. RESULT AND DISCUSSION

A. Hardware Result

The result of this system is to provide precise, safe and remotely controllable operation of UV and motorized devices, making it suitable for environments like hospitals, laboratories, or automated industrial settings. The combination of automation, safety features and remote operability enhances both functionality and user convenience. Effective Disinfection: The system can effectively control sterilization procedures by automating the UV lamp's operation. Safe activation is ensured by the use of a relay and the microcontrollercan impose safety precautions like shutting off the lamp under specific circumstances.

Figure 2. Hardware Result

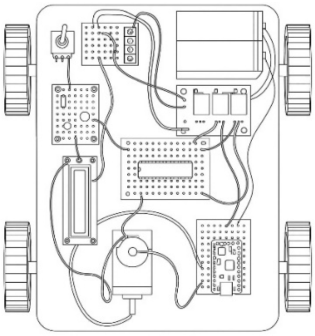

Figure 3. 2D CAD drawing

B. Laboratory Result

In order to assess the real-world effectiveness of Far-UVC radiation for surface disinfection, an experimental evaluation was carried out in various frequently contacted public and semi-public environments. Target sites included tabletops, floor surfaces, and other high-touch areas commonly used by multiple individuals throughout the day. These locations were selected to represent typical sites of microbial contamination in both residential and public settings.

Surface swab samples were systematically collected from each site immediately prior to Far-UVC exposure to establish baseline levels of bacterial and viral contamination. Following this, the surfaces were irradiated using a calibrated Far-UVC light source (222 nm wavelength) for a standardized duration, sufficient to reflect practical disinfection scenarios. Post-disinfection swab samples were then collected from the same locations. All swab samples were submitted to an accredited microbiological testing laboratory for analysis.

Figure 4. Test taken on classroom floor

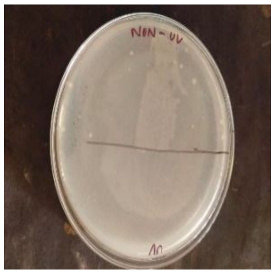

Figure 5. Test taken on laboratory floor

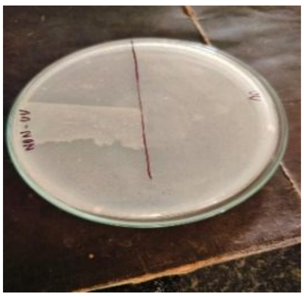

Figure 6. Test taken on common floor

Assessment of Bactericidal Activity of Far-UVC Radiation on Escherichia coli and Staphylococcus Species at Different Exposure Durations. The study evaluated the effectiveness of Far-UVC light in reducing bacterial contamination by exposing E. coli and Staphylococcus sp. to UV radiation for varying time intervals (15, 30, 45, and 60 seconds). This study focused on evaluating the bactericidal effect of Far-UVC radiation on two clinically significant strains—Escherichia coli (Gram-negative) and Staphylococcus sp. (Gram-positive)—commonly found on public surfaces. Samples exposed to 222 nm UV light for up to 60 seconds showed a marked reduction in colony-forming units: E. coli decreased from 11 to 5 colonies, and Staphylococcus sp. from 48 to 12 colonies. Sterility was confirmed by negative controls, but positive controls showed increased bacterial growth. Additionally, swab tests revealed complete elimination of high bacterial loads (+++) after 1 minute of UV exposure. These findings highlight the effectiveness of Far-UVC radiation in reducing bacterial contamination on surfaces in real-world environments.

TABLE I. TEST RESULT 1

S No	Strains	UV Treated using different Seconds. No of colonies observed after 24 hours.				Positive Control	Negative Control
		15sec	30sec	45sec	60sec		
1	E-Coli	11	10	8	5	TNTC	NBG
2	Staphylococcus sp	48	30	25	12	TNTC	NBG

TNTC- Too Numerus to Count NBG- No Bacterial Growth

TABLE II. TEST RESULT 2

S. No	Before UVC	After 1 min of UVC Exposure	Control Rate
1.	+++	Absent	No Bacterial Growth

+++ - High Growth

Colony counts were assessed after 24 hours of incubation. In E. coli, the number of colonies decreased progressively from 11 (15 seconds) to 5 (60 seconds), whereas in Staphylococcus sp., a more significant decline was observed from 48 colonies (15 seconds) to 12 colonies (60 seconds). Positive control samples showed bacterial growth that was too numerous to count (TNTC), confirming the viability of the organisms without UV exposure, while negative controls exhibited no bacterial growth, verifying the sterility of the experimental conditions. Additionally, a swab test method demonstrated high bacterial presence (+++) prior to UV exposure and complete absence of colonies after 1 minute of exposure, further validating the bactericidal efficacy of Far-UVC treatment. These findings highlight the time-dependent reduction of bacterial load under Far-UVC exposure and support its potential application in controlling respiratory pathogen transmission.

VI. CONCLUSION

Far-UVC light technology represents a promising and innovative solution for combating respiratory diseases by providing continuous disinfection in occupied spaces without posing harm to human skin or eyes. Unlike traditional germicidal UV light, far-UVC (wavelengths around 207-222 nm) is highly effective at inactivating airborne viruses and bacteria, including common respiratory pathogens like influenza and coronaviruses, while remaining safe for human exposure.

This advancement holds great potential in various settings such as hospitals, schools, public transport and other high-traffic areas where infection control is critical. As research continues to support the safety and efficacy of far- UVC light, it could become a key component in public health strategies aimed at reducing the spread of respiratory infections, providing an additional layer of protection and helping to curb future outbreaks effectively.

FUTURE SCOPE

This System provides continuous air and surface disinfection, making it suitable for use in occupied spaces such as hospitals, schools, public transportation and offices. Far-UVC light systems can operate continuously, reducing pathogen loads in real-time, thereby minimizing the risk of respiratory disease transmission in high-density environments. These systems can be seamlessly integrated into existing lighting infrastructure or deployed as standalone units, with the potential for smart control features like automated activation based on occupancy or air quality. The energy-efficient design of far- UVC systems ensures cost-effective operation over time, with long-lasting components that require minimal maintenance. Additionally, continued research and adherence to international safety standards support the technology's reliability and facilitate its adoption in various settings, contributing significantlyto public health and safety.

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