e-ISSN:2582-7219

INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY RESEARCH IN SCIENCE, ENGINEERING AND TECHNOLOGY

Volume 7, Issue 8, August 2024

INTERNATIONAL STANDARD SERIAL NUMBER INDIA

Impact Factor: 7.521

6381 907 438 6381 907 438 ijmrset@gmail.com www.ijmrset.com

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 7.521| ESTD Year: 2018|

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

Portable Advanced Sterilization System

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ABSTRACT: This paper details the development of a Portable Advanced Sterilization System [PASS] designed to enhance sterilization processes in healthcare, especially in resource-limited environments. The PASS utilizes ultraviolet [UV] light, ozone, and ultrasonic waves to ensure thorough sterilization of medical instruments and surfaces. It is crafted for portability, potential to significantly improve infection control practices. Preliminary results demonstrate significant efficacy in reducing microbial load, indicating the potential of PASS to revolutionize infection control across diverse healthcare settings.

KEYWORDS: Portable Sterilization, UV Sterilization, Ozone Sterilization, Ultrasonic Sterilization, Infection Control, Medical Device

I. INTRODUCTION

Infection control remains a critical concern in healthcare, as insufficient sterilization of medical instruments and surfaces can lead to severe nosocomial infections, increasing morbidity and mortality rates. Traditional sterilization methods like autoclaving, chemical disinfectants, and ethylene oxide sterilization, while effective, pose several challenges. These methods are often resource- intensive, requiring substantial infrastructure, energy, and operational costs, which are not always accessible in resource-limited settings . Moreover, certain medical devices and instruments are sensitive to high temperatures and harsh chemicals, limiting the applicability of conventional sterilization techniques To address these challenges, we propose the Portable Advanced Sterilization System [PASS]. The PASS integrates multiple sterilization modalities—UV light, ozone, and ultrasonic waves—into a compact, portable device. This innovative approach enhances sterilization efficacy and ensures adaptability across various healthcare environments, including field hospitals, rural clinics, and disaster response units. This paper discusses the design, development, and preliminary testing of the PASS, showcasing its potential to significantly improve infection control practices.

Paper is organized as follows. Section II describes technological foundation, Section III describes the methodology, Section IV describes the Experimental results, Section V describes the conclusion of the work.

II. TECHNOLOGICAL FOUNDATION

Traditional sterilization methods include autoclaving, which uses pressurized steam to achieve high temperatures, and chemical sterilization, which employs disinfectants like ethylene oxide and hydrogen peroxide. Advanced methods incorporate technologies such as ultraviolet (UV) light, ozone, and plasma, offering effective sterilization with shorter cycle times and lower temperatures. PASS utilizes a combination of advanced technologies:

• UV-C Light: With a germicidal wavelength, UV-C light effectively sterilizes surfaces and air by disrupting microbial DNA.

• Ozone: As a powerful oxidizing agent, ozone penetrates and destroys microbial cell walls.

• Plasma Technology: This generates reactive species that disrupt microbial DNA and cellular functions. Designing portable sterilization systems involves addressing challenges such as ensuring lightweight construction, durability, and the ability to operate on portable power sources like batteries. Materials must withstand repeated sterilization cycles, and systems must include user-friendly controls and safety features to prevent accidental exposure.

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III. METHODOLOGY

The development of the PASS involved a multidisciplinary approach, ensuring the system's efficacy, portability, and user-friendliness. The core of the PASS lies in its integration of two distinct sterilization methods: UV Sterilization: The system uses high-intensity UV- C lamps, emitting light at wavelengths between 200- 280 nm. UV-C light is well-documented for its germicidal properties, effectively inactivating microorganisms by causing DNA and RNA damage, thus preventing replication and rendering the pathogens harmless [1]. The UV-C lamps are strategically placed within the device to maximize exposure and ensure comprehensive surface coverage. Ultrasonic Sterilization: Ultrasonic waves are employed to create cavitations bubbles in a liquid medium. These bubbles collapse with significant force, generating localized high temperatures and pressures that disrupt microbial cell walls [3, 9]. This method is particularly effective for sterilizing instruments with intricate geometries or lumens, where traditional methods might fail.The block diagram as shown in Fig 1.Represents the architecture of a Portable Advanced Sterilization System controlled by an Arduino Uno microcontroller. Each component interacts with the Arduino Uno to achieve various functions necessary for the sterilization process.

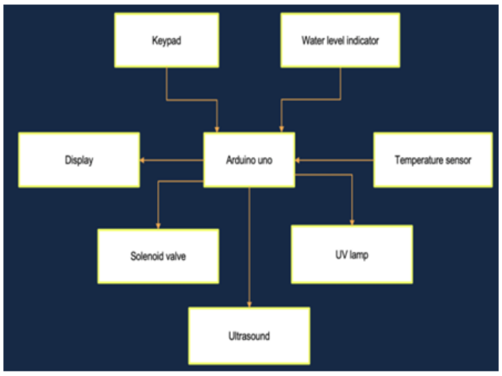

Fig 1 Block diagram of PASS System

Arduino Uno: The central component that coordinates and controls the entire sterilization process. It receives inputs from various sensors and controls outputs to different actuators.

Keypad: Allows users to input commands or set parameters for the sterilization process, such as selecting the type of sterilization, setting timers, or adjusting the intensity of the sterilization method.

Water Level Indicator: Monitors the water level in the system, ensuring there is sufficient water for operations that might require it. It sends data to the Arduino to prevent dry running or to alert when water needs replenishment.

Temperature Sensor: Measures the temperature within the sterilization chamber or surrounding environment. The data is sent to the Arduino to ensure optimal conditions for sterilization and to prevent overheating or other temperature-related issues.

UV Lamp: Used for UV sterilization, a method that employs ultraviolet light to kill or inactivate microorganisms by destroying nucleic acids and disrupting their DNA. The Arduino controls its operation, such as turning it on or off based on user input or sensor data.

Ultrasound: Utilized for ultrasonic cleaning or sterilization, which uses high-frequency sound waves to agitate a liquid and clean or sterilize items. The Arduino manages its activation and monitors its functioning.

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Solenoid Valve: An electromechanically operated valve used to control the flow of liquids or gases. In this system, it might control the water flow necessary for the sterilization process. The Arduino controls the opening and closing of the valve based on sensor inputs and user commands.

Display: Provides visual feedback to the user, showing system status, sensor readings, or user instructions. The Arduino updates the display with relevant information, ensuring users are informed about the system's operation.

Summary of Operations: Operation of pass system is depicted in the diagram Fig 2. •

1. User Input and Control: Users interact with the system through the keypad, inputting commands or settings, which are processed by the Arduino.
2. Monitoring and Feedback: Sensors like the water level indicator and temperature sensor provide real-time data to the Arduino, which processes this information to maintain optimal sterilization conditions.
3. Sterilization Processes: The Arduino controls the UV lamp and ultrasound components, activating them as needed based on user settings and sensor data.
4. Flow Control: The solenoid valve, managed by the Arduino, regulates the flow of water or other necessary liquids in the system.
5. User Interface: The display shows current system status, operational parameters, and alerts, ensuring the user is always informed.

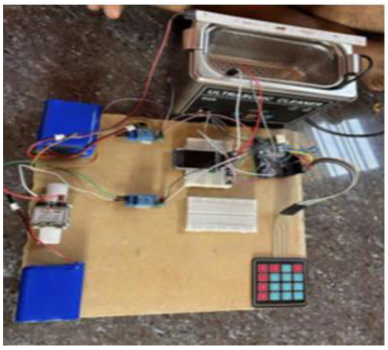

Fig 2 Working prototype of PASS System

IV. EXPERIMENTAL RESULTS

Preliminary testing of the PASS involved laboratory evaluations to assess its sterilization efficacy. The device was tested on various surfaces and medical instruments contaminated with common healthcare- associated pathogens, including Staphylococcus aureus, Escherichia coli, and Candida albicans. microbial load, with the of UV, ozone, and ultrasonic waves proving more than any single method alone. UV sterilization alone achieved a 99.9% reduction in microbial count, while the addition of ozone and ultrasonic waves further enhanced the sterilization efficacy, achieving near- total microbial eradication [5]. These findings suggest that the PASS can provide high-level disinfection, making it suitable for use in critical healthcare settings.

Material	Temperature	Water Level	Ultrasound Time	UV Time
Stainless Steel	32°C	520	15 min	5 min
Ceramics	33°C	511	18 min	5 min
Silicon	32°C	516	15 min	5 min
Cotton	33°C	510	15 min	5 min

Table 1 : Material treatment Parameters

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The table 1 shows the comparison of four materials—stainless steel, ceramics, silicon, and cotton—based on their processing conditions. Stainless steel and silicon are treated at 32°C, while ceramics and cotton are treated at 33°C. The water levels vary slightly, with stainless steel requiring the highest at 520 and cotton the lowest at 510. Ultrasound time is generally consistent at 15 minutes for stainless steel, silicon, and cotton, but ceramics require a slightly longer duration of 18 minutes. The UV treatment time is uniform across all materials at 5 minutes. This suggests that while some parameters like UV time are standardized, others such as temperature, water level, and ultrasound time are adjusted to suit the specific characteristics of each material. The combination of UV, ozone, and ultrasonic waves effectively penetrated and sterilized all surfaces, including hard-to-reach areas. The system's ability to maintain consistent sterilization across different instruments and contamination levels underscores its application in health care.

V. CONCLUSION

The Portable Advanced Sterilization System [PASS] represents a promising solution for enhancing infection control in healthcare settings, particularly in resource-limited environments. By integrating multiple sterilization methods into a portable device, the PASS offers a versatile and effective approach to disinfection, addressing the challenges associated with traditional methods. Preliminary results are promising indicating that the PASS can achieve high-level disinfection and significantly reduce microbial loads on medical instruments and surfaces. Continued development, testing, and optimization will be essential to fully realize the potential of the PASS and ensure its widespread adoption in healthcare practice.

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