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Manufacturing of an Ultraviolet (UV) Sterilization Device for Disinfecting Medical Instruments and Surfaces

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Abstract - *Ultraviolet (UV) sterilization is an effective disinfection method widely used in healthcare, water treatment, and air purification systems. This study explores the mechanisms of UV sterilization, particularly the role of ultraviolet-C (UVC) radiation in disrupting microbial DNA and RNA, preventing the replication of bacteria, viruses, and fungi. The research highlights the historical evolution of UV sterilization, its applications in modern industries, and its increasing relevance in infection control, particularly during the COVID-19 pandemic. This research aims to provide a comprehensive analysis of UV sterilization technology, its benefits, limitations, and future prospects in enhancing public health and industrial hygiene. Findings suggest that while UV sterilization is a powerful disinfection tool, further innovations are required to optimize its efficiency, safety, and accessibility in diverse settings.*

Key Words: Ultraviolet Radiation, Sterilization, healthcare

1.INTRODUCTION

Ultraviolet (UV) sterilization is a disinfection method that uses short-wavelength ultraviolet light (UVC) to destroy the DNA or RNA of microorganisms. When exposed to this UV light, bacteria, viruses, and fungi disrupted and this made as unable to replicate or infect, effectively neutralizing them [1].

This method is highly valued for its efficiency, as it doesn't involve harmful chemicals and leaves no residue. UV sterilization is eco-friendly and widely adopted for applications requiring high levels of hygiene, such as hospitals, food processing, and water treatment [2]. The use of UV light for sterilization started in the early 1900s when scientists discovered that it could kill germs like bacteria and viruses [3]. In 1903, a scientist named Niels Finsen showed that UV light could treat certain skin diseases, winning a Nobel Prize for his work. Soon after, people began using UV light to clean water [4]. In 1910, a city in France used UV light to disinfect its water supply, making it safe to drink. This was one of the first big uses of UV sterilization [5]. Also, UV sterilization can be found in everyday life, i.e. many people use small UV devices to clean things like toothbrushes and mobile phones. Factories use UV light to sterilize medical tools and pharmaceutical products. It's also used in heating and cooling systems to keep air clean. UV sterilization is popular because it is fast, doesn't use harmful chemicals, and leaves no residue, making it safe for people and the environment [6].

1.1. Ultraviolet light in our healthcare environmental

Ultraviolet sterilization is an one of essential tool in healthcare for maintaining cleanliness and preventing the spread of infections.

• Hospitals; use UV light to sterilize surgical instruments, patient rooms, and high-touch surfaces like door handles and bed rails. In operating rooms, UV robots are deployed to ensure thorough disinfection, especially in hard-to-reach areas, fig. 1. This method is particularly effective in combating antibiotic-resistant bacteria such as Methicillin-resistant Staphylococcus aureus (MRSA), which are difficult to eliminate using traditional cleaning methods [7].

Fig -1: Ultraviolet sterilization by robots in deferent department in hospital [8].

1.1.1. Factors affecting efficiency

The effectiveness of UV sterilization depends on several factors that determine how well the UV light reaches and neutralizes microorganisms, including;

• Distance: one of the most critical factors which deepened who person was near to source [9].

• Intensity: the UV light decreases significantly as the distance from the light source increases. For effective sterilization, the light source needs to be positioned as close to the target surface or area as possible [10].

- Time: exposure time is another key factor in efficiency. Longer exposure ensures that microorganisms receive enough UV radiation to damage their DNA or RNA, effectively killing or inactivating them. However, excessive exposure may degrade certain materials, such as plastic or rubber. The cleanliness of surfaces also impacts UV sterilization [11].

2. Principle of Operation of UV Sterilization Device

The sterilization device contains a UV-C light source (usually low-pressure mercury lamps or tubes).When the device is turned on, the UV-C light emitted from these lamps or tubes is directed toward the medical instruments.

- When microorganisms such as bacteria and viruses are exposed to UV-C light, they absorb its energy, which affects their DNA (Deoxyribonucleic Acid) or RNA (Ribonucleic Acid). This interaction causes damage to their genetic material, preventing them from reproducing or making them unable to cause infections.

- UV light causes the breakdown of chemical bonds within the DNA or RNA molecules of microorganisms.This damage to their genetic material halts the reproduction process of the microorganisms, effectively eliminating them.

3. Principle of Operation of UV Sterilization Device

The UV light is divided into three main types deepened on its wavelength to UVA, UVB, and UVC which was explain in table (1-1) and fig (1-1).

Table -1: Table (1-1): category of ultraviolet light with their characteristics [12].

Type	Wavelength range	Energy level	Effects	Uses / Applications	Natural reach to earth
UVA	315–400 nm	Lowest	Causes skin tanning, aging, and minor damage	Limited sterilization power; primarily used for cosmetic purposes (e.g., tanning beds)	Reaches the Earth's surface naturally
UVB	280–315 nm	Medium	Causes sunburn and some DNA damage	Limited sterilization; used in vitamin D synthesis and UVB lamps for certain therapies	Partially reaches the Earth's surface
UVC	100–280 nm	Highest	Kills microorganisms by damaging DNA/RNA	Highly effective for sterilization; used in water treatment, air purification, and surface disinfection	Does not naturally reach the Earth's surface; blocked by the ozone layer

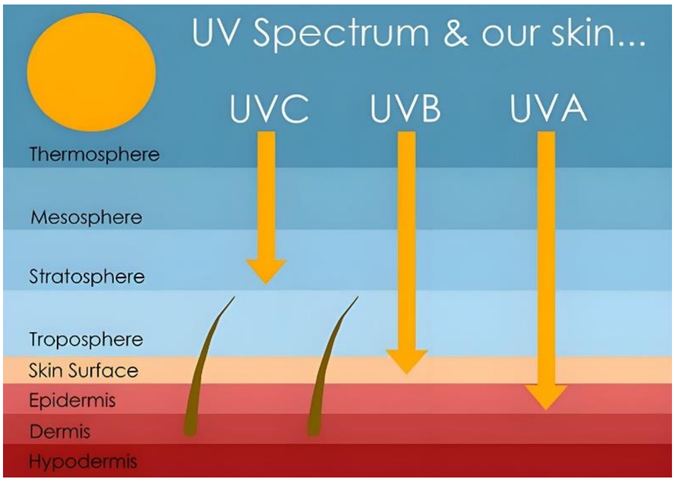

Fig-2: Illustration how ultraviolet light penetration the surface [13].

3- UV Sterilizer device Components

a- UV-C lamps or tubes.

Low-pressure mercury lamps or tubes are the primary source of ultraviolet (UV-C) radiation in the devic.

Fig -3: UV-C lamps

b-Sterilization chamber or treatment room

It contains an open sterilization chamber where medical instruments are placed.

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Fig-4: treatment room.

C- LED display and control unit.

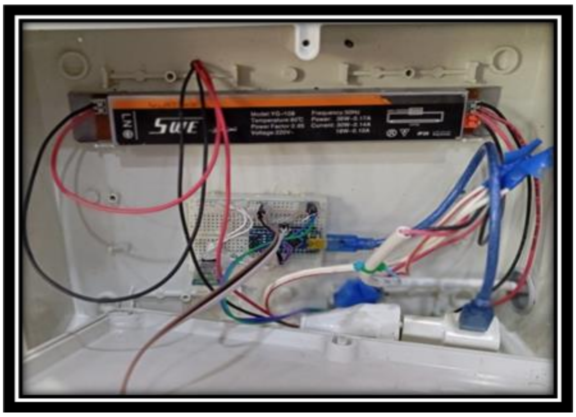

Fig-5: control unit

The UV Sterilization Process:

* Placing instruments in the sterilization device: The medical instruments are placed in the designated UV sterilization device.

* Proper light exposure: Ensure that all surfaces of the instruments needing sterilization are exposed to the UV light.

* Turning on the device: The device is activated, and UV-C rays are emitted.

4. CONCLUSIONS

The UV sterilization process is an effective and safe method for disinfecting medical instruments. By placing the instruments in the designated sterilization device, ensuring all surfaces are properly exposed to the UV light, and activating the device to emit UV-C rays, harmful germs and microbes are effectively eliminated. This process provides a high level of cleanliness and sterilization, helping to reduce the risk of infections and enhancing patient safety in healthcare settings.

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BIOGRAPHIES

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