UV-C Disinfection Technologies

How it works and what are the current applications for health care settings.

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1. Understand the principles of UV-C disinfection technology.

In the constant search for effectiveness, productivity, and risk reduction strategies to address the potential spread of infections through surfaces, we have seen multiple advancements over the years. Until 1970, bleach was widely used as a surface disinfectant in many settings, including healthcare facilities. However, other disinfectants gained popularity thanks to cost reduction and compatibility benefits, prevention of surface damage, and more effective disinfection. While currently quaternary ammonium compounds, peracetic acid, and hydrogen peroxide solutions are commonly used as surface disinfectants, they require a consistent process to ensure adequate surface disinfection, including adequate dilution, contact time, and thorough exposure of the area to be disinfected, which makes the disinfection process time-consuming. In order to address the potential gaps of surface disinfection, newer technologies such as ultraviolet light in the C spectrum (UV-C) have become available in multiple settings. UV-C use as a disinfecting agent has been documented as far back as 1877, with evidence of its effects on Mycobacterium tuberculosis in 1903, and further applications for water treatment in 1910.

UV-C is a very specific type of radiation that can penetrate the surface of some microorganisms, viruses, and fungi, delivering surface disinfection. Due to its high energy, UV-C is harmful to eyes and skin. Most systems currently available use a blue light when operating; this light does not increase effectiveness or deliver microbial inactivation, but is a way to inform the personnel the system is in use and the areas being disinfected should not be entered.

Although the technology has shown its effectiveness, there are some limitations that users should be aware of.

Learning Objectives

1. **Understand the principles of UV-C disinfection technology.**
2. **Summarize current applications in healthcare settings**
3. **Analyze the potential implementation of UV-C systems in hospital settings.**

Table 1: reference dose to inactivate different microorganisms.

Microorganisms	UV-C Dose (mJ/cm²)	Type of Microorganism
Escherichia coli	6.6	Bacteria
Salmonella typhimurium	7.6	Bacteria
Staphylococcus aureus	7.4	Bacteria
Influenza virus	3.4	Virus
SARS-CoV-2	22	Virus
Aspergillus niger (spores)	132	Fungus
Bacillus subtilis (spores)	120	Bacterial spores
Candida albicans	14	Fungus
Adenovirus	60	Virus
Rotavirus	24	Virus

Source: Adapted from Carling P1.

First, UV-C is only effective through direct exposure of surfaces to disinfect; therefore, a 'direct line of sight' is required for UV-C radiation to reach the target area. The second restriction is related to the inability to disinfect surfaces with residual organic matter or dirt, which is the main reason why current systems are marketed as adjuncts to the cleaning and disinfection process. In other words, UV-C systems alone will not deliver disinfection in targeted areas or surfaces.

Like any microbial reduction process, such as skin preparation before an incision or the sterilization process using steam or vaporized hydrogen peroxide, there are specific conditions required for successful surface disinfection. The first one relates to the manual cleaning to remove excess dirt from the surface, and the second relates to the technology itself: the specific dose of UV-C radiation a surface receives is critical to achieve disinfection.

The dose is calculated (Equation 1) as the product of two variables: the specific intensity of UV-C radiation and the time it is exposed to a specific surface. Since microorganisms require different doses (Table 1) to inactivate them, current technologies use a set of test microorganisms to evaluate the efficiency of their systems.

Equation 1:

$D = I \times t$

Where:

D = UV-C dose (mJ /cm²)
I = UV-C irradiance (intensity of the UV light measured in mJ /cm²)
t = exposure time (in seconds).

While a higher dose will reduce the exposure time, additional considerations must be taken as a higher dose may cause damage to common materials found in patient rooms and other healthcare environments. Thus, a carefully selected system, dose, time, and movement within the room are essential.

2. Summarize current applications in healthcare settings

Standard hospital risk assessments take into consideration the probability of contamination, the vulnerability of patients to infections, and the potential for exposure. Hospital standard environmental cleaning procedures include an assessment of the contamination, followed by cleaning from the dirtier to the cleaner sites within a room. In a patient room, this process would begin with the decontamination of direct patient contact surfaces, proceeding to shared equipment and common surfaces. Current CDC recommended practices state that decontamination and cleaning should be carried out in a "methodical and systematic manner"2, followed by addressing any potential body fluid spills. The environmental cleaning should be done with fresh and clean cloths or other disposable material, soaked in a cleaning or disinfecting solution. The cleaning process must ensure that the surfaces are exposed to the disinfecting agent for a suitable time to achieve the desired level of disinfection. Given the high risk of hospital-acquired infections in patient rooms, these are arguably the areas where the most thorough decontamination should be conducted. While manual processes can certainly ensure an adequate level of cleanliness and disinfection of high-touch surfaces, there is evidence that cleaning failures are directly linked to a higher rate of hospital-acquired infections3, which supports the use of adjuncts to disinfection processes.

The currently available systems span single and multiple towers, which carry multiple UV-C emitters. These systems are often referred to as 'robots' as they roam the room, avoiding obstacles and irradiating with UV-C during a pre-set time.

Lesson:

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Quiz Answers:
1. D, 2. B, 3. A, 4. B, 5. A, 6. D, 7. D, 8. A

3. Analyze the potential implementation of UV-C systems in hospital settings.

Given the benefit of this newer technology, it is likely that its use will continue to expand in healthcare facilities, particularly beyond patients and operating rooms. However, before implementing any new technology, it is important to assess its use using both risk-based and feasibility assessments.

From a risk-based perspective, the likelihood of being exposed to pathogens is certainly higher in healthcare settings, for which an adequate decontamination process is paramount. The UV-C decontamination helps to increase the margin of safety when areas and surfaces require low-level disinfection. It is important to understand that the use of UV-C technologies does not replace manual cleaning, therefore, the current processes to clean and decontaminate rooms and surfaces must remain in place.

From a feasibility perspective, the evaluations must include time to complete the decontamination process, the specific dose of the system, and whether there might be equipment or surfaces that may suffer damage when exposed to UV-C. In addition to that, an assessment of the system size, whether it has one or more towers, and the space these towers need to move within the rooms to disinfect are other considerations. The height and number of emitters from each tower or robot will play a role in the effectiveness of the process and the time to complete the decontamination, as the equipment in the room will create a cone of shadows that will prevent UV-C light from reaching every surface. This is commonly addressed by dynamic systems, moving through the room to ensure an adequate dose reaches every target surface.

Conclusions

The implementation of UV-C systems is another available tool for infection prevention in hospital settings. It enables an additional level of safety by exposing surfaces to UV-C radiation, disinfecting surfaces after a thorough cleaning and disinfection process has taken place.

As stated by currently marketed products, this technology does not replace manual cleaning, decontamination, and disinfection, but acts as an additional process or adjutant to the manual disinfection. It is important for healthcare facilities to thoroughly assess current manual processes and their effectiveness in reducing the potential bioburden in targeted areas where UV-C systems will be utilized.

Highly complex areas such as the operating room and intensive care units pose a greater challenge to the UV-C system given the complexity of the equipment in those rooms, the size of the room, and the challenges for UV-C emitters to move within the room.

Like any healthcare technology application, a thorough assessment of the benefits of this technology should be performed, exploring both the current risks of hospital-acquired infections and the feasibility of the implementation of this technology. **HPN**

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UV-C Disinfection Technologies–Practice Quiz

1. **Conventional cleaning and surface disinfection includes**
   A. Adequate dilution
   B. Contact time
   C. Exposure to disinfectant
   D. All of the above
2. **UV-C radiation is safe for people and hospital personnel**
   A. True
   B. False
3. **UV-C requires direct 'line of sight' to achieve disinfection**
   A. True
   B. False
4. **UV-C replaces manual cleaning**
   A. True
   B. False
5. **A specific dose is needed to achieve surface disinfection**
   A. True
   B. False
6. **Consideration when setting the dose includes**
   A. exposure time
   B. material compatibility
   C. System movement within the room
   D. All of the above
7. **Risk assessment for environmental cleaning includes:**
   A. Probability of contamination
   B. Vulnerability of patients
   C. Potential for exposure
   D. All of the above
8. **Cleaning failures may lead to hospital acquired infections**
   A. True
   B. False

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