Hospital Pharmacies' Evaluation of UVC Sterilization Equipment: Analyzing Its Contribution to Infection Control

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Abstract

This project studies how well and how easily Ultraviolet C (UVC) technologies can be used to clean up and sanitize hospital pharmacies. Since controlling infection is critical, especially in sensitive areas of pharmaceutical compounding and storage, UVC technology meets this need safely and efficiently. This research examines how well disinfection works, the plans for setting up devices, worker protection concerns and issues with system integration. Reduced microbial loads on surfaces and equipment in the results show that UVC can help improve hygiene in the pharmaceutical industry. Still, attention to how long the treatment is applied, the impact of shadowing and maintenance suggests that implementation must be exact.

Keywords: ***Ultraviolet C (UVC), hospital pharmacy, disinfection, sterilization devices, infection control, microbial reduction, surface decontamination, pharmaceutical hygiene, healthcare safety, non-chemical sterilization.***

1.Introduction

New disinfection methods have completely transformed how healthcare institutions prevent infections, as ultraviolet C (UVC) technology has become critical for fighting infection. Part of the electromagnetic spectrum, ultraviolet radiation is split into UVC (100-290 nanometer), UVB (290-320 nanometer) and UVA (320-400 nanometer). UVC is a class of ultraviolet radiation that offers the strongest form of germicidal properties which has caught the interest of infection prevention specialists globally. What makes UVC efficient against microbes is that it passes through cells and interacts with both DNA and RNA molecules, destroying them through a damaging photochemical reaction so that microbes cannot survive(1). Because of this principle, UVC technology is becoming more important in hospitals, where maintaining sterility is very important for patients’ safety and obedience to the rules.

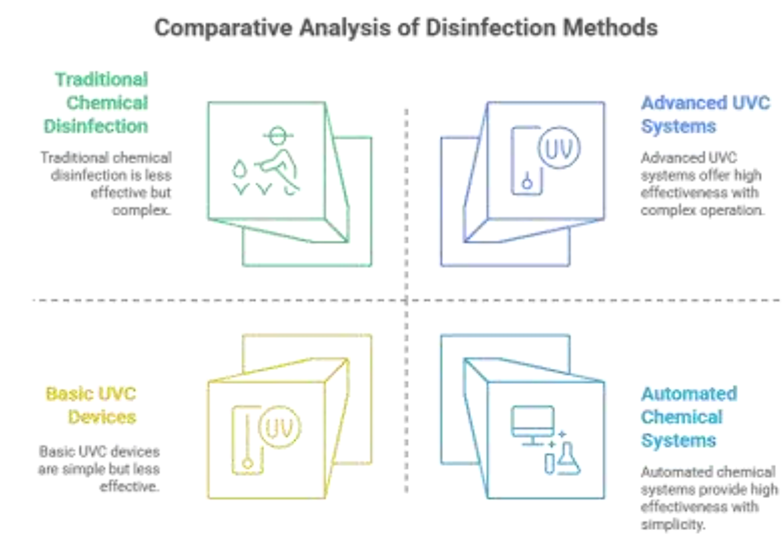

FIGURE 1 Comparative Analysis of Disinfection Methods

From a historic point of view, UVC began as an experimental research tool in the laboratory and only became a recognized medical technique when the COVID-19 pandemic made its use necessary. Worldwide, there has been a major rise in demand for disinfection solutions that can cope with complex microbial challenges and do not need an operator. Even though traditional chemical disinfection works, sometimes its limitations for example, in employee consistency, chemical waste, environmental considerations and lengthy procedures make it difficult to keep up with the day-to-day needs of many healthcare providers. In the field of pharmaceutical compounding, only strict protection from contamination will do, because creating sterile medications must be done according to specific aseptic rules and hygiene standards. Since a tiny amount of microbial contamination in closed spaces can lead to product issues, unsafe circumstances for patients and violations of healthcare regulations, picking the right disinfection equipment is crucial to those responsible for healthcare and pharmacy(2).

UVC technology has antimicrobial properties based on research conducted for many years, proving its action against a wide variety of bacteria, viruses, fungi and spores. When UVC photons are absorbed by the nucleic acid bases known as thymine and cytosine in DNA, they form cyclobutane pyrimidine dimers and other related substances which in turn disrupt normal cellular functions. Because of this molecular injury, microbes cannot reproduce and stop working which leads to their death or inactivation just a few seconds to minutes following exposure to radiation. Modern UVC systems contain advanced features that help guarantee all areas are exposed evenly, guard against operators being exposed to unsafe radiation and verify UVC is working at its best.

2.Latest UVC Technology Platforms and New Engineering Solutions

There are several approaches for UVC generation in technology that vary in how they are used and what advantages they have for healthcare. Mercury vapor lamps are the main UVC technology used today, generating ultraviolet light at a wavelength close to the best for killing harmful microorganisms in DNA. S everal factors contribute to making them superior: significant energy efficiency, the ability to operate up to 8,000 hours continuous use and letting the machine deliver the same dose each time, as this bound protocols require. To ensure low-pressure mercury lamps produce high UVC levels and few unwanted emissions, engineers must factor in control of pressure levels, properly design electrodes and select envelope material.

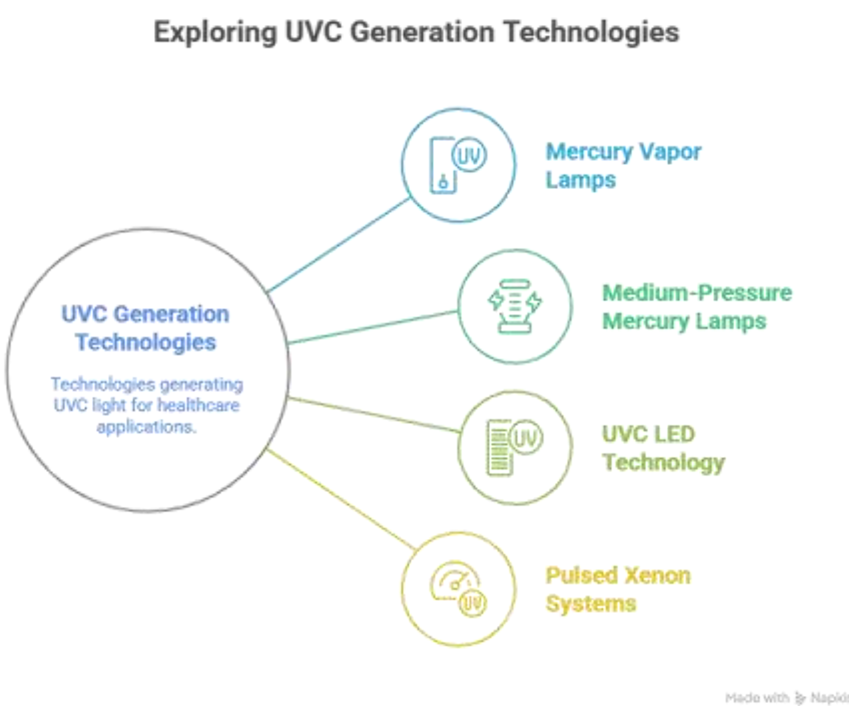

FIGURE 2 Exploring UVC Generation Technologies

Broad ultraviolet emission from multiple wavelengths is achieved by medium-pressure mercury lamps through operating under greater internal pressure and heat. Although such systems provide more intense radiation needed for high volume production, they draw more energy and create more heat, requiring careful management of heat and special arrangements for installation. Displaying a mixture of rays in the ultraviolet range, medium-pressure systems can boost the antimicrobial actions against bacteria found in spores and viruses that appear less sensitive to the single type of radiation emitted by the 254-nanometer model. Yet, the more complicated and costly operation of these systems usually restricts their use to high-volume processing areas where the benefits of their faster processing naturally fit.

LED technology is the newest method for making UVC, allowing for flexible selection of UVC wavelengths, instant switching between on and off, small designs and long operation up to 10,000 hours with optimal use. Unlike traditional lamps, UVC LED systems are free of mercury, deal better with environmental and safety issues and allow for precise wavelength control to target different microbes effectively. Being solid state makes it much easier to fit LEDs into mobile gadgets, advanced control systems and creative projects than with regular lamps. The recent improvements in LED manufacturing have boosted their performance and reduced their cost, making these devices comparable to common alternatives in most healthcare settings(3).

This approach uses strong flashes of radiation at the UVC spectrum in very short periods. When used together, UVC photochemistry and heating disrupt microorganisms and disperse biofilms. The speed of treatment is high and heat remains controlled thanks to the pulsed system, so this technology can be trusted in applications that are damaged by continual UV radiation. Because of their extensive range of visible and invisible wavelengths, light from pulsed xenon units may help fight germs by producing photodynamic effects and increasing cell oxidants.

3.Strategic Benefits and How were used in clinical settings

When added to healthcare environments, UVC technology brings about several improvements that deal with issues found in traditionally applied disinfection methods. Capitalizing on UVC disinfection’s non-contact approach prevents the operator variability seen in manual cleaning and disinfecting, since inexperience, rush approach and mistakes might affect the thoroughness of the treatment. By using electronic management systems, users can provide reliable, consistent treatment steps for documentation and meeting regulations. Because properly made UVC systems can treat many areas in a matter of seconds to minutes, they quickly support hectic healthcare operations with little or no disruption to patient care.

Chemical-free use of UVC is an important benefit since it prevents residue buildup, protects equipment from incompatible chemicals and avoids polluting the air and disposing of chemical-based disinfectants. For this reason, the characteristic is very useful in pharmaceutical compounding where chemical residues could make sterile items unsafe or change the makeup of active pharmaceutical ingredients. An auto self-polishing method helps cut costs in the long run and reduces the risks that come with depending on outside chemical supplies. Environmental factors point to UVC technology because it creates little waste, relies on less packaging and keeps chemicals out of the wastewater.

Thanks to its versatility, UVC technology is applied everywhere from disinfecting patient rooms and operating rooms to use in clean rooms for medicine and cleaning of medical devices. A mobile UVC unit is good for treating various areas with a single device, but fixed installations fit better into regular workflow routines. Not disturbing the sterile barrier on packages gives pharmaceutical applications a major benefit, as primary packaging for sterile systems must first be disinfected before use. It removes the requirement for chemical transfer or using extended aeration cycles typical with hydrogen peroxide vapor systems.

Stopping bacteria with UVC means companies fulfill both the rules of regulatory bodies and strict quality standards set for accreditation in healthcare and pharmaceuticals. Due to the inclusion of sensors, data recording and control systems, these devices allow for the thorough recordkeeping needed to show that proper care and trackability were used during infection control. UVC technology’s predictable way of killing microbes allows researchers to check and improve treatment plans and adjust UVC exposure to match what is needed for various requirements.

4.Both challenges and precautions as well as coping strategies are part of this subject

There are hundreds of positive aspects to using UVC technology, but it’s important to check for significant limitations and deal with safety issues during planning and while the system is working. Since UVC light must be in direct view of a surface to work, important attention must be paid to placement, blocked areas and the area’s ability to be reached by the light. Because complex shapes, indentations and materials with multiple layers do not always get enough UV light, it’s possible that dangerous microorganisms will remain in those spots. Because surfaces are uneven, proper cleaning may require extra methods and possibly the use of several exposure positions or different types of reflectors.

Compatibility of materials also matters, because many substances such as pharmaceuticals, plastics and basic materials, may react adversely to UVC rays. Compliance testing is needed for everything receiving UVC exposure to discover if product quality, appearance or chemistry may be affected by the treatment. Certain materials can break down if UVC is used, so handling them requires care, different methods or removing them from the equipment. Since UVC radiation cannot penetrate far, it is not much use for sterilizing areas where things may be contaminated inside or on thick surfaces(4).

It is very important to take safety precautions with UVC technology by teaching staff, setting up engineering restrictions and using careful procedures to protect them from radiation. Just seconds of direct exposure to UVC can lead to serious harm to the skin and eyes, so interlocks and warning devices are needed, along with proper personal protective equipment procedures. All installations must be equipped with suitable shielding, good ventilation and procedures that stop ozone production when necessary. A key part of a UVC safety management system is routine safety training, well-kept equipment and exposure consideration.

A growing issue is that sublethal UV exposure may lead to microbes becoming resistant, so protocols should be designed and followed with this in mind. Studies have indicated that good UV treatment requires at least adequate UV capacity or avoiding the same exposure multiple times to stop resistant microbes from developing and to maintain effective long-term treatment. So, it’s important to confirm the right doses, keep checking how well the treatment works and maintain rules for providing the required lethal amounts to all focused microorganisms. Assurance programs for quality must involve biological sources, checking environmental conditions and conduct ongoing validation trials to ensure no changes in effectiveness appear.

What the Future May Bring in Technology

The ongoing changes in UVC technology give many options to enhance performance, add more uses and integrate with other parts of the healthcare sector. Because LEDs keep improving, UVC systems will become both more valuable and widely used in healthcare settings. Smart sensors and AI makes it possible for key exposure controls to adjust automatically in response to the real-time environment, pollution levels and the properties of the materials, aiming for greater performance and less wasteful exposure.

When UVC is applied together with other disinfectants such as photocatalytic oxidation, the effect of other technologies is enhanced, addressing part of what is lacking in single UVC systems. Using different types of radiation might help care for more diseases, possibly with shorter treatment sessions. Using different wavelength combinations and pulsing technologies may uncover the best ways to manage germs that reduce the risk of harm and save resources(5).

Making standards and regulations will help expansion and guarantee similar results in different applications used by various companies. Having set testing processes, key metrics and safety rules ensures healthcare facilities can choose technology confidently and easily compare its capabilities to other systems. When integration is achieved with present building automation, infection control protocols and quality management guidelines, implementation and operation can be made simpler. With UVC technology advancing and showing results in health care, its place in full-scale infection prevention plans is expected to grow, helping make health care safer for patients, smoother for staff and more effective for the public.

5.Controlling Pathogens in Healthcare Facilities: A Thorough Look at Ultraviolet Germicidal Technologies

How Microorganisms Become Resistant to Microbicide Effects and Adapt to UV Radiation

One of the biggest and most interesting issues in using antimicrobials in healthcare settings is the resistance of microbes to ultraviolet radiation. To resist UV radiation, bacteria use different strategies than antibiotic resistance.

Instead of breaking down substrates, pumping out toxins or changing targets, bacteria fix their DNA with sophisticated mechanisms used for billions of years to fight sunlight. Organisms use photorepair mediated by photolyase that reverses damage caused by UV rays when lighted and can use nucleotide excision repair and recombination repair at any time, even if no light is present. In some microorganisms, including those found in the desert, by the ocean and in other extreme environments, these cellular defense systems are very successful due to the extra pressure to repair damage caused by UV rays in their environment.

New research shows that hospital pathogens can develop UV resistance after receiving low levels of radiation from germicidal UV several times. Researchers have observed in Escherichia coli populations that were repeatedly subjected to UV irradiation that a number of mutants were able to survive the harsh UV rays much better than the original parent strains, with some showing over ten-fold more tolerance to UV. As a result, the DNA repair system is stimulated, the number of protective proteins is boosted and rearrangements are made to the cell’s structure that decrease its vulnerability to sunlight damage. The risks for healthcare are high, because insufficient UV lighting or equipment failures might result in microbes that cannot be stopped by usual treatments, making people more likely to catch healthcare-associated infections(6).

Because of the way they are built, spore-forming bacteria must be handled differently during UV disinfection since they are very resistant and difficult to kill. Unlike other bacteria, Bacilli Clostridium such as Clostridioides difficile, are protected by UV-absorbing substances in their multilayer spore coat, small proteins that guard the DNA and a low water content that limits reactions in sunlight. Therefore, to inactivate bacteria with UV light as effectively as with vegetative cells, you must use much more energy and let the treatment go on for longer periods. Because spore resistance becomes very important in healthcare, these organisms continue to contaminate the environment for long periods, even when regular disinfection is performed.

Different UV sensitivity shows up in viral pathogens due to factors such as their genomes, coats and how they multiply, so the approach to using UV needs to be considered with these things in mind. The majority of enveloped viruses such as influenza, coronaviruses and herpes viruses, are more affected by UV light because their lipid envelopes are easily harmed by it. Furthermore, non-enveloped viruses such as noroviruses, adenoviruses and polioviruses, owe their resilience to UV rays to strong protein coatings, meaning that exposure to UV light in large quantities is necessary. When viruses change their outer coat or gain abilities to fix their genetic material, there are new concerns for solar radiation-based disinfection.

Since fungal pathogens are structurally and visually different, it is not always easy for UV to deactivate them. Aspergillus niger and Cryptococcus neoformans which contain melanins, have much lower UV damage thanks to the way melanins work to absorb and dissipate this energy. Having different shapes can cause some dimorphic fungi to react differently to UV light which complicates designing a single treatment method. Because fungi have strong cell walls, UV rays often do not reach vital parts of cells, but some fungi can mend DNA swiftly after damage by UV radiation.

Things in the environment that Impact UV Disinfection

How effective ultraviolet germicidal irradiation systems are mainly hinges on a number of conditions in the environment that shape photon delivery, bacteria exposure and how well treatment is done. Changes in the temperature inside treatment areas can influence both microbial behaviors and the way UV lamps work and most mercury-based UV lamps operate most effectively at different temperatures than usual facility conditions. If temperatures are low, lamps take more time to reach their full UV level, while higher temperatures can harm the lamp and also alter what type of radiation it gives out(7). A low microbial temperature can sometimes shield organisms by lowering the rate of metabolism and changing how permeable their cells are.

Operating in high humidity conditions can reduce the effectiveness of UV disinfection in several different ways by influencing not only equipment performance but also the behavior of microorganisms. Condensation threats that result from high humidity in the environment can reduce light walkthrough and lead to shadowing which complicates keeping an even UV dose. Absorption of UV radiation by water vapor can reduce how effective the UV irradiation is in chambers with elevated humidity from continuous use. Meanwhile, conditions with very low humidity could alter a microbe’s ability to withstand drying out and let cells fix damage which could influence how sensitive it is to UV light.

How air is distributed and moved in a treatment zone influences the efficiency of UV systems by managing the movement of particles, the levels of pollutants in the air and the device's heat control. The shape of the airflow created by laminar airflow systems in pharmaceutical clean rooms can help or hinder the effects of UV lamps placed around these rooms. Rough airflow situations ensure particles are well mixed, yet they can lead to unnecessary contamination and unpredictable effects in the shadows. Parts of UV radiation are lost or absorbed by airborne dust, lint and aggregates which become a barrier between the source and the surface the light is intended to disinfect.

How effective UV disinfection is often depends on organic coatings, antibacterial properties of surfaces and the reflection, absorption and shade offered by different objects(8). It is possible that stainless steel and polished aluminum increase the uniformity of treatments by creating multiple reflection paths for UV light and decreasing the occurrence of shadows in complex layouts. Some surfaces that absorb a lot of light, on the other hand, can cause UV energy to disappear, lowering the system's efficiency and leaving some areas with insufficient UV light. For instance, the uneven nature of surfaces and the presence of microorganism biofilms on them shield them against direct UV light which, in turn, leads to the material being exposed to much higher treatment doses.

Chemical substances in healthcare can interfere with UV disinfection by having UV absorb it, by taking part in photochemical reactions or by scavenging harmful chemical groups and decreasing antimicrobial effects. UV photons that hit cleaning agents, pharmaceuticals and biological materials found in hospitals may be gobbled up by those compounds, thus being blocked from reaching and damaging microorganisms. Photoexciting some chemical compounds may make them create reactive species that can either destroy or protect target microbes. Having solvents, preservatives and active ingredients mixed in a pharmaceutical compounding area can make it tough to use UV disinfection.

6.Methods and Standards for the Quality Assurance of Products

Applying detailed quality control programs for UV disinfection calls for precise tools, standardized approaches and continuous reviews that guarantee ongoing adequate operation and compliance with laws. Using UV sensors that have been properly calibrated allows us to measure levels of radiation, how it is distributed and the stability of these measurements for any validation procedure. It is difficult to decide on the right measurement instruments, because they have to meet requirements about spectral specificity, their angle of detection and how stable their calibration is. Broadband instruments may not always determine how germicidal a polychromatic UV source is, while precise targeting of wavelengths is necessary for narrow-band machines to be useful.

Demonstrating how well a UV system works involves using standard indicator organisms, but the choice of these organisms depends on qualities of the target pathogen, its resistance and what regulations say. Because the spores of Bacillus subtilis are highly resistant to UV light and easy to culture, they have often been used as conservative biologics in waste treatment, although their usefulness for healthcare pathogens is not clear. Laboratories can find growing Staphylococcus aureus or Pseudomonas aeruginosa to be useful for study because they provide clinically relevant details, though the right conditions for growth, harvest and storage are essential and essential to preserve their properties. Working with viral indicators is challenging, since they often do not behave the same as true pathogens and they have hard-to-grow requirements(9).

Dosimetry calculations and modeling allow for predicting the effectiveness of UV systems and creating better treatment routines, yet it is often hard to accurately define system geometry, optical properties and where the microbes are located. By using ray-tracing models, we can calculate light distributions throughout complex treatment volumes, but these calculations rely on correct details such as the setup of lamps, reflectors and the nature of surrounding surfaces which may vary with use. Using computational fluid dynamics, it is possible to predict how airborne particles and bacteria move and mix, guiding UV exposure; however such models must be confirmed against real-life experiments to be accurate.

It is important for environmental monitoring programs to consider that the state of healthcare environments changes, affecting contamination patterns, microbial populations and the way things are done. These surface sampling approaches show current levels of contamination, but they do not always give the complete picture of where the microorganisms are and whether they are alive. Air sampling is used to find out if air samples contain contamination, but sampling conditions and the size of the particles are important in UV testing. Analyzing the data from monitoring requires methods that can deal with natural variability, uncertainty in sampling and the limit to detecting changes in the system.

Control over UV disinfection data demands that we record all parameters, actions taken during upkeep, test outcomes and investigations into any deviations in formats suitable for legal inspection and audits. All logbooks should record hours the lamps are on, the intensity of the light at each reading, the actions carried out to maintain them and any notes on problems seen. All validation procedures should be recorded using enough detail to make sure trustworthy results can be repeated by anybody, with information on the tests, conditions, standards and the analysis used. Change control procedures should handle modifications to equipment, changes in protocol and any changes in operations that might influence the performance or validation of the system.

7.Looking at the Analysis of the Economics and Efficiency

The introduction of UV disinfection technology in healthcare involves a main investment, additional running costs and the chance to save money when used with current infection prevention efforts. Different types of equipment cost vastly different amounts, depending on the system's design, treatment it offers, included automation and regulations each product requires. The choice to install UV technology is guided by analyzing the entire cost over its operational life, including equipment wear and tear, service agreements, electricity use and necessary training.

Operational expenses include costs for electric energy, buying lamps for the lights, specialized labor and materials and these costs depend a lot on which UV technology and use scenario you have. Most mercury lamp systems need new lamps about every 8,000 to 12,000 operating hours, with each lamp costing anywhere from hundreds to thousands of dollars. LED systems may have a lower upkeep cost over their lengthy lifetimes but might cost more to purchase than traditional alternatives, depending on each situation and how power is priced where you are. It's important to take into account not only the UV lamp's power but also side equipment like cooling systems, ventilation units and the electronics that affect operating costs in energy simulation.

Benefits from fewer healthcare infections, savings from using less disinfectant, smoother operations and better compliancy should be shown to offset the cost of purchasing and setting up a UV system. Each healthcare-associated infection that requires extra care and postpones the patient's hospital checkout can cost up to $50,000, so preventing only a small number might be enough to cover the initial investment in an ultraviolet system. Not only do chemical disinfectants cost money directly using UV disinfection can bring savings for PPE, ventilation, waste removal and managing inventory(10).

Manual labor savings and the expenses related to operating, maintaining and testing UV disinfection systems are both recognized by labor cost considerations. Using computerized UV systems can lower the time spent sanitizing surfaces, giving healthcare staff extra time for important care tasks. Nonetheless, running a UV system often necessitates extra training, regular checks and monitoring which means adding labor. The impact of new systems on healthcare labor depends on design, automation, how well they fit with existing procedures and how effectively staff handle these changes.

To be valuable for healthcare administrators, return on investment should count the effects of time value, low returns due to risks and the trade-off of choosing another infection prevention method. Analyses of the payback period should take into account varying use of the system, infection rates across seasons and possible changes in how quickly pathogens develop resistance. Sensitivity analyses suggest where important assumptions and parameter ranges are and what impact these may have on the outcomes of an investment project.

Usage of Smart Building Technology and Automation in Buildings

Bringing UV disinfection technology into intelligent building systems offers a new chance to improve infection prevention, make operations more efficient and use data for better decision making. Through better sensors, intelligent algorithms and network systems, today's building automation platforms join UV disinfection efforts with heating, air conditioning, ventilation and security systems to respond effectively to contamination or infection events. Sensors on occupancy monitor vehicles automatically program UV systems to run only when spaces are not occupied. Changes in the air's quality, moisture or temperature that may trouble the UV system can be caught by environmental monitoring systems which then control operational settings to keep optimal conditions.

Using the internet of things (IoT), sensing systems at many treatment sites monitor UV lamp working, doses received and the environment, so that officials can track and fix problems quickly, ensuring reliability and averting service outages. Using wireless communication protocols, companies in the UV industry can keep records of their operational data in electronic health records, infection monitoring systems and databases for ongoing improvement on compliance and quality. Using performance history, contamination data and environmental information, machine learning can devise the best treatment routines, alert about possible equipment problems and propose improvements that improve effectiveness with low cost.

Applications of artificial intelligence in UV disinfection cover forecasting, automatic systems and flexible response to sudden changes. Systems that depend on advanced image processing can inspect for surface contamination, spot places needing extra attention and make sure everything is arranged correctly in the UV treatment chamber. Tools in natural language processing study infection surveillance reports, maintenance records and published scientific articles to spot new health risks, patterns of resistance and smart suggestions for using ultraviolet systems.

With the help of integrated systems, UV disinfection activities can be matched to patient care activities, infection investigations and studies that improve overall efforts to prevent infections. If an infection prevention team receives an automated warning, it means the UV system has failed in a high-risk area or during elevated infection rates. By automatically connecting treatment data to patient areas, planned procedures and reports of infections, we can support the review of UV's performance and recommend changes to existing protocols.

Because UV systems are part of medical equipment, cybersecurity must use strong tools to secure them and keep cyber threats from changing disinfection processes that could cause harm to patients. It is necessary to network segment UV control systems and set up encryption protocols, just as it is to add access controls to keep these systems separate while enabling needed data access and monitoring. You should monitor your system, update it frequently and train individuals to keep your sensitive healthcare systems safe from any possible attacks.

8.Conclusion and Future work

The thorough review of ultraviolet germicidal irradiation technology in healthcare facilities shows lots of opportunities, some difficulties and changes happening, all of which should be considered by healthcare administrators, infection prevention specialists and those implementing technology. Properly set up and used UV systems have been proven by science to significantly reduce microbial contamination in many medical settings such as surface wiping and organized pharmaceutical production. Turning these findings into helpful results for patients demands knowledge of microbial resistance, changes in the environment, limitations of care delivery and what is affordable. New resistance methods, especially better DNA repair and reaction to UV, make it necessary to carefully apply, verify and keep checking the radiation dosage during a product's entire operation period.

Because UV disinfection technology is so varied, healthcare leaders now have many options to choose from, yet they also have to consider their own needs and limits. Healthcare professionals rely on traditional mercury lamp systems because they provide known reliability, validated methods and lots of proven experience. Still, new types of LED lighting have some clear benefits in flexibility, environmental protection and integration which can make their higher upfront costs and changing capabilities worthwhile. Pulsed xenon systems are found where fast treatment cycles and broad coverage of antimicrobials make their special procedures and pricing acceptable. Choosing the much needed UV technology should take into account requirements, barriers, workflows and goals, instead of just focusing on costs.

The way the environment affects an UV system's function reflects that proper system planning should be based on how the technology's capabilities match the real working conditions. Problems with treatment effectiveness can be caused by changes in temperature, humidity, airflow, surfaces and chemical factors, some of which may only become apparent after you start using the system. The process of developing standard operating procedures should cover environmental aspects by adjusting the system's size, setting suitable controls, planning monitoring work and setting contingencies for all likely operating situations. These environmental factors must be considered in quality assurance by using thorough validation work, monitoring performances over time and performing new studies when needed to make sure the system is still effective.

To justify using UV technology in an industry, it is necessary to look deeper than capital costs and take into account its impact on the whole ownership cycle, better running of core processes, risks it can manage and strategic pluses that are not easily measured by common financial tools. Using UV technology for healthcare-associated infection prevention offers a strong reason to make important investments by boosting patient outcomes, decreasing exposure to liability and increasing operational efficiency. Even so, the full benefits can come to light only when the company chooses the right system, prepares team members well, makes sure their processes are reliable and constantly optimizes its performance with ongoing organization support and resources. Working UV technology into various infection prevention plans, quality strategies and performance programs makes it more valuable and ensures it can be kept for a long time.

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Conflicts of interest

The authors have no conflicts of interest to declare

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