



UV Effectiveness Against Coronavirus

E X P E D I T E D S H I P P I N G · S U P E R I O R C U S T O M F A B R I C A T I O N

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1.0 Executive Summary

This white paper examines the effectiveness of ultraviolet (UV) light treatment in eliminating different strains of coronavirus. Initially, UV light and its properties that contribute to sanitation, as well as lighting conditions that promote thorough disinfection are presented to provide a background on the mechanisms of UV light treatment. UV bands responsible for killing harmful microbes are dangerous to humans. Taking this precaution into consideration, best practices surrounding UV light safety are also showcased in the paper. UV disinfection has been around for decades and is commonly found in food processing, wastewater plants, hospitals and laboratories. These use cases reinforce the feasibility of utilizing UV light to eliminate coronavirus.

Larson Electronics is a manufacturer of industrial lighting systems, explosion proof devices and power distribution products. The company has more than 40 years of experience in the industrial sector, serving a wide range of organizations. Leveraging the establishment's expertise in lighting equipment, UV light devices used for UV disinfection are showcased in the paper to provide sanitation solutions for businesses and operators affected by the coronavirus.

2.0 Introduction

UV light contains several unique properties and characteristics, which can be used to disinfect viruses, bacteria, mold, spores and other harmful microbes. This sanitation method relies on UV-C wavelengths, i.e. UV bands within a range of 200 nm to 280 nm, to deactivate the cellular ribonucleic acid (RNA) and deoxyribonucleic acid (DNA), as well as the reproductive capabilities of microorganisms. According to data from the International Ultraviolet Association (IUVA)¹, UV treatment has been around for more than 40 years. As a tried-and-tested solution, UV disinfection is prevalent in hospitals, medical or healthcare centers, laboratories, food processing, wastewater facilities, HVAC system management and more.

At the beginning of 2020, the spread of coronavirus 2019 (COVID-19 or SARS-CoV-2) caused a surge in using UV light to sanitize buildings, work sites, equipment, respirator masks and patient rooms. UV treatment is confirmed to eliminate COVID-19 by Juan Leon, an environmental health scientist at Emory University². Through published studies and documentation, researchers have verified UV-C sanitation to deactivate previous strains of the coronavirus, such as Severe Acute Respiratory Syndrome (SARS-CoV) with the first human case appearing as far back as 2002 and Middle East Respiratory Syndrome (MERS-CoV) with the first human case appearing as far back as 2012. During the spread of SARS-CoV and MERS-CoV (respectively), UV light disinfection played a vital role in preventing the spread of disease.

In addition to coronavirus, UV light is used to deactivate other types of harmful disease-causing microbes. According to experts from University of British Columbia, University of Alberta,

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University of Colorado-Boulder and Trojan Technologies³, UV-C light is capable of killing tuberculosis, *e.coli*, *methicillin-resistant S. aureus* (MRSA) and more. This form of sanitation also targets mold, spores, fungi and yeast.

There is a myriad of factors that must be taken into consideration when administering UV-C light to eliminate viruses or bacteria in the area. These factors include: light intensity, duration of treatment, distance between the UV light source and object or surface, obstructions and environment (temperature and humidity). To ensure effective UV disinfection, different types of UV-C devices can be utilized. A portable sanitation cart that emits a full, 360-degree UV-C beam is ideal for sanitizing large rooms or facilities; while a handheld UV-C lamp is designed for cleaning objects or hard-to-reach surfaces and equipment. A compact UV sanitation box could be used to disinfect personal devices and tools on the field or at facilities. UV light is also capable of disinfecting air in occupied spaces.

UV-C light is harmful to humans as it can cause burns on the skin and damage the cornea. To ensure safety, individuals should proactively avoid UV exposure through the use of safety glasses, gloves, suits and other protective gear.

3.0 UV Light Sanitation

UV light contains special properties that deactivate the RNA and DNA of harmful microbes. Successful UV-C sanitation requires taking the following into consideration: UV wavelength or band range, light intensity, exposure and duration of treatment. As short-wave UV-C light is dangerous to humans, safety must be prioritized during UV disinfection by wearing protective gear, including gloves, suits, glasses, visors and masks.

3.1 How Does UV-C Disinfection Work?

UV light consists of three primary wavelength ranges: long-wave UV-A (315nm to 400nm), medium-wave UV-B (280nm to 315nm) and short-wave UV-C (200nm to 100nm), as defined in ISO-21348 Standard⁴. In outdoor environments, UV-C is completely absorbed by the ozone layer of the Earth's atmosphere. This UV range is known as the germicidal range due to its ability to deactivate viruses and bacteria (UV-A and UV-B do not have the capabilities – because of this, the focus of the paper is the UV-C range). UV-C light can be generated by artificial light sources, such as mercury vapor and fluorescent lamps. This technological advancement ushered the mainstream application of UV radiation for disinfection, allowing UV-C light to be used in buildings.

During sanitation, UV-C light in large, concentrated doses causes RNA and DNA mutations in microbes during absorption. The ideal wavelength for peak absorptivity occurs at a wavelength of 254nm to 262nm. According to a 2012 study published in *US National Library of Medicine*

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National Institutes of Health⁵, UV-C treatment has the following devastating effects on microbes:

“The light-induced damage to the DNA and RNA of a microorganism often results from the dimerization of pyrimidine molecules. In particular, thymine (which is only found only in DNA) produces cyclobutane dimers. When thymine molecules are dimerized, it becomes very difficult for the nucleic acids to replicate and if replication does occur it often produces a defect that prevents the microorganism from being viable.”

It should be emphasized that when enough thymine dimers are made in the cell, DNA replicated in cell mitosis ceases. This deactivation mechanism is also applicable to viruses that only have RNA, i.e. “photochemical dimerization reaction takes place between two uracil bases”. UV sanitation of an area is considered successful when the virus or bacteria is deactivated and reproductive capabilities are significantly reduced or stopped. Such objectives prevent the microbe from spreading and decreases the rate of infection (for harmful viruses or bacteria).

3.2 Intensity, Exposure and Duration

For thorough and consistent disinfection, UV light must be applied radiantly with an exposure rate of 400 mJ/cm² (exposure rate requirements may vary). The rate of exposure is critical to the application of UV. When an object is removed from the UV field, irradiation ceases immediately (carryover treatment does not occur). The response of UV treatment is often described as sigmoidal. Immediately after exposure, microorganisms sustain maximum injury. After the initial phase, only a minimal dose of UV is needed to finish off the remaining survivors. The process ends in a tailing phase, which diminishes UV-resistant microorganisms. An estimated 5-60 minutes of exposure is required when conducting UV treatment. This range is wide; as light intensity must also be factored in during the process. Intense UV light exposure is more effective and makes the sanitation process quicker, compared to UV light administered at low intensity levels and far distances. Furthermore, surfaces must come in contact with the light beam to ensure effective sanitation. The presence of shadows may hinder UV-C light rays from reaching the target area.

3.3 UV Light Safety

UV-C light is a powerful solution against disease-causing microorganisms. For humans, exposure to this range of UV light is harmful. Direct exposure can lead to skin burns and damage the cornea. Unlike standard (non-UV) illumination, looking at UV lamps does not cause a natural squinting reaction. In some cases, the negative effects of UV exposure are delayed by more than six hours. As a safety precaution when sanitizing rooms, humans should not be present in the area during the process. Operators may setup temporary signs around the space to ensure people are aware of ongoing sanitation and avoid exposure.

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3.4 Methods of UV Treatment

There are numerous ways to facilitate UV treatment and administer UV-C light for sanitation in rooms and on surfaces or objects. For large spaces or facilities, a portable UV cart with four to eight UV-C fluorescent lamps is ideal to ensure wide and full coverage of the area. This solution is also applicable to sanitizing public transit fleets (buses and trains) and commercial planes. A UV handlamp can be utilized to disinfect hard-to-reach surfaces, odd-sized equipment and objects. This type of UV light may come equipped with a light guard to reduce light spillage or unwanted UV exposure in the surrounding area. A permanent UV sanitation solution for offices or buildings could come in the form a dual lighting fixture with a combination of standard (non-UV) and UV-C lamps. The air of occupied spaces can be sanitized using UV-C light. This type of disinfection device consists of a UV-C lamp protected by a heavy-duty enclosure (to prevent exposure) and is equipped with vents to promote air flow. The compact unit cleans the air passively and discreetly (no noise).

4.0 UV-C and Coronavirus

The coronavirus comes in many forms. During the spread of these strains (respectively), UV light was used as a reliable method of sanitation. The effectiveness of UV-C light in deactivating SARS-CoV-2 extends to rooms and protective equipment, such as N95 masks. Maximizing UV light treatment requires using different types of UV devices to promote the reach and intensity of UV-C light beams.

4.1 Types of Coronavirus

According to the National Institute of Allergy and Infectious Diseases⁶, there are many forms of coronavirus. Three strains that are potentially fatal to humans (if left untreated) include: SARS-CoV, MERS-CoV and SARS-CoV-2. These strains target the breathing or respiratory systems of humans, making clean air an essential aspect of recovery. Under a microscope, the coronavirus contains club-like spikes around its body and has a large RNA genome⁷. SARS-CoV-2 is highly infectious and can be spread through contact and the air. Moreover, men and senior citizens are more susceptible to getting sick from this coronavirus strain, compared to women and children. To date, there are no pharmaceutical drugs or vaccines available on the market today that eliminates SARS-CoV-2. Medical treatment for coronavirus involves addressing the primary and underlying symptoms associated with the disease, such as inflammation, difficulty breathing, fever, pulmonary fibrosis and more.

4.2 UV Effectiveness on Previous Coronavirus Strains

4.2a SARS-CoV

UV-C light is effective in eliminating different types of coronavirus. In a 2004 study⁸, scientists examined the effects of UV-C light in the 254nm spectrum on survivability of SARS-CoV cultures. The tests were performed in a biosafety level 3 (BSL3) lab. Researchers were able to inactivate SARS-CoV to non-infectious levels through UV-C exposure, heat treatment of 65°C+ and “alkaline (pH > 12) or acidic (pH < 3) conditions”, as well as formalin and glutaraldehyde treatments. Following this study, scientists attempted to eliminate SARS-CoV from non-cellular products in a 2006 experiment⁹ using the following disinfection methods: heat treatment, UV-C light and chemical treatment. The results indicated that heat treatment at 60°C deactivated SARS-CoV in 15-30 minutes. UV-C light was able to achieve sanitation in 40 minutes. Comparing the two disinfection methods, multiple cycles of heat treatment can damage the surface or equipment not designed for use or exposure at high temperatures. At germicidal doses, UV-C light does not have the same effect on surfaces (an extremely high dose of UV-C light is required to cause damage to non-sensitive surfaces).

The results from the two studies above can be confirmed in another research. In a 2003 study¹⁰, scientists successfully disinfected the SARS coronavirus to undetectable levels by exposing the microbes to UV irradiation for 60 minutes. The researchers were able to conclude that UV exposure caused the virus to become ineffective and reduced viral activity to a non-infectious state. More recently, a study published in 2020¹¹ showed that UV-C treatment against SARS-CoV was still effective since its emergence more than 15 years ago. In this study, researchers applied shortwave UV-C light to inactivate SARS-CoV from platelet concentrates and plasma. During treatment, a half to 75% dose of the full UV-C dose (0.2 J/cm²) was administered to SARS-CoV. This treatment reduced the virus to ineffective levels and to the limit of detection (LOD) in platelet concentrates. Researchers were able to eradicate SARS-CoV in plasma at 25% of the full UV-C light dose (30 J/cm²). Uniform treatment of the samples were ensured through vigorous agitation during application of UV-C light.

All studies conducted over a period of more than 15 years that attempted to prove the effectiveness of UV-C light treatment against SARS-CoV were successful and displayed very similar results, when applying the same UV germicidal light and dosage range. Furthermore, recent studies showed that less than the full UV-C dose is capable of deactivating the virus to non-infectious levels.

4.2b MERS-CoV

In addition to SARS-CoV, UV-C treatment was tested and used extensively during the MERS-CoV outbreak in 2012. This coronavirus strain reached a 45% mortality rate and spread to nine countries during its peak. A 2016 study published in *Infection Control and Hospital Epidemiology (ICHE) journal*¹² revealed UV-C light to effectively deactivate MERS-CoV. During the study, researchers applied UV-C light which reduced MERS-CoV to undetectable levels at a reduction rate of >99.999%. This rate was achieved after five minutes of UV-C exposure and remained undetectable after continued treatment of 30 minutes. A 2018 study¹³ confirmed the above findings, which also showed UV-C light to be effective in reducing MERS-CoV to safe levels. The tests utilized UV-C light in the 254 nm range with a total dose of 0.2 J/cm² to platelet

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concentrates and plasma. During a test that applied 0.15 J/cm^2 (75% of the full UV-C dose) of UV-C light, MERS-CoV was eliminated to infectivity levels below the detection limit.

4.3 UV Impact on SARS-CoV-2

To date, SARS-CoV-2 is the most recent strain of the coronavirus. Compared to SARS-CoV and MERS-CoV, this strain has a high secondary infection rate and is capable of spreading more rapidly. The Food and Drug Administration (FDA) released a 2020 memo¹⁴ recommending the use of UV disinfecting devices that leverage the UV-C spectrum to eliminate SARS-CoV-2.

A 2020 study¹⁵, recommends using germicidal UV radiation to prevent “viral replication” of SARS-COV-2 and improve lung capabilities for patients. Researchers from the study concluded that such devices, which include systems used to administer UV-C light or radiation, can improve survival rate of individuals. At the front lines, UV-C light is proven to be effective in sanitizing N95 filtering facepiece respirators (N95 FFRs). Medical staff must deal with the shortage in N95 respirators and other protective devices by disinfecting the equipment and reusing them. This practice was tested by researchers from the University of Nebraska Medical Center¹⁶, through administering a 300 mJ/cm^2 dose of UV germicidal irradiation on N95 FFRs. The scientists highlighted that single-stranded RNA SARS-COV-2 can be inactivated with UVGI exposure of $2\text{-}5 \text{ mJ/cm}^2$, which was exceeded by the researchers in the study.

During the decontamination process, scientists utilized two UV-C light towers with eight UV lamps in the 254nm spectrum. N95 masks were fastened on wires, which held several respirators on the line (total of three lines). The UV units each produced an intensity of $400 \mu\text{W/cm}^2$. To improve exposure rate, the room hosting sanitation was covered with a UV-reflective coating. A UV sensor monitored light intensity and proper dosage inside the room. Cycles were designed to run until dosage reached above 300 mJ/cm^2 . Cycles were stopped using a remote immediately after reaching the minimum UV dose. Medical specialists that participated in the study intend to re-use N95 FFRs until the respirator fit is compromised (due to the shortage in masks). Moreover, researchers advised UV-C disinfection to be feasible in sanitizing other types of medical equipment. The practice of sanitizing N95 respirators is supported by N95DECON¹⁷, an organization consisting of scientists and clinicians across the US, including Harvard University, Massachusetts Institute of Technology, University of Michigan, University of California and more.

The findings above can be confirmed through another study published in 2020¹⁸. In this study, scientists observed an applied UV-C dose of $1,000 \text{ mJ/cm}^2$ on each side of N95 FFRs to eliminate SARS-CoV-2. An initial conservative UV-C dose of $2,000 \text{ mJ/cm}^2$ is recommended by the authors to ensure thorough sanitation, account for potential errors in dose estimation and complete coverage of surfaces on the masks. Although heat treatment at 60°C for 90 minutes was also tested as an alternative disinfection method for N95 FFRs, scientists cited uncertainty in applying heat treatment to protective gear as it could compromise the effectiveness of the devices after multiple sanitation cycles. UV-C light, at recommended doses (180 mJ/cm^2 to $6,900 \text{ mJ/cm}^2$), does not have these effects on N95 FFRs. The authors took six UVGI studies

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performed on N95 FFRs into account in their recommendation. A 2020 study published in *Journal of the American Academy of Dermatology*¹⁹ provided similar recommendations. Four models of N95 FFRs were tested in the study, which were exposed to UVGI doses of 120-950 J/cm². The results showed minimal degradation on the masks.

5.0 Conclusion

Published scientific research and studies conducted by medical organizations have proven the effectiveness of using UV-C light to deactivate or sanitize various strains of the coronavirus, including the latest SARS-COV-2 strain. The mainstream, prevalent use of UV light in well-established industries, such as food processing, wastewater treatment and healthcare (hospitals), reinforces the viability of the sanitation method, making it a tried-and-tested solution. Reliability and peace of mind are the secondary benefits that come with UV sanitation, as this disinfection method has been around for decades.

To ensure proper disinfection, UV-C light intensity, duration, exposure and deployment should be carefully maximized. Using a variety of UV lights and devices, from portable UV disinfection carts and UV air sanitizers to compact UV handlamps and UV sanitation boxes, is recommended for a complete approach to sanitation on the field or in facilities. During the disinfection process, individuals should avoid exposure to UV light, as it can damage the skin and cornea. Proper safety equipment, including gloves, suits, masks, glasses and visors, must be used to prevent UV exposure.

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