The Efficacy of Antimicrobial non-UV LED Lights for Home, Public and Industry

HIGHLIGHTS FROM SIX STUDIES IN MULTIPLE SETTINGS

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Introduction

This report highlights research into the effectiveness of the properties of a new class of antimicrobial light, which is found in the visible light spectrum (400-420nm).

Although the germicidal properties of ultraviolet (UV) light have long been known and applied for many years to destroy microorganisms, it is only recently that the antimicrobial properties of visible light have been applied to combat environmental contamination and the spread of disease and infection.

The most commonly recognized light disinfection method, UV, utilizes the UV-C (250nm) wavelength to cause photodegradation of DNA, which results in cell death. It is well documented that this type of disinfection is especially harmful to all cells, including cells within the human body, animals and plants. This deadly side effect has reduced UV-C's overall usefulness as to where and when it can and should be applied. UV light also possesses the power to significantly degrade the quality of many different types of materials, such as plastics, making them brittle and subject to cracking and failure. This impact, while not deadly, can be very costly and compounds the challenges of using UV lighting for applications where this spectrum of light can have devastating effects on both humans and the environments in which it is applied.

Antimicrobial White Light

Vyv's antimicrobial non-UV LED light blends 400-420nm wavelengths, a spectrum of light that creates a harmful photoreaction within endogenous non-iron porphyrin molecules found in microorganisms. The porphyrin molecules are highly photo-activated, which most frequently results in an energy transfer to what's known as ground state molecular oxygen. This energy transfer produces Reactive Oxygen Species (ROS) such as singlet oxygen, which are lethal to the cell in high doses. These ROS typically cause irreparable damage within the cell, especially to its membrane structure, resulting in bacterial cell death by destroying it from the inside out.

Antimicrobial light is not as quick-killing as hazardous UV light; it requires a longer exposure time to accomplish the task. With that said, this wavelength does not affect the heme porphyrins that exist within humans and, secondly, do not cause any cellular damage. Unlike UV light, which focuses its destructive power on DNA (which exists in all living entities) the antimicrobial frequencies (400-420) do not affect the DNA in cells at all. All of this allows for both continuous and, perhaps most importantly, unrestricted use of these antimicrobial lights in spaces occupied by people, animals and plants.

With the advent of LED lighting there is now the capability to tune and refine light to exacting frequencies, angles and distances from targets. This new approach has created what can be considered a brand-new class of antimicrobial solutions that is highly effective in a wide variety of applications in many different industries — healthcare, food safety, pharmaceuticals & biotech, consumer goods and services, travel and transportation, agriculture and many more.

As another weapon of choice in the war against bacteria, fungi, mold, yeast and other deadly pathogens, a new advantage has been added to this antimicrobial power: the ability for this light to remain effective even after white light is added. This is very significant. Now, this lighting can be placed in any environment that also requires normal illumination for people to work and live, while simultaneously exposing the environment to its beneficial antimicrobial properties. This "always on" approach is easily integrated into existing cleaning protocols. So, while the technology is disruptive in the sense of being innovative, it is anything but disruptive in its practical application as a continuous cleaning and pathogen-killing component.

Vyv has commercialized and patented this antimicrobial white light system which contains a significant energy distribution of the 400-420nm wavelengths while still emitting white light with imperceptible differences to the human eye. These lights can be used as regular overhead illumination systems while also producing a sufficient intensity of the 400-420nm wavelengths to reduce environmental microbial contamination. The use of antimicrobial white light in these lighting systems allows for continuous use and exposure in occupied areas, simultaneously reducing the microbial surface bioburden over time, without impacting facility operations or surface materials within the environment.

Unlike UV light, which focuses its destructive power on the molecule's DNA (which exists in all living entities), 400-420nm light does not affect the cell's DNA at all.

Testing the Efficacy of Antimicrobial Light

The efficacy of this antimicrobial light has been proven to kill multiple species of bacteria, fungi and spores, with no degradation of equipment or materials, in high-volume and high-stakes active environments.

The advancement of isolating visible antimicrobial light has created opportunities to test its efficacy in labs, controlled room settings and most importantly, actively-used environments. The progression of testing—ranging from highly controlled to real-world environments—while measuring multiple variables that prove its efficacy as an acceptable addition to existing cleaning and disinfecting protocols, is important to prove its real value to decision-makers in commercial and government organizations, as well as to consumers.

The efficacy of antimicrobial light for preventing cell growth has been proven against a large number of species of bacteria, fungi, yeast and mold, with no degradation of equipment or materials, in high-volume and high-stakes active environments.

An important variable in testing the efficacy of this new class of antimicrobial light is the lux level of the lights being used. Lux is the standard unit of measure of luminance and luminous emittance, measuring the perceived power of light per unit area. It is equal to one lumen per square meter and is used as a measure of brightness, as perceived by the human eye, of light that hits or passes through a surface. In the studies discussed in this paper, lux levels are typically increased as part of the method or approach in order to accelerate results. It is impractical and expensive to prolong a lab study using low lux levels; lab studies are conducted at higher intensities than active environment testing in order to use resources more efficiently and deliver results in a more timely manner.

Summaries and data highlights from the following studies are included in this paper:

1. New York State Department of Health
2. Duke/University of North Carolina combined team, led by William A. Rutala, PhD, MPH
3. HP Hood LLC (Food & Beverage)
4. Rensselaer Polytechnic Institute's Center for Biotechnology and Interdisciplinary Studies (CBIS)
5. Bayfront Health St. Petersburg, Florida
6. Stony Brook University Hospital, New York (SBUH)

Section 1: Laboratory Testing

Laboratory testing provides the most measurable data, given that it is gathered in a highly controlled environment, allowing for specific types and volumes of bacteria to be deployed and accurately measured at regular intervals.

STUDY 1: **NEW YORK STATE DEPARTMENT OF HEALTH**

Test Antimicrobial White Light efficacy against multiple species of bacteria

At the New York State Department of Health (NYSDOH) Wadsworth Biodefense Laboratory, Vyv's antimicrobial LED lights were tested to determine their efficacy at reducing the amount of three different medically important bacteria—Methicillin-resistant *Staphylococcus aureus* (MRSA), *S. pyogenes* and *E. coli*—and one medically relevant spore, *C. difficile*, in liquid cultures. The study exposed the bacteria and spores to a range of intensities and durations, and calculated the log reduction in bacteria concentration.

The largest absolute dosage of 144 J/cm^2 shows an approximate 4-log reduction in bacterial count.

Topline results showed that under the testing conditions:

- There was an almost 2-log (99%) reduction compared to the control in the spores tested.
- There was an even greater reduction in the bacteria tested.
- The largest absolute dosage of 144 J/cm^2 shows an approximate 4-log reduction in bacterial count.
- *C. difficile* spores, the causative agent of a common hospital acquired infection (HAI), proven to be extremely difficult to inactivate, were also exposed to the Vyv lights under low intensities for long periods of time. While the lights were less effective against the spores than all other gram-positive and gram-negative bacteria tested, there was still an almost 2-log, or 99%, reduction in the spore counts after exposure.

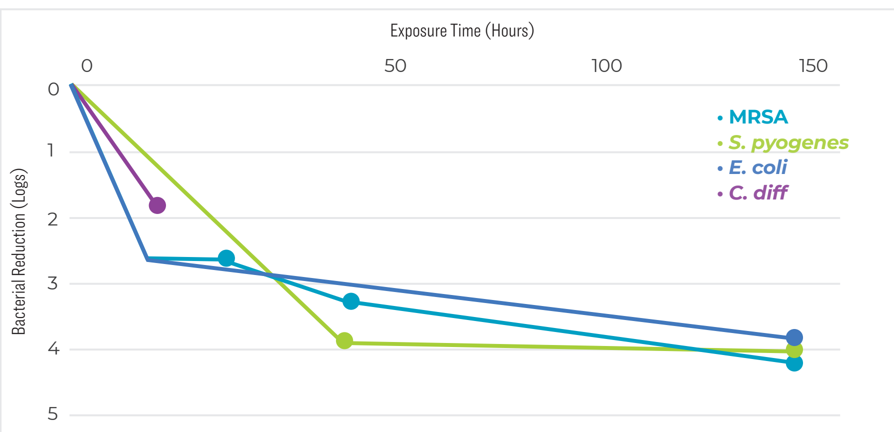

Figure 1. **Bacterial reductions with increasing absolute dosages of Antimicrobial White Light.** Source: NYSDOH, 2012.

Conclusion

In this laboratory setting, the Antimicrobial White Light technology provided by Vyv showed great effectiveness against multiple bacterial types and also inactivated bacterial spores.

STUDY 2: **Duke/University of North Carolina team led by William A. Rutala, PhD, MPH**

Test efficacy of Antimicrobial White Light technology

In 2016, a group of seven North Carolina-based physicians led by William A. Rutala, PhD, MPH set up a laboratory-based evaluation to determine the effectiveness of Antimicrobial White Light for the reduction of epidemiologically-important pathogens.

The four test organisms were:

- *C. difficile* spores
- MRSA
- VRE
- Multi-Drug Resistant *Acinetobacter baumannii* (MDRA).

The study objectives and acceptable results were achieved within 3 days.

The group selected Vyv's overhead light fixture technology which uses LEDs configured with Vyv's light to test this efficacy of killing pathogens and preventing further contamination. Formica test surfaces were inoculated with 100-500 CFUs of test organisms.

TREATMENT	PATHOGEN	TIME (LEAST NUMBER OF HOURS TO ACHIEVE MICROBIAL REDUCTION				MAXIMUM REDUCTION ACHIEVED (%)
		25%	50%	90%	100%	
Violet-Blue Light	MRSA		3	48	48	100
	VRE	5	24	24	48	100
	MDRA	1	5	NA	NA	88
	C. difficile	5	5	72	NA	66
White Light	MRSA	7	24	48	72	100
	VRE	24	NA	NA	NA	47
	MDRA	6	24	48	72	100
	C. difficile	5	NA	NA	NA	25

NA, not achieved.

Table 1. **Time to specified percent reductions of epidemiologically-important pathogens with violet-blue light and white light.** Source: University of North Carolina Medical School and Medical Center; Duke University Medical School and Medical Center, 2016.

Conclusions

The results demonstrated that the antimicrobial light inactivated three vegetative bacteria—MRSA, VRE and MDRA—on surfaces with contact times of 1 hour and 72 hours. Statistical differences ($p<0.05$) were observed using violet-blue light for VRE at 24 and 48 hours; for MRSA at 3, 5, 6 and 7 hours; for MDRA at 5, 6, 7, and 24 hours; and for *C. difficile* spores at 5 and 72 hours.

Inactivation was more significant when the surface irradiance was increased by adding the violet-blue light. Furthermore, because of the differing results by bacteria, by duration of exposure, it is a beneficial feature of the lighting system that it can operate in the background, without any manual intervention. Across the span of three days, the objectives of the study, and acceptable results were achieved.

In a presentation at ID Week in 2016, the North Carolina team led by William A. Rutala, PhD, MPH reported that this test demonstrated that this antimicrobial light significantly reduced both vegetative bacteria and spores at some time points over a 72-hour exposure period. In addition to episodic disinfection (e.g., UV and traditional cleaning methods), the team concluded that continuous use of antimicrobial light technology could be considered for multiple healthcare decontamination applications, including Operating Rooms.

Additionally, they felt that given that environmental surfaces in patients' rooms—and certainly other surfaces throughout the hospital environment—are often either not thoroughly disinfected or that recontamination occurs rapidly, it is important to apply other methods to create persistent antimicrobial effectiveness.

In addition to episodic disinfection (e.g., UV and traditional cleaning methods), the team concluded that continuous use of antimicrobial light technology could be considered for multiple healthcare decontamination applications, including Operating Rooms.

The Antimicrobial White Light technology was proven to eliminate 90-99% of each bacterial species found in the manufacturing process without harming the surrounding materials.

Study 3: **HP Hood LLC**

Test to evaluate efficacy of antimicrobial light in food manufacturing and its impact on materials

A study for HP Hood, a Massachusetts-based dairy company (annual sales of $2B with 12 manufacturing plants) provides an opportunity to move beyond healthcare to understand the efficacy of antimicrobial light in a food manufacturing and processing environment. The company's R&D division was interested in investigating two aspects of its efficacy: the effect of antimicrobial light on materials used in the manufacturing environment, as well as its ability to prevent the growth of a variety of microbial species that would be highly problematic if present during the manufacturing process. The desired outcome would be to validate these lights as able to diminish or eliminate bacterial contamination from the manufacturing process, without negatively impacting the condition of the equipment in use.

Study 3: **Objective 1**

Test for materials degradation under Antimicrobial LED lighting vs normal LEDs

Materials testing consisted of exposing a variety of food processing and manufacturing materials to Vyv lights and comparing them to materials exposed to normal LEDs to check for material breakdown. This testing utilized Vyv light that went to at least 1000 lux. Materials were exposed for as long as seven days and included a variety of gaskets, tubing, wash-down hoses, bottles and finished packaged products.

Conclusions

Testing food processing parts showed no difference in material quality after being exposed to the antimicrobial lights, compared to a normal LED light. Additionally, testing food processing parts and materials along with packaged finished products showed no difference between material quality after being exposed to Vyv's white antimicrobial lights, compared to a normal LED light.

Study 3: **Objective 2**

Test efficacy of Vyv lights at preventing the growth of a variety of microbial species

Vyv tested eleven microbial species, (a wide range of dairy, spoilage, and pathogenic microbial strains in liquid conditions) to assess the efficacy of Vyv for HP Hood under Vyv lights and compared the reduction to the same strains tested under normal fluorescent lights. These experiments were performed at higher intensities for timing purposes and represent results of standard Vyv lighting being used for as long as 1.5 months. Small samples were taken from the liquid cultures at a variety of time points and plated. Colony counts were obtained for the purposes of calculating the total bacterial concentration in the sample. Two species (*Lactobacillus plantarum* and *Lactobacillus bulgaricus*) are specific to dairy processing, and therefore not reported here.

BACTERIAL SPECIES	TYPE/RELEVANCE	REDUCTION (VS CONTROL)
Salmonella typhimurium	Pathogenic	99%
Staphylococcus aureus	Spoilage	99%
Saccharomyces cerevisiae	Yeast	99%
Pseudomonas aeruginosa	Spoilage	99%
Bacillus circulans	Spoilage	90%
Lactococcus lactis	Spoilage	90%
Bacillus cereus	Pathogenic	90%
Streptococcus thermophilus	Dairy	90%
Listeria monocytogenes	Pathogenic	90%

Table 2. **Reduction in total bacterial count (vs the control) under Vyv lights, by species, and their purpose in relation to Hood's food processing concerns.** Source: Vyv, 2016.

Conclusions

Of the nine (projectable) microbial species tested against Vyv's Anti-microbial Lights all showed 90% or 99% reductions in bacterial counts compared to the control cultures. The results of these experiments demonstrate the ability of Vyv's technology to play a role in reducing the presence of pathogens and spoilage microbes that are relevant to food and dairy processing.

Section Two: Controlled Room Testing

While laboratory testing provides the most measurable data, testing in controlled room environments allows for researchers to monitor progress from a known, quantifiable starting point. In the case of measuring bacterial reductions, it is important to have at least some of the data derived from a controlled room setting, helping to bridge the gap between tightly controlled studies and analysis of real-life environments with multiple variables.

Bacteria on all three surface types showed statistically significant mean decreases compared to the controls at many time points.

Study 4: **Rensselaer Polytechnic Institute's Center for Biotechnology and Interdisciplinary Studies (BCIS)**

Test antimicrobial light on cultures that have dried on different types of surfaces

The team at Rensselaer Polytechnic Institute's Center for Biotechnology and Interdisciplinary Studies (CBIS) wanted to explore the light's efficacy against cultures that had dried on a contaminated surface. This study mimics conditions more representative of real-world situations where contamination occurs on a surface, but intermittent cleaning (mopping or wiping) does not occur before the contamination dries. Not only is this a situation where these lights can act as part of an integrated disinfection process, but for certain durations, it is the only protocol actively remediating the contamination.

Reductions in bacterial load on steel surface coupons.

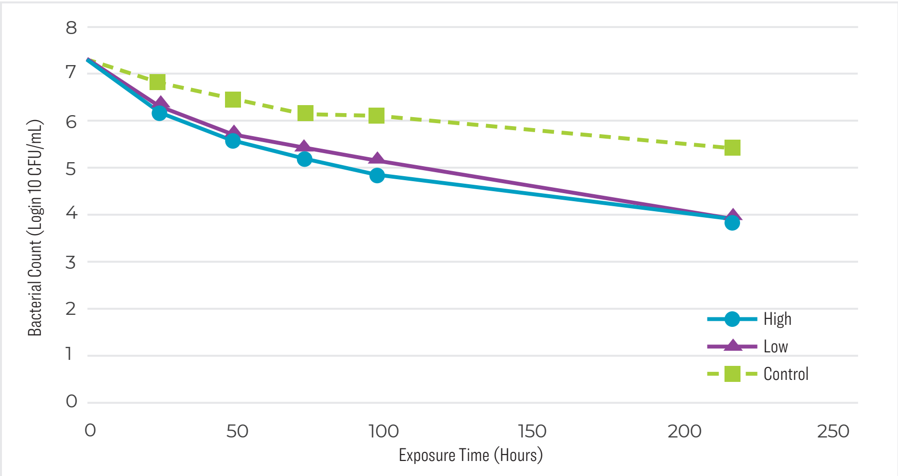

Figure 2. ***S. aureus*** **kill curves on steel surface coupons under control fluorescent lighting (dotted line) and antimicrobial lighting systems (solid lines).** ***S. aureus*** **kill curves on glass and plastic surface coupons looked similar.** Source: Vyv, 2012.

One hundred microliter aliquots containing 107 cells of *S. aureus* or *A. calcoaceticus* bacteria were deposited on surface coupons of glass, ABS plastic, or stainless steel and allowed to dry. They were then exposed to Vyv's Antimicrobial White Light for either 9 days (216 hours) or 14 days (336 hours) at either high intensity (0.16 mW/cm^2) or low intensity (0.09 mW/cm^2) while control samples were exposed to standard fluorescent lights. Dried bacteria experience stress from desiccation, which may provide non-specific cross protection to other stressors. Quantitation occurred by washing the cells off the surface coupons and enumerating them on nutrient plates. Experimental samples were compared to the control samples to look at bacteria inactivation beyond the normal loss seen from desiccation.

Reductions in *A. calcoaceticus* titers on glass surface coupons under Vyv Antimicrobial Light.

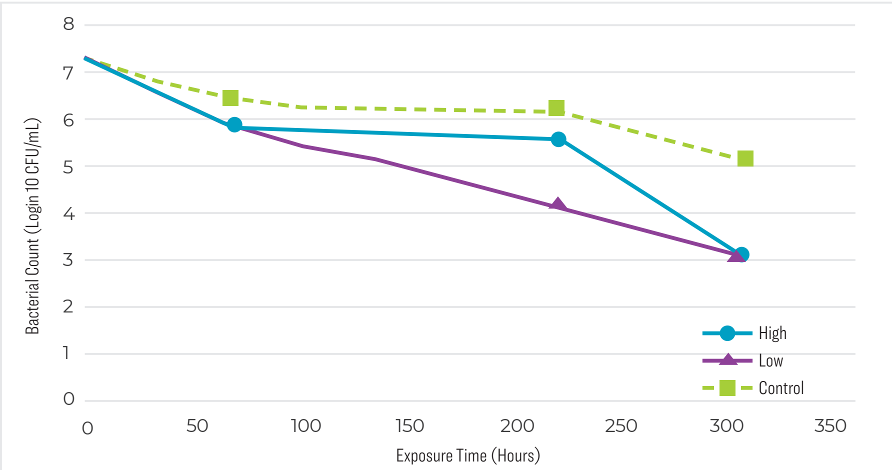

Figure 3. ***A. calcoaceticus*** **kill curves on glass surface coupons under control fluorescent lighting (dotted line) and Vyv Antimicrobial White Light technology (solid lines).** Source: Vyv, 2016.

Conclusions

Bacteria on all three surface types showed statistically significant mean decreases compared to the controls at many time points, ranging between an additional 0.8-log to an additional 2.29-log decrease in bacterial titer by the final time point, dependent on bacteria and surface type.

Section Three: Active Environment Testing

The most important testing occurs in active environments, where the technology's performance is evaluated based on results delivered in the real world. The efficacy of this new class of antimicrobial light has been proven time and time again in multiple active environment settings. This section highlights two significant third-party studies, but there are many more that offer additional proof of its efficacy.

Study 5: **Bayfront Health St Petersburg**

Test the efficacy of passive antimicrobial LED lighting technology to reduce contamination in a trauma room

Bayfront Health St. Petersburg (Tampa, Florida) is the city's longest-standing hospital, with 480 beds and Pinellas County's only trauma center. In recognition of the inadequacy of standard housekeeping methods for removing microbial contamination from the modern-day healthcare environment, healthcare systems have implemented an array of advanced disinfection technologies to assist with surface contamination. Most of these technologies require the room to be sealed, making them impractical. This study evaluates passive LED antimicrobial lighting technology in an environment that cannot be closed: a Level II trauma room.

Changes in microbial surface contamination before and after installation of antimicrobial lights in an active trauma room.

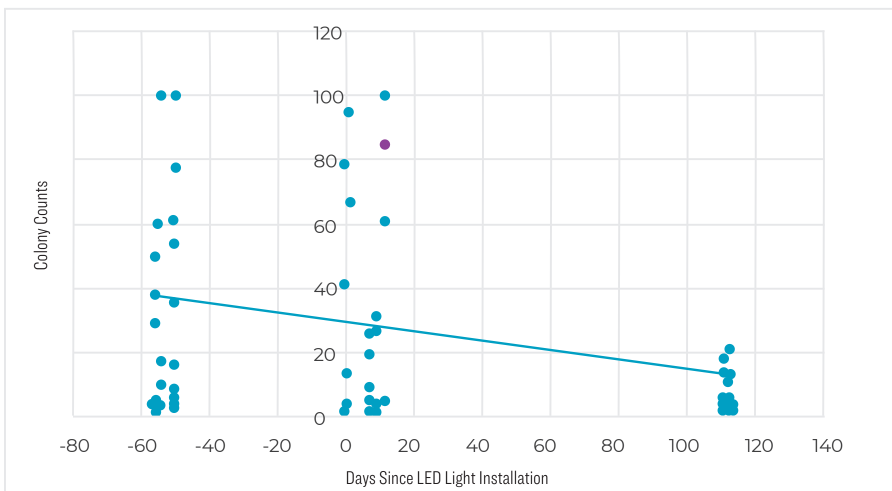

Figure 4. **Colony counts from 5 sites in an active trauma room before, 2 weeks after, and 15 weeks after installation of Vyv Antimicrobial White Light technology.** Source: Bayfront Health St. Petersburg.

Average patient minutes per day in active trauma room.

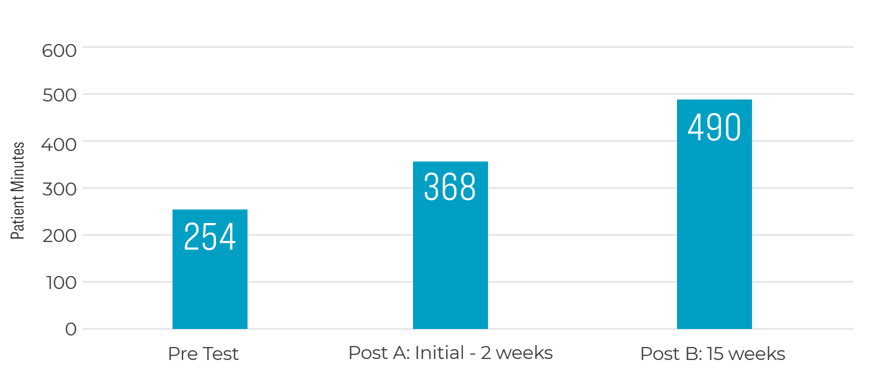

Figure 5. **Average patient minutes per day in active trauma room before, 2 weeks after, and 15 weeks after installation of Vyv Antimicrobial White Light technology.** Source: Bayfront Health St. Petersburg.

The trauma room was cultured in five locations using RODAC plates during three separate time intervals: Pre-Installation (Pre, n=30); Post-install 2 weeks (Post A, n=25); and Post-install 15 weeks (Post B, n=25). Colony counts were calculated after 48 hours. Trauma room usage was monitored for average patient minutes per study day using electronic medical records for verification.

This study demonstrates that antimicrobial LED lights significantly reduced the microbial surface contamination in a trauma room within 15 weeks, even when room usage increased.

Conclusions

The data derived from this study demonstrate that antimicrobial LED lights significantly reduced the microbial surface contamination in a trauma room within 15 weeks, even when room usage increased. The results suggest that white antimicrobial LED light may not produce immediate results. Over time, however, these lights are effective at reducing the overall microbial contamination. Further research is needed to pinpoint precisely when a significant reduction in microbial surface contamination occurs.

Upon completion of the study, some limitations were noted, however none that diminish the efficacy of the lights. For example, a larger sample size may remove some day-to-day variability. There was also a large break (13 weeks) between Post A and Post B, which makes it difficult to determine how soon after installation the technology significantly reduced contamination. Additionally, contamination rates can vary greatly between patients due to the nature of trauma. This is the benefit, as well as a challenge, when conducting a study within an active environment.

Study 6: **Stony Brook University Hospital (SBUH)**

Test Antimicrobial LED Lighting in an active Medical Intensive Care Unit (MICU) nurses' station

Stony Brook University Hospital (SBUH) is Eastern Long Island's premier academic medical center. With 603 beds, SBUH serves as the region's only tertiary care center and regional trauma center. The nurses' station serving this hospital's 20-bed MICU was the setting for this test and, like the Bayfront trauma room, is perhaps the most "real world" test because activity at the nurses' station was nearly constant; there was zero down time during testing.

Optimizing the lighting layout or altering within the ceiling was out of the scope of this project. Vyv overhead lighting was installed where lighting fixtures currently existed. Only Vyv Antimicrobial White Light technology was used during the course of the study and lux levels were set at only 66% of standard lighting levels to show the efficacy of operating at two-thirds of illumination capacity. A total of 54 Vyv lights replaced existing lighting fixtures in the areas surrounding the MICU, including the nurses' station, hallways, family waiting room, and a secondary pharmacy.

SITE #	LOCATION	SITE #	LOCATION
1	Nursing Station 1 (NS1) Keyboard	11	Nursing Station 3 (NS3) Keyboard
2	NS1 Phone	12	NS3 Phone
3	NS1 Phone	13	NS3 Mouse
4	NS1 Chair Arm	14	NS3 Second Keyboard
5	NS1 Crash Cart/Paper Disposal/COW	15	NS3 Countertop
6	Nursing Station 2 (NS2) Keyboard	16	Core Fax Machine
7	NS2 Phone	17	Core Phone
8	NS 2 Copy Machine	18	Core Printer
9	NS2 Chair Arm	19	Family Room Tabletop
10	NS2 Crash Cart/Paper Disposal/COW	20	Family Room Seat Cushion

Table 3. **Sampling sites adjacent to MICU nurses' station.** Source: Vyv.

The twenty collection surfaces were highly specific; each was sampled daily for five days at selected time points. Samples were taken pre-installation and at seven weekly collections post-installation (weeks 2, 4, 8, 10, 16, 20 and 24). Colony counts were determined using non-selective Replicate Organism Detection And Counting (RODAC) plates. Plates were incubated at 30°C for 48 hours and colonies were counted on each plate.

Average colony counts before and after installation of Vyv's Antimicrobial LED Lighting Technology.

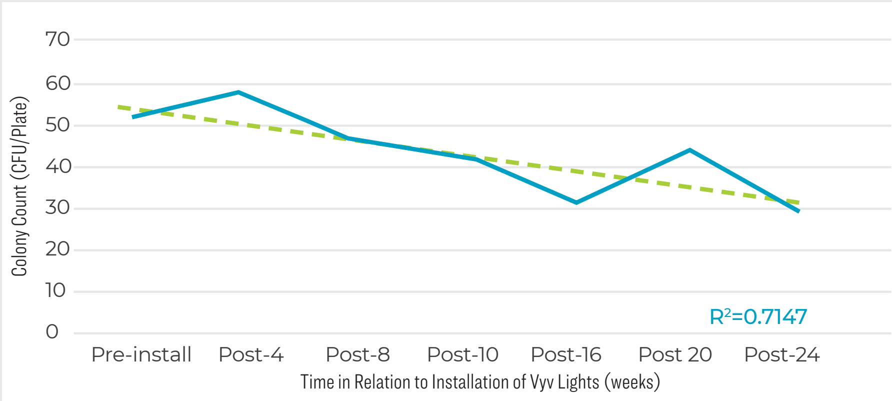

Figure 6. **Average colony counts across 20 surfaces before and after the installation of Vyv lights.** Source: Vyv.

Conclusions

In one of the most active environments in a hospital—a MICU nurses' station—the use of Vyv's technology resulted in a statistically significant decrease in average bacteria colony count between the pre- and post-installation samples; this occurred when averaged across all 20 sample sites. The data from this clinical study show that the technology was able to reach sustained, significant reductions in surface bioburden across a variety of surface types, despite constraints in lighting placement and lighting levels that were only two-thirds of the standard brightness. A 43.4% reduction in surface bioburden was generated, so it can be expected that optimized lighting designs would produce even greater reductions.

Vyv's technology was able to reach sustained, significant reductions in surface bioburden across a variety of surface types.

Overall Conclusions

The data from these studies represent a body of work that supports the efficacy of this new class of antimicrobial light technology in a variety of environments with heavy bioburdens. Each solution is customized based on the objectives, but the common denominator—understanding the impact of visible light on bacteria, fungi, mold and yeast, whether contaminants are in liquid or dried form, and regardless of the surface (glass, vinyl, stainless steel, plastic)—is abundantly clear: Vyv's antimicrobial light is highly effective as a method of preventing microbial growth without causing side effects.

About Vyv

Vyv® is a pioneer and maker of a new class of antimicrobial light technology with solutions across industries, including: healthcare, travel, sports, food safety and processing, agriculture, and consumer goods, to name just a few. Vyv's patented technology multi-tasks to effectively and continuously prevent the growth of microorganisms (bacteria, fungi, yeast, mold and mildew) on indoor surfaces while also illuminating the space. Vyv surrounds their proprietary LED technology with the science and engineering expertise required to deliver antimicrobial growth protection for a cleaner world. For more information, **visit vyv.tech**

Antimicrobial Light Efficacy Against Bacteria, Fungi, Yeast and Mold

Gram-positive Bacteria

- *Staphylococcus aureus*, including Methicillin-resistant Staphylococcus aureus MRSA)
- *Clostridium perfringens*
- *Clostridium difficile (C. diff)*
- *Enterococcus faecalis*
- *Staphylococcus epidermidis*
- *Staphyloccocus hyicus*
- *Streptococcus pyogenes*
- *Listeria monocytogenes*
- *Bacillus cereus*
- *Mycobacterium terrae*

Gram-negative Bacteria

- *Acinetobacter baumannii*
- *Pseudomonas aeruginosa*
- *Klebsiella pneumoniae*
- *Proteus vulgaris*
- *Escherichia coli (E. coli)*
- *Salmonella enteritidis*
- *Shigella sonnei*
- *Serratia spp. Bacterial Endospores*

Yeast & Filamentous Fungi

- *Aspergillus niger*
- *Candida albicans*
- *Saccharomyces cerevisiae*

Source: Vyv, 2020