

The Efficacy  
of 405nm  
Antibacterial  
LED Light

**HIGHLIGHTS FROM  
SIX STUDIES IN  
MULTIPLE SETTINGS**

**vital vio**

# Introduction

This report highlights research into the effectiveness of the antimicrobial properties of 405nm violet-blue light, which is found in the visible light spectrum.

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 violet-blue 405nm light have been applied for combating 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.

# Antibacterial White Light

Vital Vio's Antibacterial LED Light uses the violet-blue 405nm wavelength, a spectrum of light that is harmful to microorganisms initiate a photoreaction with endogenous non-iron porphyrin molecules found in bacterial 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.

405nm visible light is not as quick-killing as harmful UV light; it requires a longer exposure time to accomplish the task. With that said, the 405nm 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 the molecule's DNA (which exists in all living entities) 405nm does not affect the cell's DNA at all.

All of this allows for both continuous and, perhaps most importantly, unrestricted use of these antibacterial lights in spaces occupied by people, pets and plants. With the advent of "tunable" LED lighting—the capability of refining light to specific frequencies—the technology now exists to fully leverage 405nm. This new approach has created what can be considered a brand-new class of antibacterial solutions that is highly effective in a wide variety of applications in many different industries, including: healthcare, food safety, pharmacology, 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 the violet-blue antimicrobial power of 405nm: the ability for 405nm 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 antibacterial 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.

Vital Vio has commercialized and patented an Antibacterial White Light system which contains a significant energy distribution of the 400-450nm 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 400-450nm wavelengths to reduce environmental microbial contamination. The use of Antibacterial 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), 405nm does not affect the cell's DNA at all.

The efficacy of 405nm antibacterial light has been proven against multiple species of bacteria, fungi and spores, with no degradation of equipment or materials, in high-volume and high-stakes active environments.

## Testing 405nm Efficacy

The advancement of isolating 405nm visible 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 value proposition to decision-makers in the industry sectors noted above, as well as to consumers.

The efficacy of 405nm visible light for preventing microbial growth has been proven against multiple 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 405nm is the lux level of the lights being used. Lux is the standard unit of measure of illuminance 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 Antibacterial White Light effectivity against multiple species of bacteria

At the New York State Department of Health (NYSDOH) Wadsworth Biodefense Laboratory, Vital Vio lights using 405nm visible light 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.

Topline results showed that under the testing conditions:

- There was an almost 2-log, or 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<sup>2</sup> 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 Vital Vio 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.

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

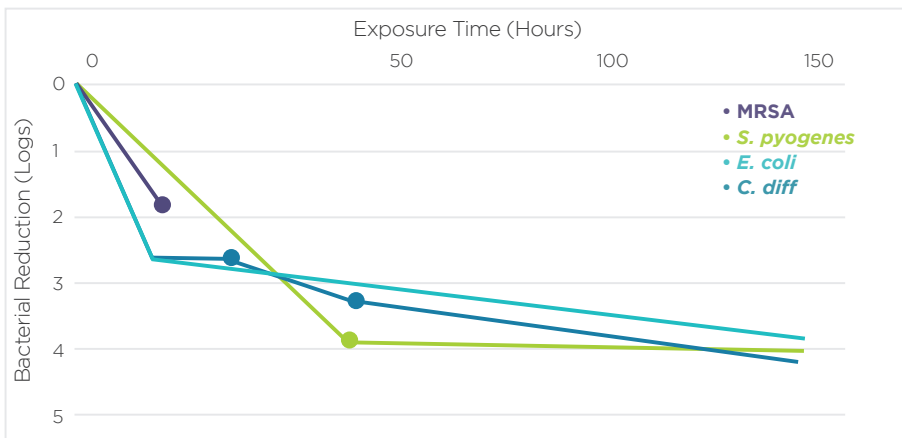


Figure 1. **Bacterial reductions with increasing absolute dosages of Antibacterial White Light.** Source: NYSDOH, 2016

### Conclusion

In this laboratory setting, the Antibacterial White Light technology provided by Vital Vio showed great effectiveness of 405nm light against multiple bacterial types and also inactivated some bacterial spores.

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

**Test antimicrobial activity of an Antibacterial 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 Antibacterial 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 group selected Vital Vio’s overhead light fixture technology which uses LEDs configured with 405nm light to test the efficacy of 405nm as a method of killing pathogens and preventing further contamination. For-mica test surfaces were inoculated with 100-500 CFUs of test organisms.

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

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
	<i>C. difficile</i>	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
	<i>C. difficile</i>	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 405nm 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 405nm 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 antibacterial 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 antibacterial light technology could be considered for multiple healthcare decontamination applications, including Operating Rooms.

405nm Antibacterial 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 405nm efficacy 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 405nm light in a food manufacturing and processing environment. The company's R&D division was interested in investigating two aspects of the efficacy of 405nm light: the effect of antibacterial 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 they were present during the manufacturing process. The desired outcome would be to validate 405nm light 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 405nm LED lighting vs normal LEDs

Materials testing consisted of exposing a variety of food processing and manufacturing materials to Vital Vio lights and comparing them to materials exposed to normal LEDs to check for material breakdown. This testing utilized Vital Vio 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 405nm 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 Vital Vio's white lights, compared to a normal LED light.



## Study 3: Objective 2

### Test efficacy of 405nm lighting at preventing the growth of a variety of microbial species

Vital Vio tested eleven microbial species, (a wide range of dairy, spoilage, and pathogenic microbial strains in liquid conditions) to assess the efficacy of Vital Vio for HP Hood under Vital Vio 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 Vital Vio 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)
<i>Salmonella typhimurium</i>	Pathogenic	99%
<i>Staphylococcus aureus</i>	Spoilage	99%
<i>Saccharomyces cerevisiae</i>	Yeast	99%
<i>Pseudomonas aeruginosa</i>	Spoilage	99%
<i>Bacillus circulans</i>	Spoilage	90%
<i>Lactococcus lactis</i>	Spoilage	90%
<i>Bacillus cereus</i>	Pathogenic	90%
<i>Streptococcus thermophilus</i>	Dairy	90%
<i>Listeria monocytogenes</i>	Pathogenic	90%

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

### Conclusions

Of the nine (projectable) microbial species tested against Vital Vio's Antibacterial Lights all showed 90% or 99% reductions in bacterial counts compared to the control cultures. The results of these experiments demonstrate the ability of Vital Vio'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 405nm 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 efficacy of 405nm 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 405nm 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 under Antibacterial White Light.

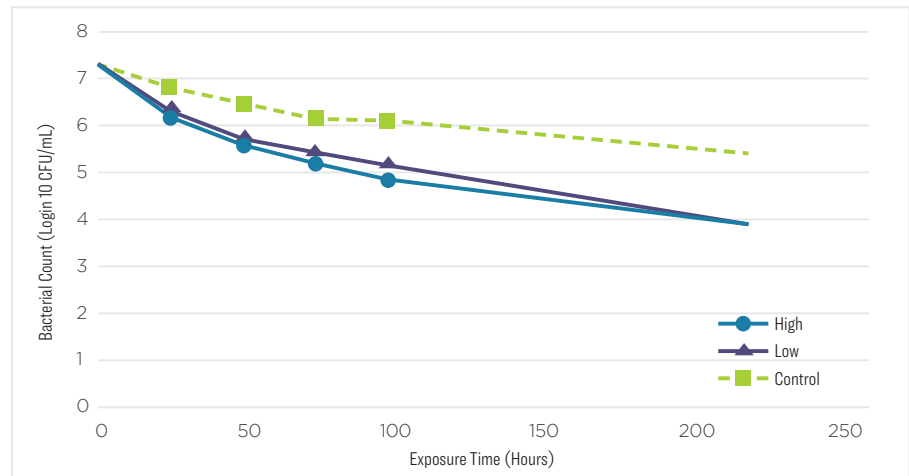


Figure 2. *S. aureus* kill curves on steel surface coupons under control fluorescent lighting (dotted line) and Antibacterial Lighting systems (solid lines). *S. aureus* kill curves on glass and plastic surface coupons looked similar. Source: Vital Vio, 2016

One hundred microliter aliquots containing  $10^7$  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 405nm from Vital Vio's Antibacterial White Light for either 9 days (216 hours) or 14 days (336 hours) at either high intensity (0.16 mW/cm<sup>2</sup>) or low intensity (0.09 mW/cm<sup>2</sup>) 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 Vital Vio antibacterial light.**

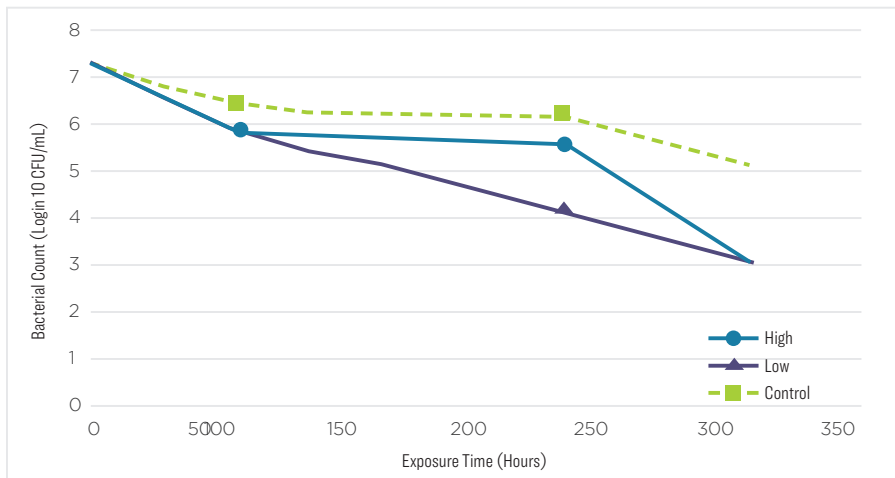


Figure 3. *A. calcoaceticus* kill curves on glass surface coupons under control fluorescent lighting (dotted line) and Antibacterial White Light technology (solid lines). Source: Vital Vio, 2016

**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 405nm 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 the efficacy of 405nm.

### Study 5: Bayfront Health St Petersburg

#### Test the efficacy of 405nm, utilizing passive antibacterial LED lighting technology to effectively reduce microbial contamination in a trauma room

Bayfront Health St. Petersburg (formerly Bayfront Medical Center) 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 at removing microbial contamination from the modern-day healthcare environment, healthcare systems have implemented an array of advanced disinfection technologies to assist with surface disinfection. Most of these technologies require the room to be sealed, making them impractical for some applications. This study evaluates a passive LED antibacterial lighting technology in a (costly) environment that cannot be closed: a level II trauma room.

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

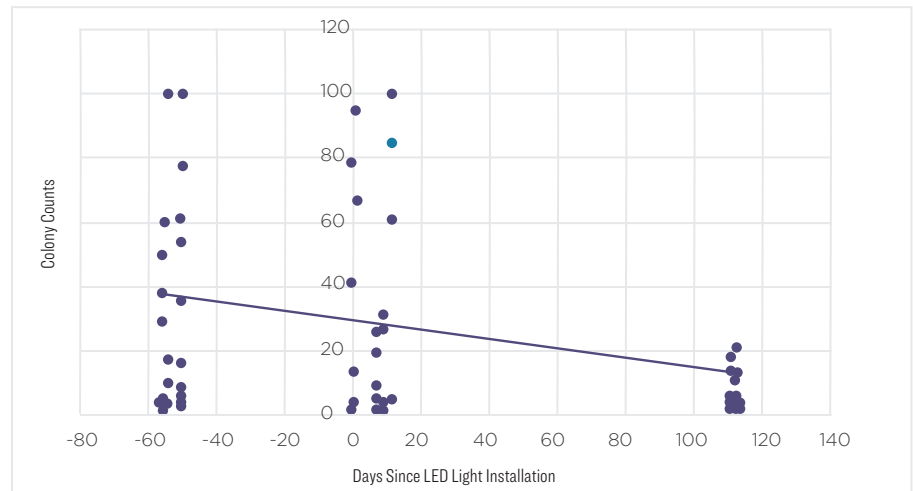


Figure 4. Colony counts from 5 sites in an active trauma room before, 2 weeks after, and 15 weeks after installation of Vital Vio Antibacterial White Light technology. Source: Bayfront Health St. Petersburg

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.

### Conclusions

This data derived from this study demonstrate that the antibacterial LED lights significantly reduced the microbial surface contamination in a trauma room at 15 weeks, even when room usage increased. The results suggest that white antibacterial 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 determine 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 405nm. For example, a larger sample size may remove some variation from day-to-day. There was also a large break between Post A and Post B (13 weeks), 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.

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

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

### Test Antibacterial 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 of 405nm because activity at the nurses' station was nearly constant; there was zero down time during testing.

Vital Vio overhead lighting was installed where lighting fixtures currently existed. Only Antibacterial 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 405nm, even while operating at two-thirds of illumination capacity. A total of 54 Vital Vio lights replaced existing lighting fixtures in the areas surrounding the MICU including the nurse's station, hallways, family waiting room, and a secondary pharmacy. Optimizing the lighting layout or altering within the ceiling was out of the scope of this project.

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 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: Vital Vio

This study is one of the most comprehensive studies that Vital Vio has participated in to date. 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 Vital Vio's antibacterial LED lighting technology (without Week 2).**

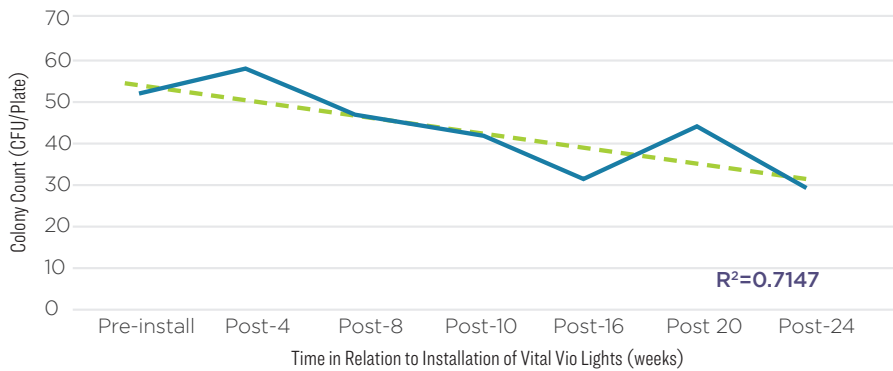


Figure 5. **Average colony counts across 20 surfaces before and after the installation of Vital Vio lights, without Week 2 post-install which may have been only in Eco-mode for this particular week.** Source: Vital Vio

### Conclusions

In one of the most active environments in a hospital—a MICU nurses' station—the use of Vital Vio's 405nm technology resulted in a statistically significant decrease in average bacteria colony count between the pre-installation samples and the post-installation samples; this occurred when averaged across all 20 sample sites. The data from this clinical study show that the 405nm 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. Despite less than ideal conditions, a 43.4% reduction in surface bioburden was generated, so it can be expected that optimized lighting designs would be able to produce even greater reductions.

The Stony Brook study differed from a typical study in a number of ways, but these differences did not compromise the results. Other hospital spaces have downtimes, which allow for cleaning technology to “catch up” using 100% violet-blue light mode. However, the constant use of the nurses' station makes it more difficult to achieve optimal results, and did not allow for the use of this mode. Additionally, as part of the study design, active room sampling typically occurs at the same time every day, so as to have fewer confounding variables, such as the amount of time since the last intermittent cleaning (which may affect surface bioburden). Due to scheduling constraints and available resources, samples were taken at varying times during this study. Also, the Stony Brook study was conducted for an extended timeframe (24 weeks vs a typical 12-week study), so it was able to demonstrate more sustained reductions in surface bioburden.

405nm 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 405nm as an antibacterial solution 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 and yeast, whether contaminants are in liquid or dried form, and regardless of the surface (glass, vinyl, stainless steel, plastic)—is abundantly clear: 405nm is highly effective as a method of preventing microbial growth without causing side effects.

## About Vital Vio

Vital Vio® is the market leader in Antibacterial Lighting, providing solutions in a variety of industries, including: healthcare; travel; sports; food preparation and food service; agriculture; and consumer goods, to name just a few. The company's patented methods apply the power of 405nm (non-UV) light to be used in combination with traditional intermittent cleaning in hospitals, homes, public spaces, and workplaces. Vital Vio's 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. Vital Vio surrounds their proprietary LED technology with the science and engineering expertise required to deliver antibacterial growth protection for a cleaner world. For more information, visit [www.vitalvio.com](http://www.vitalvio.com)

## 405nm Visible Light Efficacy Against Bacteria and Fungi

### Gram-positive Bacteria

- *Staphylococcus aureus*, including Methicillin-resistant *Staphylococcus aureus* MRSA)
- *Clostridium perfringens*
- *Clostridium difficile* (*C. diff*)
- *Enterococcus faecalis*
- *Staphylococcus epidermidis*
- *Staphylococcus 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: Vital Vio, 2019