Air Purification and Surface Disinfection

Presentation By:

Lighting and Leading the Way to Healthier Air

illumiPure's Air Guardian air purification systems have been expertly engineered to disinfect air and surfaces like no other solution on the market. With its patented technologies, high integrity fixtures, and state-of-the-art monitoring application, illumiPure's Air Guardian air purification solution represents the highest standard of healthy surface and air disinfection products available. Science backed, tested, and real-world proven, Air Guardian is an effective solution to reduce the spread of airborne pathogens for even the most at-risk public spaces.

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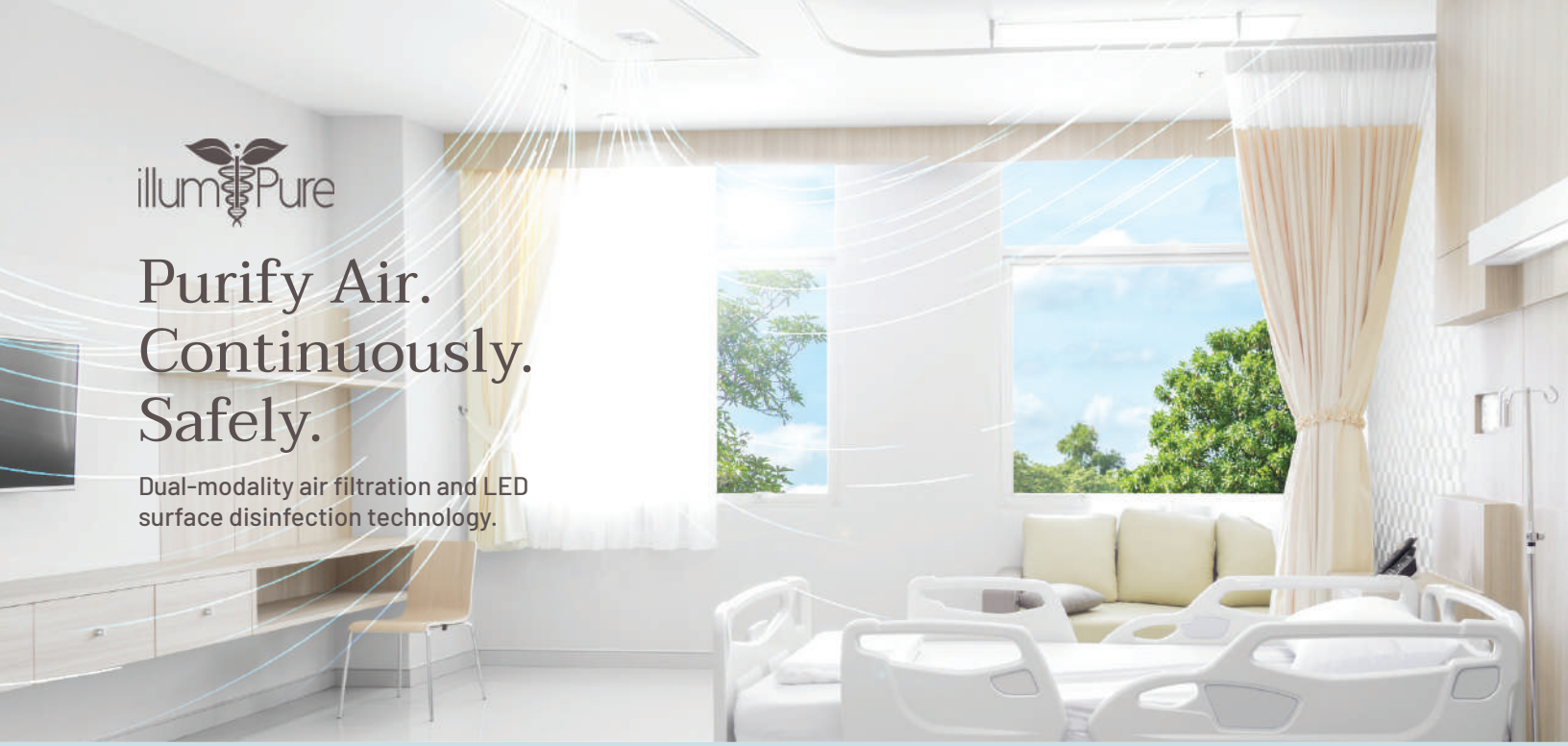

illumPure

Purify Air. Continuously. Safely.

Dual-modality air filtration and LED surface disinfection technology.

A continuous disinfection solution designed for healthcare environments, proven to kill >99% of pathogens

Many pathogens are eliminated within the first 4 hours, while >99% of the most difficult fungi, mold, and spores are destroyed within 24 hours.*

Discover our dual-modality solution for achieving LED surface disinfection and continuously purified air.

Advantages:

- Area-specific indoor air quality & disinfection
- Room ventilation and dilution of ambient air with purified air
- Ability to completely change and purify room air within minutes**
- Integrated, real-time monitoring of indoor air quality with mobile app and dashboard

Treat pathogens at their source

Our patented technology solution for better air quality and cleaner, safer environments provides surface disinfection, air disinfection and purification, as well as precision airflow and ventilation for any individual space or room.

*All viruses are known to be affected by UVC; however, inactivation time varies by type of virus.
**Room air changes can occur every several minutes depending upon variations of room size and fixture selection.

Complete surface + air disinfection solution

CleanWhite™
Continuous Surface Disinfection

CleanWhite provides continuous surface disinfection using patented, antimicrobial white-illuminating LEDs which destroy over 99% of surface microbes, including bacteria, spore forms, fungi, mold, and other harmful pathogens.

Air Guardian®
Air Treatment Technology

Air Guardian continuously neutralizes pathogens and purifies air. It provides complete air purification, including, disinfection, filtration, and destruction of chemical contaminants. Air Guardian produces frequent room air changes and protective airflow in any space.

Air Guardian Plus™
Dual-Modality Air + Surface Disinfection Technology

Combines Air Guardian and CleanWhite in a single fixture to provide both surface and air disinfection. Both Air Guardian and Air Guardian Plus offer integrated, real-time monitoring of indoor air quality with mobile app and dashboard.

Compare illumiPure to traditional UVGI & HVAC solutions

Features	HVAC	UVGI with UV lamps	illumiPure Solution
Provides local in-room air filtration	✗	Limited	✓
Personalized ventilation	✗	Limited	✓
Provides upper-room UVGI	✗	✓	✓
In-room flow regimes	✗	Limited	✓
HEPA or HEPA-level filtration	✓	Limited	✓
Provides removal of volatile organic chemicals (VOCs)	✗	Limited	✓

CE ETL RoHS FDA #10077990 EPA #98105-TX-1 Class I Medical Device MADE IN USA

illumiPure

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AIR GUARDIAN®
DETAILED SPECIFICATIONS

Breathe pure, safe air. Continuously.
Disinfect surfaces. Continuously.

An innovative new air disinfection solution that makes every space safer

June 2021

This document is a high-level specification of the Air Guardian®

This document has been prepared for **prospective clients** for review
Air Guardian® and Air Guardian Plus™ devices, Including CleanWhite™ technology

Air Guardian
Product Specifications and Description

Air Guardian – an Enclosed Ultraviolet Germicidal Air Disinfection and Purification Device

- An FDA registered device that safely and rapidly disinfects and purifies room air.
- Air Guardian® removes microbial pathogens, including the virus that causes COVID-19.
- Air Guardian's unique multi-mode process also removes hazardous particles and pollutants so effectively that pure, clean, safe air is constantly released into the room.

The Air Guardian® Difference

Multifocal Reaction Chambers

Air Guardian's patented design for disinfection and purification includes multi-focal reaction chambers, (MFRC), which are fueled by up to 210 Watts of UV energy. Inside the reaction chambers, UV-C wavelengths exhibit multi-step energies (primary and reflective) in precise wavelengths. This energy fuels the chamber reactor, which includes continuous oxidation of microbial organisms, organic and inorganic materials, particulates, and harmful chemical compounds. The chamber also incorporates airflow design elements that capture and hold air (residency) for extended periods of exposure to the reactor processes.

UV-A nano-reaction chamber

Upon induction into the Air Guardian® device, air is first pulled into a central antechamber; through a UV-energized ceramic matrix, embedded with TiO2 nano-crystal particles. UV light catalyzes these nanocrystals on the honeycomb surface, resulting in electron-hole pairs. This process initiates the production of reactive oxygen species (ROS). The ROS include super-oxides, hydroxyl radicals, singlet oxygen, and hydrogen peroxide. The especially large surface area of the nanoparticle embedded honeycomb produces a high concentration, or cloud, of reactive oxygen species.

UV-C multifocal nano-reaction chambers

From the antechamber, air is then pulled into the multi-focal reaction chambers. Inside the MFRC, air passes through continuous clouds of reactive oxygen species (ROS). The ROS are generated on up to 9,000 square inches of surface area, embedded with TiO2 nanocrystals and catalyzed by the high multi-step UV-C energies. The oxidation process destroys and inactivate pathogens and is highly effective at removing small particles, pollutants, and volatile organic compounds (VOCs).

Powerful, Continuous UV Irradiation

UV-C irradiation inside the multi-focal reaction chambers is powered by up to 210 Watts of UV energy in a narrow spectrum, 265 nanometers wavelength spike; considered to be optimal for microbial pathogenicity. Secondary, reflective "daughter" spikes, constantly bounce inside the reaction chambers, multiplying the initial UV Watt energy by retaining up to 40% of the energy of the initial wavelength. This dosing efficacy of this ultraviolet mirroring effect within the reaction chambers is unlike any other solution.

Reliable, effective dose-energy

The Air Guardian® UV-C LED diodes emit constant wavelengths and energy - maintaining efficacy and consistency throughout the 30,000 hour warranted lifespan.

Unsurpassed Air Residency

Using an innovative and adaptive fluid dynamic-based design, Air Guardian® is able to increase the amount of time air spends within the device (residency). Unlike any other system, this exposes air to longer periods of irradiation and oxidation – up to 23 seconds in the 2 x 2 device. Most disinfection devices can only treat air for sub-seconds (between .02 to .1 second) – a minimal dose/time effect. Thus, unlike Air Guardian®, most disinfection systems rely primarily on filtration, and are only capable of minimal pathogen and particle destruction.

Safe, Sealed Fixture

The sealed Air Guardian is certified by multiple regulatory agencies as safe, emitting no ultraviolet light, oxidizing molecules, or volatile compounds into room air. The Air Guardian® fixture extracts existing room air at a rate of 200-300 ft^3 per minute, which facilitates rapid room air changes. Each fixture can replace 12,000-18,000 ft^3 of air per hour. Room air changes can occur every few minutes, depending upon variations of room size and fixture selection.

Features

- Unique and powerful Multi-Focal Reaction Chambers
- Because Air Guardian® MRFC processes can remove harmful pathogens from the air through multi-step energetic and oxidative processes, high levels of purification and disinfection can be achieved without filtration (proven in testing). Other systems rely on HEPA or MERV filtration as a primary means of removal.
- Air Guardian® filters include both activated charcoal and either a HEPA or Micron filter for an additional layer of safety.
- Purified air is vented at least three feet away from the induction fan, and vents can be placed where optimal protective airflow is created based on each individual space
- Third party testing has certified that Air Guardian® emits no ozone or volatile compounds as a result of the disinfection and purification methods within the device.
- Third party lab and clinical models demonstrate 4 Log pathogen reductions in whole-room testing and 6 Log reductions in single pass results for all tested organisms, including RNA and DNA viral species, spores, vegetative bacteria, bacteria with ARG mutations, and fungal forms.
- Computational fluid dynamic (CFD) tests have validated air residency times within the device as 6.8 seconds for the 2 x 4 model and 23.2 seconds for the 2 x 2 model[1]
- Air Guardian® requires minimal maintenance. LED lights have a rated 30,000 lifespan with no degradation or wavelength shift. Filter changes, when recommended, can be performed in minutes, and costs between four and ten dollars USD.

Certifications And Compliance

- CE, ETL, RoHS
- Compliant with standards and all safety requirements from the International Commission on Non-Ionizing Radiation (ICNIRP)

[1] Residency times in CFD models vary by fan speed. Air Guardian® devices are designed such that fan speeds can be adjustable, depending on air quality and use case.

- Aligned with CDC and NIOSH recommendations for optimal airflow, pathogen removal mechanisms (UV-C) and layered safety strategies
- Air Guardian® UVGI technology is recommended by ASHRAE as a high priority application for disinfection and infection prevention
- Aligned with REHVA recommendations for improving ventilation, reducing cross contamination, and optimal airflow
- Patent pending
- FDA Facility #10077990
- EPA Establishment # 98105-TX-1
- FDA Medica l Device Classification Device Class 1 Listing #0420497

Warranties:
Ultraviolet energy: UV-A & UV-C LED diodes: 30,000 hours
UV-C wavelength specificity warranted at 265 nm for 30,000 hours
Fans: 5 years LED driver: 5 years
Chamber Housing: 25 years

Air Guardian® 2x2 and 2x4 devices can be installed in plenum spaces or on ceiling surfaces. A portable device is also available (see separate spec sheet) which provides protective, disinfected and purified airflow, in a moment's notice, anywhere it may be needed.

Applications
Retail, office, commercial, food production and storage, grow facilities, correctional facilities, municipalities, schools and universities, multi-unit housing, residential, athletic/exercise facilities, And healthcare, including ambulatory surgery, assisted living and retirement centers, dental offices, dialysis clinics, hospitals, long term care facilities, medical offices, nursing homes, urgent care centers, and veterans' facilities.

Technical Specifications

	2x2	2x4
CFM fan speed (variable)	50-200	75-300
Number of exhaust vents	2	2
Number of induction centers	1	2
Weight (lbs.)	10.65	24
Amps (10%)	0.75	1.5
Wattage	38	80
Decibels	33	41
Chamber total square feet	19	63
Chamber total linear feet	18	28.7
Chamber total Square inches	2750	9000
UV-C Wavelength	265nm	265 nm
Photocatalyst, powder coat	TiO2	TiO2
Activated carbon filters	1	2

Optional HEPA or Micron filters	1	2
Voltage	122 ~ 277	122 ~ 277

Efficacy

It has been proven that the sum of the Air Guardian® applied science mechanisms and design elements kill, inactivate, or destroy microbial pathogens within seconds or sub-seconds while resident within the cubic volume of air which passes through the multi-focal reaction chambers and through the other internal structures and elements within the device.

These elements include unique structures that slow airspeed, create turbulence, and produce vortices; the multi-focal mirroring effects of wavelength daughter bounces against reflective nano-crystals embedded within a ninety-three percent reflective surface coating, the conjugation of UV energies and oxidation, and the complex physics that govern the behavior of short wavelengths within the dimensions and length of the reaction chambers.

The high UV kill-curve in single-pass Log reductions is a result of dose energy over time, rather than distance traveled within the chambers. The proprietary CFD design elements within the chamber increase the time under dose, where the dose is between 55 Watts and 210 Watts.

CLEAN WHITE™ PRESENTATION

Breathe pure, safe air. Continuously.
Disinfect surfaces. Continuously.

An innovative new surface disinfection solution that makes every space safer

June 2021

This document is a high-level presentation of the novel surface disinfection device of CleanWhite™

This document has been prepared for **prospective clients** for review
Air Guardian® and Air Guardian Plus™ devices, Including CleanWhite™ technology

Continuous Surface Disinfection

POWERED BY illumiPure

CLEAN WHITE™ Technology

Proprietary Disinfecting White Light LEDs

Destroys bacterial, fungal, yeast, and spore-forming species with scientifically proven mechanisms.

5 Key Differentiators of CleanWhite™ Technology

Clinically Tested

Proven in clinical trials to kill MRSA, C. diff, salmonella, E.coli, and other harmful bacteria linked to HAIs on hard and soft surfaces in less than 24 hours.

Made in the USA

All illumiPure products are manufactured, assembled, tested, and shipped from our own advanced facility in Houston, Texas.

IAQ & Customization

Vertices™ AQS (Air Quality System) monitors the air quality and will adjust according to set parameters. IoT (Internet of Things) and automation available.

Proprietary UV Free

CleanWhite 405/470nm spectrum removes harmful UV rays while enhancing wavelengths most beneficial to killing bacteria.

24/7 White Light

CleanWhite technology provides *SAFE, CONTINUOUS DISINFECTION* in occupied spaces under the proprietary white light 405/470nm antibacterial spectrum array.

Product Overview

1. Air Guardian's® integrated solution protects against SARS-CoV-2, the virus that causes COVID-19.

2. CleanWhite panels emit precise light spectrums which constantly kill microbes on any surface.

3. Effective against MRSA, C. difficile, salmonella, E. coli, and other pathogens.

4. Penetrates and kills pathogens within biofilms, which are often resistant to chemical disinfectants.

5. Revolutionary drug-free approach for continuous inactivation of pathogenic microbes in occupied spaces.

6. Advanced controls enable energy/dose changes to improve kill times.

Air Guardian Plus™ and CleanWhite™ Panels

Fixtures available in 2x4 and 4x4 sizes

Product Overview

1. CleanWhite T8 tubes are ballast compatible with ‘plug and play’ installation.
2. CleanWhite Par38 bulbs conveniently replace existing lightbulbs.
3. CleanWhite troffer precision-formed diffuser produces comfortable, pleasant illumination.
4. Continuously reduce and eliminate dangerous bacteria, mold, and fungus from surfaces.
5. EPA and FDA registered. Certified by CE, ETL, ROHS, and other agencies.
6. Smart system disinfection “on demand”: IoT ready, remote control, automation, monitoring, and RFI/EMI available.

Additional CleanWhite™ Solutions

Available in retrofit kits and other fixture designs

Ultraviolet Lighting Devices and their Potential Risks

What is Ultraviolet Light? What are the effects of UV?

Ultraviolet (UV) 'light' is invisible to the human eye and refers to the electromagnetic spectrum between visible light and X-rays, ranging from 10~400 nanometers.

Many manufacturers disinfect by directly exposing surfaces to spectrum below 400nm. Overexposure to these ultraviolet waves can weaken the immune system and lead to serious health issues, including cancer.

Some UVC lamps generate ozone, which cause material degradation to plastics, polymers, and dyed textile, and produce formaldehyde, aldehydes, and other harmful secondary organic aerosols.

Illumination in wavelength energy bands below 400nm (UV) cannot be safely used in occupied spaces.

Longer, less energetic wavelengths outside of the UVC spectral band, however, are scientifically proven to disinfect if applied in the proper doses.

UV-C 260-270nm: Peak germicidal wavelength range; DNA damage, mutagenic
UV-A/UV-B 280~400nm: Germicidal activity via protein damage; skin reddening (erythemia); carcinogenic
400~700nm: Photodynamic therapy using photosensitizers
405nm: Peak germicidal activity via photoexcitation of porphyrins
470nm: Inhibits pathogens and inactivates bacteria through disruption of cell membranes

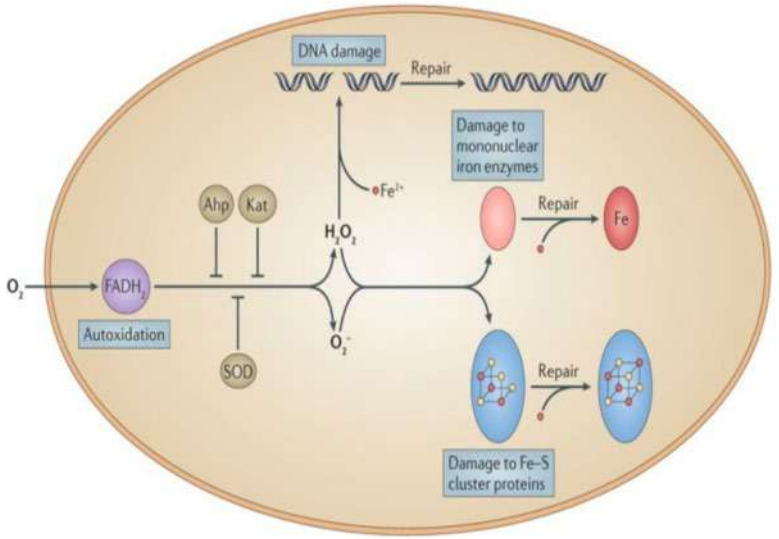
Antibacterial Blue Light (aBL)

Well-Studied and Proven Effective: A Drug-Free Approach for Inactivating Pathogenic Microbes

1. Antimicrobial blue light (aBL) in the visible light spectrum illuminates in a blue-violet color. Blue Light in the range of 405-470nm, residing just above the ultraviolet light band, is intrinsically antimicrobial and photodynamically inactivates the cells of a wide spectrum of bacteria and fungi. The antimicrobial effects of certain blue light wavelengths have been proven to effectively kill many pathogenic species including resistant strains. Research and literature on the subject have been exhaustive and scientifically studied for well over a decade.

2. The 470nm wavelength has been proven to be especially effective against certain microbes, such as Pseudomonas aeruginosa, Leuconostoc mesenteroides, Staphylococcus aureus, and Bacillus atrophaeus. Pseudomonas aeruginosa is often the infectious bacterium found in burn wounds and HAIs.

3. Studies have also shown that 405nm wavelengths may also reduce airborne microbial content, although not as quickly or effectively as ultraviolet air disinfection. Years of study and evidence reports that aBL is safe and effective for disinfection while humans are present, even over long durations.



Alternative Technologies

How do others on the market compare to CleanWhite™ Technology?

While periodic or one-time cleaning is important, continuous disinfection is vitally important to indoor safety. Safe, continuous surface disinfection has not been proven with any cleaning agent, molecular coating, electrostatic spray, or UV wavelength. Antimicrobial blue light (aBL) is the only proven mechanism.

HVAC Unit UV Light

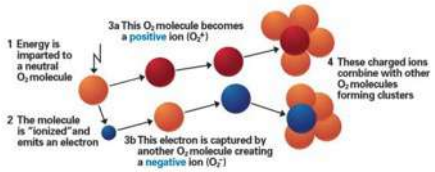
- Creates ozone, and releases endotoxins and small particles back into space
- Increased cost (installation of UV lights at every point within ductwork)
- Decreased treatment time due to HVAC airflow having higher CFM, not effective for high levels of disinfection capabilities

Portable Air Purifying Units

- Short term solution
- Requires a greater amount of time for full room air filtration
- Disinfection rates on bacterial particulates provide much lower effectiveness <99.9%
- Will not provide surface level bacterial disinfection

Anti-Bacterial Disinfection Spray (Electrostatic)

- Labor-intense; increased maintenance costs for cleaning services/requires 3rd party sanitation firms with expensive contracts
- Requires continuous manual applications
- Ongoing costs for purchasing of cleaning solution (refills) and additional materials
- Cannot disinfect while occupants present



Bipolar Ionization

- Can emit harmful ozone and VOCs
- Validated studies fall short of accuracy and accreditation
- Causes CO2 buildup, negatively impacting occupants and causing potential impairment
- Significant degradation of effectiveness over time; unreliable solution for disinfection

CleanWhite Technology continuously disinfects surfaces, preventing the formation of microbial colonies, pathogenic reservoirs, and complex biofilms. Evidence shows bactericidal blue light in the range of 405/470nm has the potential to help stem the ongoing pandemic of MRSA and other bacterial infections. Antibiotic-resistant organisms, increasingly prevalent in the COVID era, can be continuously suppressed using antimicrobial blue light.

CleanWhite™: Safe, Continuous Disinfection

1. Proprietary CleanWhite Technology is a safe, UV-free decontamination method enabling, continuous disinfection via high CRI white luminaires for general lighting purposes. Bactericidal properties are based on high-power narrow-band semiconductor emitters at 405/470nm.

2. Antimicrobial 405/470nm light is harmless to humans, yet effective, as the mechanism of disinfection only affects the cell walls of microbes.

3. CleanWhite technology completely suppresses wavelengths which would normally be harmful to eyes and mucosal tissues to provide clean, crisp, white-light disinfection. Lights appear normal and aesthetically comfortable to observers due to the integration of antibacterial spectrum under standard white illumination.

4. The purple-violet color of light used by other manufacturers is the only way to embed effective dose energy, creating distracting and suboptimal working conditions.

5. Many LEDs are known to shift over time into varying wavelengths nearby. CleanWhite chips are specially designed in a way that prevents wavelength shift from occurring over the lifetime of the chipset.

6. CleanWhite Technology has been scientifically proven in clinical trials to kill harmful bacteria linked to airborne HAIs on hard and soft surfaces in less than 24 hours.

CleanWhite™ Alternative Technology Comparison Chart

Vendor	VyV	Kenall/ Indigo-Clean	LifeX Clean or similar	CleanWhite™
Can illuminate in white spectrum	No. Must illuminate in purple- violet to achieve maximum disinfection.	No. Must illuminate in purple-violet to achieve maximum disinfection.	X	**Y**
Can illuminate in white spectrum with full disinfection	X	X	X	**Y**
Wavelength precisely spiked at near-UV 405nm and at no other harmful nearby wavelengths	X	X	X	**Y**
Single diode includes ability to illuminate in white spectrum with embedded 405/470nm precision wavelength spikes	X	X	X	**Y**
Proven in laboratory testing to kill pathogens at 4-log within 24 hours at normal white light illumination	X	X	X	**Y**
Energy in joules/cm2 can be increased on the same chipset board	X	X	X	**Y**
Controllers can adjust energy levels by sensing room occupancy, time of day, scheduled periods	X	X	X	**Y**
Can be integrated to an air purification and disinfection system	X	X	X	**Yes, Air Guardian®**
Fixtures and LEDs made in the United States	Unknown	Unknown	Unknown	**Y**
Guaranteed non-shifting wavelengths throughout warranty period, blocks harmful blue wavelengths	X	X	X	**Y**
Ability to increase joules/cm2 to surface energy levels to kill most vegetative bacteria within 2-4 hours	X	X	X	**Y**

CleanWhite™ Applications

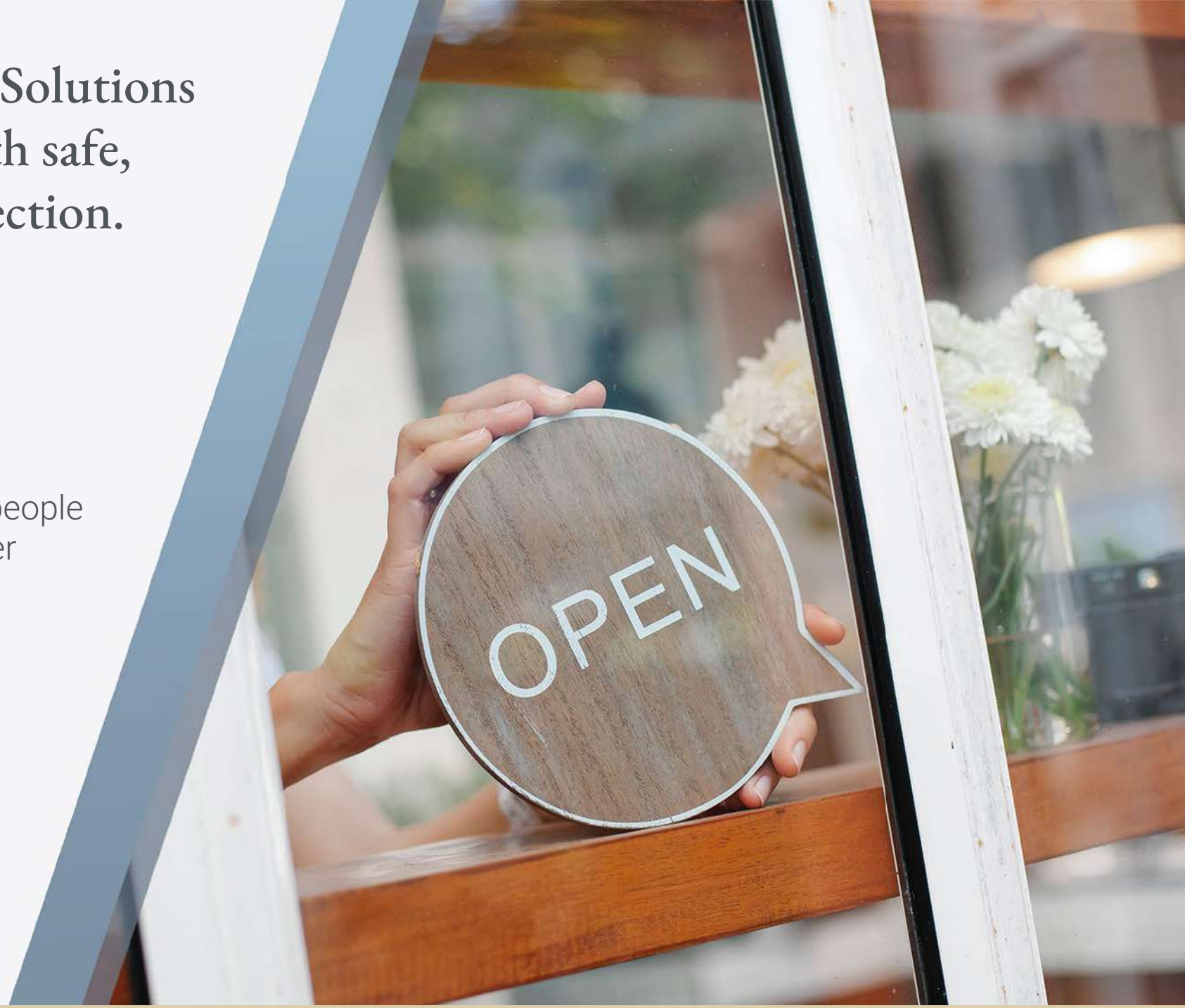
illumiPure's CleanWhite Solutions are applicable in a wide range of different industries, sectors, and businesses. They provide safe, continuous disinfection for occupied spaces to essentially any agency operating within a facility or enclosed space.

Below are some of the main types of organizations taking advantage of CleanWhite technology.

- Medical Centers / Outpatient Offices
- Assisted Living Centers / Retirement Communities
- Public Safety: Fire Stations / PD
- Franchise Chain Locations
- Restaurants
- Banks
- Hotels / Casinos
- School Facilities
- Warehouse Facilities
- Administrative Offices
- Indoor Arenas
- Convention Centers
- Gyms
- Movie Theatres
- Commercial Real Estate
- City Facilities

illumiPure's CleanWhite™ Solutions provide peace of mind with safe, continuous surface disinfection.

Let us help you offer a space where people gather safely and enjoy being together once again.



AIR GUARDIAN PLUS™
BLOG, *THE NEW EPIDEMIC*

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The New Epidemic

The continued global fight against resistant pathogens and the value of antimicrobial visible light illumination.

Five years ago, a small cut on my finger became infected while working in a hospital. I first noticed it on Thursday afternoon. By Monday, the infection had moved from my hand up my elbow. On Tuesday, I needed surgery.

The culprit was a resistant form of gram-positive cocci (GPC). When I recovered, I learned how fortunate I had been. Among those who are infected with this particular pathogen, the mortality rate can be as high as 15-20% depending on various factors, such as location and time to treatment.

The antibiotics I received were among the last drugs available to which the GPC was not fully resistant. After two different courses of treatment, they eventually worked.

I was fortunate that my encounter with that particular bacteria was five years ago. Today, GPC have acquired more forms of resistance and can cause more virulent forms of infection.[1]

Antibiotic resistance

Generally, the categories of antibiotics once effective against gram-positive cocci (GPC) were vancomycin and cephalosporins. Today, GPC have acquired multiple forms of resistance against them. These two antibiotic stalwarts are often ineffective against several GPC strains.

For GPC and other resistant pathogens, only a few effective drugs remain. One such drug is Daptomycin. Daptomycin has clinical risks, both in suboptimal doses (clinical failure) and minimal trough doses[2] (skeletal muscle toxicity). Drugs like Daptomycin also have complex pharmacokinetic requirements, especially in septic patients.

When drugs like Vancomycin and Daptomycin fail, resistant GPC bacteria can be virulent enough to cause sepsis, organ failure, and death. Sepsis is one of the significant causes of mortality within acute care hospitals.[3] One in five deaths globally are from sepsis:

"For 2017, Rudd and colleagues reported that the global burden of sepsis was twice that of previous estimates, with an estimated 49 million cases and 11 million deaths. Moreover, the annual number of sepsis cases over the past two decades fell worldwide by more than 50%. Yet sepsis still contributed to almost 20% of all deaths every year in the world, more than 20 deaths every minute."

Effects of the viral pandemic – the rapid growth of antimicrobial resistance

While the world has focused on SARS-CoV-2 and COVID, bacteria, fungi, and other microbial strains have been working hard to acquire ARG (antimicrobial-resistant genes) and share it through streamlined gene transfer methods (HGT).

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[1] Vazquez-Guillamet C, Kollef MH. Treatment of Gram-positive infections in critically ill patients. *BMC Infect Dis*. 2014;14:92. Published 2014 Nov 28. doi:10.1186/1471-2334-14-92

[2] the lowest concentration reached by a drug before the next dose

[3] 1. Kempker JA, Martin GS. A global accounting of sepsis. *The Lancet*. 2020;395(10219):168-170. https://www.sciencedirect.com/science/article/pii/S014067361933065X. doi: https://doi.org/10.1016/S0140-6736(19)33065-X.

It has even been shown that when chemicals kill ARG bacteria and the cell walls rupture, free-floating DNA (in an aqueous solution) can also be acquired by other bacteria.[4]

In the recent article, The Next Pandemic Is Already Here[5], the authors state:

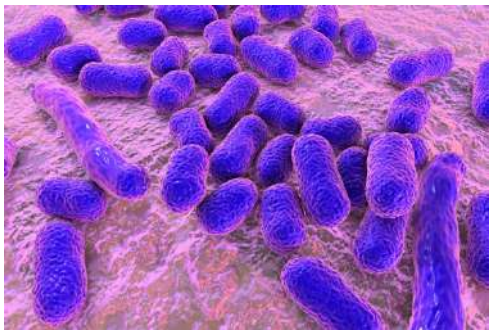
"It used to take 21 years on average for bacteria to become resistant when antibiotics were first used. ***Now it takes just one year on average for bacteria to develop drug resistance.*** *Today, the CDC lists 18 different types of antibiotic-resistant bacteria and classifies five as urgent threats to human health."*

Thus, as the world moves slowly beyond the acute period of the COVID lockdowns, either through vaccination or population immunity, it is returning to **the simmering, disturbing, and desperate problems of pathogenic resistance, increased toxicity, and an annual mortality rate that is astoundingly high**.

Many patients with COVID died from respiratory infections, comorbid to pneumonia, from resistant bacterial and fungal pathogens that found root in the lungs of Covid patients. Combined with COVID, ARG-resistant pathogens were often what caused the endpoint of survival.

"The Great Eskape"

There is another species of especially nasty bacteria quickly gaining notoriety.



In her article, The Great ESKAPE[6], author Sophia Häfner speaks about the dangers of the "Eskape" pathogens, including *Enterococcus faecium, Staphylococcus aureus, Klebsiella penumoniae, Acinetobacter baumannii, Pseudomonas aeruginosa,* and *Enterobacter* spp. But the author is especially concerned about Acinetobacter baumannii (A. baumannii):

"*Virulence-wise, A. baumannii is equipped with an entire arsenal of vileness, such as at least three transmembrane secretory systems, besides the ability to secrete outer membrane vesicles (OMVs) loaded with virulence factors.*

Into the bargain, the bacterium is literally coated in pathogenicity factors: lipopolysaccharides (LPS), capsular exopolysaccharides (CPS), and a selection of outer membrane proteins (OMPs). Among these, the beta-barrel protein OmpA is the most known and abundant, as it serves both as a grappling hook for adherence and invasion, and as fatal messenger inducing host cell apoptosis."[7],[8]

As for the resistance, the bacterium is sturdy enough to persist on abiotic surfaces and resist desiccation or disinfectants - to a degree that 60% of pathogens remain after terminal cleaning of medical facilities – mainly through its ability to form biofilms. Once inside the host organism, this sense of community comes in handy for

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[4] Calderón-Franco, David & van Loosdrecht, Mark & Abeel, Thomas & Weissbrodt, David. (2020). Free-floating extracellular DNA: Systematic profiling of mobile genetic elements and antibiotic resistance from wastewater. Water Research. 189. 10.1016/j.watres.2020.116592.

[5] The Next Pandemic Is Already Here by Marty Makary MD, MPH, Indrani Das, Farah Hashim, Christi Walsh, NP January 20, 2021

[6] 1. Häfner S. The great ESKAPE. *Microb Infect*. 2021:104830. https://www.sciencedirect.com/science/article/pii/S1286457921000526. doi: https://doi.org/10.1016/j.micinf.2021.104830.

[7] C.-R. Lee, J.H. Lee, M. Park, K.S. Park, I.K. Bae, Y.B. Kim, *et al.*
Biology of Acinetobacter baumannii: Pathogenesis, Antibiotic Resistance Mechanisms, and Prospective Treatment Options

[8] Front Cell Infect Microbiol, 7 (2017), 10.3389/fcimb.2017.00055 P. Nasr **Genetics, epidemiology, and clinical manifestations of multidrug-resistant Acinetobacter baumannii.**
J Hosp Infect, 104 (2020), pp. 4-11, 10.1016/j.jhin.2019.09.021

immune evasion, notably on medical devices like catheters, combined with CPS and other factors shielding the pathogen from the complement system."

The many sources of resistance

While many ESKAPE pathogens appear in hospitals – especially in comorbid or immunocompromised patients, the fault isn't always with the hospital. Studies have repeatedly shown that mutations occur much more rapidly in communities. Mutations can rapidly occur in pathogens within the community (outside the hospital environment) – and in many ways: within beef and poultry farming, in food production, with the veterinary and human use of antibiotics, within the mixed effluents of water treatment facilities, within municipal water supplies, and in many other places within communities.

As previously stated, pathogens have learned how to resist chemical disinfectants, cleaners, antibiotics, and harsh environments. This learned resistance comes from mutations within the DNA of "treated" colonies. These beneficial mutations are known as ARG (antimicrobial-resistant genes). ARG organisms can share their resistance genes through a process called horizontal gene transfer (HGT). HGT can spread ARG through entire microbial colonies.

ARG movement from community to hospitals

It is also worth noting that many acute care hospitals intake patients from nursing homes and long-term care facilities.

"…public health experts say that nursing facilities, and long-term hospitals, are a dangerously weak link in the health care system, often understaffed and ill-equipped to enforce rigorous infection control, yet continuously cycling infected patients, or those who carry the germ, into hospitals and back again.

"They are caldrons that are constantly seeding and reseeding hospitals with increasingly dangerous bacteria," said Betsy McCaughey, a former lieutenant governor of New York who leads the nonprofit Committee to Reduce Infection Deaths. "You'll never protect hospital patients until the nursing homes are forced to clean up."[9]

Lines of Defense

As previously illustrated, the WHO is urgently seeking the development of new antibiotics to treat threatening, resistant organisms. A baumannii is a top priority. However, the organism's ability to adapt, mutate, resist, and persist makes it a formidable adversary. Vaccination studies have resulted in limited but successful testing in rodent models. However, vaccine development seems unlikely, given the financial considerations of a finite pool of candidates. Other efforts to combat A. baumannii have been studied, including *"periplasmic translocation inhibition, iron chelation, [and] monoclonal antibodies. More creative approaches involve gallium nanoparticles, and quite compellingly, a renewed interest in bacteriophages."*[10]

As the war on ESKAPE pathogens, including GPC and A. baumannii, continue, battles have already been lost – in massive numbers. In 2014, Rand Europe projected that annual deaths from resistant infections would reach ten million per year globally by 2050[11] - exceeding yearly deaths from cancer.

And yet, in 2017, Rudd et al. showed that real sepsis mortality numbers already exceeded those tragic projections, with over 49 million resistant infections each year, along with 11 million deaths.[12] These numbers show global mortality rates at an astounding twenty percent.

[9] https://www.nytimes.com/2019/09/11/health/nursing-homes-fungus.html
[10] 1. Häfner S. The great ESKAPE. *Microb Infect*. 2021:104830. https://www.sciencedirect.com/science/article/pii/S1286457921000526. doi: https://doi.org/10.1016/j.micinf.2021.104830.
[11] https://www.bbc.com/news/health-30416844
[12] 1. Kempker JA, Martin GS. A global accounting of sepsis. *The Lancet*. 2020;395(10219):168-170. https://www.sciencedirect.com/science/article/pii/S014067361933065X. doi: https://doi.org/10.1016/S0140-6736(19)33065-X.

CleanWhite 405/470 antimicrobial white-illuminating blue-light LEDs

Despite SARS-CoV-2 and Covid-19, resistant pathogens remain a worldwide threat. Vaccination development continues to focus on SARS-CoV-2 and emerging variants. Other treatments have shown promise but remain in early development.

One approach that has been proven effective against resistant pathogens is continuous photocatalyzed visible light disinfection.

Using precision photo-energy spikes, illumiPure's 405+470 LEDs can kill most studied pathogens, include ESKAPE pathogens and resistant ARG forms. Importantly, it accomplishes this while illuminating in a visible white light.

Other 405 nm solutions cannot reach adequate dose energy to effectively kill pathogens[13] without emitting in the blue-violet light spectrum.

illumiPure's solution excludes all other blue wavelengths, including those in the harmful 435-455 nm spectrum, wavelengths known to be damaging to retinal cells. illumiPure uses a patented impurity-free polymer for fixture lenses, which enable over 90% of emitted wavelength energy to pass through the lens. The ability to surface-dose with >90% of the emitted energy is exclusive to illumiPure.

The inability[14] of other fixtures to adequately dose surfaces with LED energy as promised in specification documents is rarely acknowledged and, in general, poorly understood.

When modeling the efficacy of dose energy (as expressed in specification documents as Watts or Joules/cm^2) one must consider the reflection of the photons against the inner surface of the lens. Most fixtures have lenses that cover the LED chips as part of the fixture. Lenses used by other fixture companies, with few exceptions (we have seen no exceptions to date), are not impurity-free.

Unless the product literature explicitly states that their fixture lenses enable unimpeded passage of full-energy 405 wavelengths, with no reflection back into the fixture, buyers may assume impedance and bounce-back. In general, most lenses used in LED 405 fixtures bounce 40-50% of the energy back into the fixture, which throttles the dose energy emitted from the fixture and its ability to reach surfaces at needed energy levels.[15] And, when energetic wavelengths reflect back into the fixture and the energy dose lands on the chips or circuits, which may cause faster chip degradation and wavelength variance.

DOSE ENERGIES

The importance of delivering dose to surfaces at high levels (Joules/cm^2) cannot be understated, especially with dangerous ESKAPE pathogens:

Maclean et al. (2009) investigated 405 nm irradiation at 10 mW/cm^2 (.01 Joules) against a broad range of microorganisms including all ESKAPE-pathogens. Their findings concerning the sensitivity of different genera is comparable to the results obtained here. A. baumannii, S. aureus, and P. aeruginosa are more susceptible to visible light, while for E. coli, enterococci and K. pneumoniae higher doses are necessary for 1 log reduction.

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A critical observation of this study shows that while 405 nm light does demonstrate an inactivation mechanism on bacterial species at (using the MacLean et al, study dose of .01 J/cm^2), the "inactivation dose" needed for a "noticeable" colony reduction is actually 300 J/cm^2.

It is for this reason that many fixtures cannot deliver enough dose for reasonable disinfection over time. Because a) the Watts/cm2 energy is diminished by the lens and b) the energy needed for a reasonable kill time can only be delivered in purple-violet visible light.

Consider the experimental results referenced above and a modeled extrapolation for using 405 nm light for killing ESKAPE pathogens on surfaces:

". . . compared to Maclean et al. (2009)… the tendencies are similar, including the necessity of an exposure of about 300 J/cm2 for enterococci until inactivation progress is noticeable.

[compared to the MacLean et al. (2009) study] ... the inactivation dose of 42.9 J/cm2 for 1 log reduction of P. aeruginosa is comparable to the 57.1 J/cm2 result achieved here.

Concluding, the results for the necessary dose at 405 nm irradiation in this study are relatively high, especially concerning the inactivation of Enterobacteriaceae - including Klebsiella and Escherichia – and enterococci. For S. aureus there are several studies coming to similar conclusions with doses between 50.2 and 61.6 for a 1 log reduction (Enwemeka et al., 2008; Guffey et al., 2013; McKenzie et al., 2016). Furthermore, our data is in agreement with the literature that Acinetobacter baumannii, declared as one of the most problematic species in the WHO priority list (World Health Organization, 2017), is the most susceptible ESKAPE pathogen at 405 nm irradiation.

"Inactivation doses" to achieve a 1 Log reduction (90%) or a 5 Log reduction (99.999%) may be delivered in an additive fashion, either in short periods of time at high dose, or longer periods at lower dose – but they must add to the required observed dose for inactivation using the 405 nm wavelength.

Antimicrobial action and substrate saturation in a spatial environment

Experimental processes often measure required energy doses for Log reductions through a process of short-distance illumination of 405 nm wavelengths on surfaces, including agar plates, is quite different from what happens in the process of disinfection within a whole room.

For example, if 400 joules of energy is needed to reduce colonies of a bacterial species at a 1 Log, and the LED light energy emission is 40 Joules/cm^2/sec then the following would be expected:

1. The energy, in Joules, would need to be measured at the substrate surface of the bacteria

2. In a fixture rated at 40 Joules/cm^2/sec, we must assume that there would be a) no impedance from the lens and b) no energy reduction in the distance between the fixture and the surface substrate (fixture-to-surface distance)

3. Assuming 40 Joules/cm^2/sec is delivered to the bacteria, we proceed to #4

4. The process of photo-catalyzation would then begin when the 405 nm wavelength photons reach the bacterial eukaryotic cell. Then, photo-excitation (catalysis) may begin, initiating an oxidation process, shown below, beginning at the cell wall and continuing in the DNA-containing organelles.

5. In this example, 40 Joules/cm^2/sec would then need x amount of time to "saturate" the bacterial substrate, whether the bacteria is contained within an ORM (organic rich media), in surface colonies, or in biofilms
6. The saturation process varies by substrate, and thus one must add significant saturation time to allow for the full process to occur, at dose
7. For example, if 400 Joules is needed to achieve a 1 Log reduction of the specific bacterial species, one must account for the bacteria's presence in colony form on surfaces, within ORM, or within biofilm.

Thus, one cannot assume that within 10 seconds whole room disinfection will occur (40 Joules/cm^2/sec x 10 seconds = 400 Joules = I Log reduction). Rather, that should be considered the point at which effective bactericidal saturation begins; when a noticeable kill process begins.

Time must be allowed for saturation/oxidation to reduce the bacteria located on surfaces, in ORM, or in biofilms.

In this example, at 10 seconds, assuming #3 above, kill dose saturation begins.

Time to achieve a 6 Log reduction depends upon bacterial concentration and substrate location.
405 nm is effective at completely reducing bacteria in ORM or biofilms, but additional time for saturation is required, which increases Log reductions, depending on the biofilm community or ORM solution.

For example, a **bacteria that is susceptible to a 400 Joules/cm2 dose of 405 nm energy**, the time to achieve 4-6 Log reductions will vary, depending on initial concentration, bacterial environment, and substrate.

To estimate time needed for a 4-6 Log reduction on all surfaces and media, a conservative approach should be used. illumiPure would calculate that projection using the following variable algorithm:

10 seconds to achieve an effective kill-dose of 400 Joules/cm^2
Within 60 seconds of 405 nm saturation, the 405 nm energy begins to photo-catalyze porphyrins to produce reactive oxygen species, beginning at the cell wall
Further saturation migrates the oxidation processes to cell organelles
Based on studies that extrapolate on the MacLean et al. original experiments, 95 minute saturation periods are used to measure log reduction amounts. In this case, a 4 Log reduction could be projected at the 95 minute mark, which would provide adequate time to saturate bacteria present, in all forms, at the effective kill-dose energy levels

Thus, for a bacterial strain which has a 400 Joule energy dose, illumiPure could expect a 4-6 Log reduction within 95 minutes.

The above process is described, in detail, to illustrate the difference between experimental measurements and real world whole-room reductions. This is an important understanding when evaluating different solutions.

Importantly**, if** full dose energy can only be achieved in a purple-violet light, then the illumination of that light, with at least 40 Joules of energy, must be continuously used for that period. When the light is turned off (dose energy is below 40 Joules), bacterial re-growth can be expected from aerosolized sources or incomplete colony/biofilm reductions.

That's why illumiPure's always-on capability is so important. The always on mode suppresses the formation of biofilms, CFUs on surfaces, and in ORM. With little existing presence, any new introduction of bacteria is saturated and killed much more efficiently then it would have if dose-energy had not been consistently present.

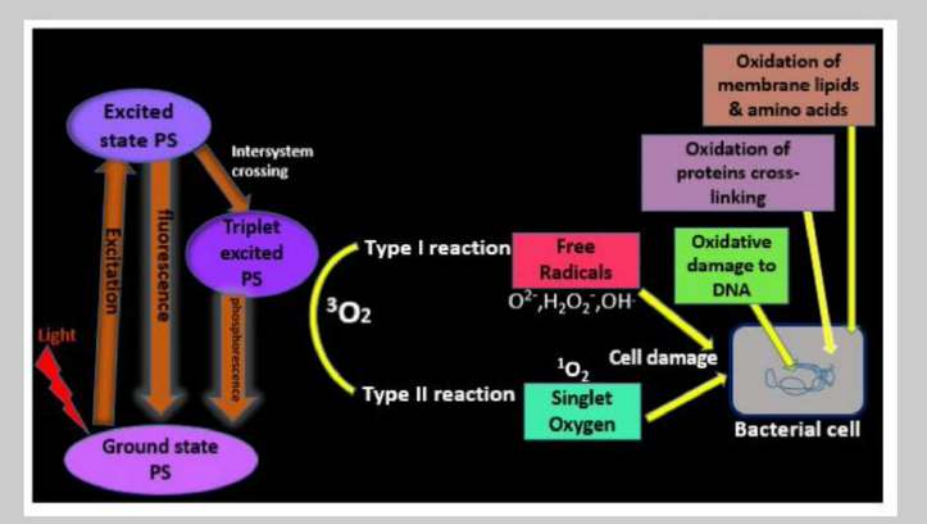
Other considerations when evaluating illumiPure CleanWhite 405/470 antimicrobial white-illuminating blue-light LEDs versus other aBL (antimicrobial blue light) fixtures:

Almost all competing fixtures use lenses in which 405 wavelengths bounce back into the fixture and reduce the actual emitted energy dose by up to 50%.

All competing fixtures will require illumination in shades of violet-purple to achieve effective energy doses

If dose-energy is reduced because of lens impedance or the ability of the LED chip to deliver actual dose versus rated Watts (25 Joules, for example) the time to kill-dose saturation is extended AND the incremental progression of saturation is slowed at lower dose

With reduced or lower energy doses, an extended period of purple-violet illumination will be needed to achieve proper levels of disinfection in all substrates. Based on the resiliency or susceptibility of the bacteria (e. coli, for example) purple-violet illumination could theoretically be required for several hours.



In other words, a fixture that cannot provide adequate dose levels without illumination in purple-violet light, and which does not have an impedance-free lens, is probably not going to be an effective solution, whether occupants are present or not. To overcome lens impedance and expected real energies emitted from the purple-violet LED chip, an extremely high level of Joule energy would be needed. Increased watts increases lumens, such that in a real-world room, purple-violet lights would be correspondingly bright, as high as 100-120 Watts.

Operating continuously, in surface dose energies between 30 joules/cm^2 and 80 joules/cm^2, illumiPure's single-chip technology 405+470 LEDs and patented lens material can deliver dose energies that can rapidly kill or inactivate bacteria, yeast, mold, and some viral species – even in biofilm form.

With illumiPure 405+470 LEDs, the time needed for high Log-reduction is four to twenty-four hours, depending on the initial colony counts within a given space. Many species of bacteria and microbes are reduced in high Log levels within 3-4 hours.

CleanWhite® 405+470

Air Guardian® Plus includes an integrated, fully controllable component of the Air Guardian® Plus device, which disinfects surfaces, called CleanWhite.

CleanWhite® is a patented 405+470 aBL surface disinfection technology that is not harmful to humans.

CleanWhite emits antimicrobial blue light (aBL) (visible spectrum, near UV) in a white light illumination, which can constantly provide saturation at dose energies required to kill a vast species of microbes (containing cellular porphyrin) on any surface, substrate, ORM, or biofilm.

The mechanism proven in clinical studies is a 405+470-nanometer light-induced photodynamic process in which the wavelengths trigger a reaction within the cells and cell walls of the microbes – causing cellular destruction and preventing repopulation.

CleanWhite™

Continuous Surface Disinfection

CleanWhite provides continuous surface disinfection using patented, antimicrobial white-illuminating LEDs which destroy over 99% of surface microbes, including bacteria, spore forms, fungi, mold, and other harmful pathogens.

Air Guardian Plus™

Dual-Modality Air + Surface Disinfection Technology

Combines Air Guardian and CleanWhite in a single fixture to provide both surface and air disinfection. Both Air Guardian and Air Guardian Plus offer integrated, real-time monitoring of indoor air quality with mobile app and dashboard.

Breathe pure, safe air. Continuously.
Disinfect surfaces. Continuously.

An innovative new air and surface disinfection solution that makes every space safer

Air Guardian® and Air Guardian Plus™ White Paper
Including CleanWhite™ technology
June 2021

This document is a high-level description of the novel air purification and surface disinfection devices of Air Guardian® and Air Guardian Plus™

This document has been prepared for **prospective clients** for review
Air Guardian® and Air Guardian Plus™ devices, Including CleanWhite™ technology

illumiPure's Mission and Vision

illumiPure's mission is to design solutions that offer the highest level of air purification, ventilation, and surface disinfection. To blend proven science with creative innovation and engineering. To constantly seek new scientific discoveries and technical breakthroughs that might become part of our future solutions.
To constantly enhance, improve, and expand our products - to help everyone, in every setting, breathe the cleanest, purest, and safest air possible.
We believe in the importance of setting new standards for indoor air quality.
We believe in educating the public; about how the air we breathe affects our health, cognition, well-being, and even lifespan. We believe that everyone has an absolute right to breathe clean, safe air.
We are committed to environmental and social responsibility - to be globally aware, and within that context, remain conscious of our commitments - from the materials and suppliers used to produce our products to the relationships we have with our employees, partners, and customers.

The illumiPure® approach

illumiPure® designed Air Guardian and CleanWhite to protect individual occupied spaces, regardless of the building's age, construction design, ventilation challenges, or other variables that may contribute to poor air quality.

We advocate for clean air spaces in every building, with no exceptions or exemptions, regardless of construction design or local air pollution conditions.

If buildings are "too old" to be modernized with better air circulation, disinfection, ventilation, or built environment solutions, then we propose that each individual room is protected with technologies that meet the Air Guardian's ability to ventilate, purify, and disinfect air and surfaces within each room.

We believe that no one should be exposed to pathogens, microbes, or contaminants that can impair cognitive function, transmit infections, or cause chronic or permanent diseases - such as obesity, cancer, heart disease, neurological degeneration, and many others.

Indoor Air Quality - General

Guidelines and regulations for indoor air quality, including pollution, pathogens, specific molecular compounds found in ambient room air, and particle counts will vary and may include stand and/or federal regulations. Recommendations have also been established for certain buildings and use cases[1]. The CDC, for example, has different recommendations for room air changes, HVAC controls, and surface disinfection in certain types of businesses, buildings, rooms, and intended occupants.

Regulations and requitements may be stablished by the Centers for Disease Control[2] (and Opening up America Again in conjunction with the US Government)[3], IAQ oversight groups, ASHRAE[4], REHVA, EPA, FDA, FIFRA, and APIC.

For information about Air Guardian's alignment and compliance with regulatory agencies, see https://www.immaculight.com/technical and EPA, FDA, and other information here:

Certifications
CE, ETL. RoHS, IUVA
Patent-pending Immaculight
FDA Facility #10077990
EPA Establishment# 98105-TX-1
FDA Medica Device Classification: Device Class II - Listing #D420497

The Air Guardian - the ultimate UVGI-based air disinfection and purification solution

[1] Additional regulations, policies, procedures, and guidelines are often seen in specific use-case settings - such as classrooms, air travel, oncology, pediatric, dental, dialysis, intensive care, operating rooms, clean rooms, and other areas.
[2] https://www.cdc.gov
[3] https://www.whitehouse.gov/openingamerica/
[4] https://www.achrnews.com/articles/143009-discussing-the-cdc-and-ashrae-recommendations-for-hvac-systems

Air Guardian® Science, Efficacy, and Design Summary

1) Air Guardian® is the only commercially available, upper-room sealed UVGI device that will remove - not just filter - nearly all infectious pathogens in an ingested cubic volume of air.
2) Air Guardian® can be installed either in the ceiling plenum or mounted on the ceiling surface, and is available in multiple form factors, including 2x2, 2x4, and portable form factors.
3) Air Guardian® devices are pre-configured to be controlled as either a single device or in tandem with up to four other devices from a single controller. Aspects of the Air Guardian® device can be controlled by the end user, via the controller itself or the Vertices™ integrated IAQ sensor system (described below). The controllable aspects are on/off, dose energy, and fan speed.
4) Third-party Computational Fluid Dynamic testing has certified Air Guardian® ambient air ingestion rates, air residency rates within the device, and the volume (in kg/second) and spread of downward airflow - all produced from patented design elements.
5) Air Guardian's innovative induction fan design, including angle, speed, and location is uniquely effective at drawing room air, which helps stimulate upward air movement around the downward columns of vented and dispersed air within the breathing zone.
6) Upward air movement is also generated by Air Guardian® through convection forces, which is created when cool air (approximately four degrees cooler than ambient room air) is vented from the multiple supply sources, which are positioned well away from air induction locations. This is a function of exposing resident air to a titanium dioxide surface area equal to twenty to sixty-three square feet.

7) The air temperature gradient between ingested and vented air is due to the known effects[5,6] of TiO2 surface reflection and thermal absorption. Thermal cooling is supplemented by fluid dynamic forces (airflow), near-zero surface friction, and the thermal shielding on the exterior of the Air Guardian® device shell, which enables the gradient between ambient room air and the interior of the device chambers.

8) The sum of Air Guardian® design elements enable more rapid ingestion of room air, enhanced upward air movement and convection, and thus more frequent - and complete - room air changes (ACH) while using fewer devices than any other solution.

9) Air Guardian's high kill-curve reduction rates and particle/chemical dissolution capability mean that each room air change (ACH) is of higher value than an equivalent ACH from any other sealed UVGI solution. Thus, room air change rates from other vendors may be a misleading measure of infection prevention and improved air quality and must be carefully considered.

10) With Air Guardian's innovative and patent-protected design, a cubic volume of ambient room air, is forced through a residency period within the device, for a period of 6.6 to 23 seconds (depending on device model). During residency, ingested air volume is exposed to powerful ultraviolet energies generated by proprietary UV-A and UV-C LED diodes.

11) Air Guardian® Ultraviolet LED energy is between 55,240 - 210,000 millijoules - continually directed at microbial, particulate, and chemical air elements. All captured air volume is exposed to UV energies.

12) Because of Air Guardian's proprietary diode and circuit design, the UV-C dose wavelength is a precise, unchanging, exact 265nm, which has been proven in multiple studies to be the optimal wavelength for microbial destruction and fastest kill-curve Log reductions.[7]

13) Warranties - Air Guardian® uses long-lasting proprietary LED diodes, the warranty for the diodes is 30,000 hours, or more than three years of constant use. It is guaranteed never to shift off the 265nm wavelength during that time. The device itself, excluding LEDs and fans, is warranted for 25 years. The fans have a 50,000-hour warranty. These warranties reflect the superior grade of materials, manufacturing techniques, quality control, assembly, and design.

14) Maintenance - Air Guardian® has recommended periods for filter replacement, which depend on use case. The filter replacement process is simple and device-accessible, and is described in the installation and maintenance guideline document, which can be found at https://www.immaculight.com/installation-guide.

15) It has been proven that the sum of the Air Guardian® applied science mechanisms and design elements kill, inactivate, or destroy microbial pathogens within seconds or sub-seconds while resident within the cubic volume of air which passes through the proprietary internal structures of the device. These elements include intense UV energy and continuous photo-catalyzed oxidation.

16) The high UV kill-curve in single-pass Log reductions is a result of dose energy over time, rather than distance traveled within the chambers. The proprietary CFD design elements within the chamber

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[5] B. Givoni, M.E. Hoffiman, Effect of building materials on internal temperatures, Research Report, Building Research Station, Technion Haifa, (1968).
(i) H. Taha, D. Sailor, H. Akbari, High albedo materials for reducing cooling energy use, Lawrence Berkeley Laboratory Report 31721, UC-530, Berkley CA, (1992). DOI: 10.2172/7000986
(ii) A. Seneca, A. Santamouris, W. Miller, A. Livada, A comparative study of the thermal performance of reflective coatings for the urban environment, in Proceedings of the International Conference Passive and Low Energy Cooling for the Built Environment, Santorini, Greece, (2005).

[6] https://www.scientific.net/KEM.545.95

[7] https://www.cdc.gov/niosh/nioshtic-2/20034387.html

increase the time under dose, where the dose is between 55,240 - 210,000 millijoules of precision wavelength irradiation.

17) Photo-catalyzed oxidation is also highly destructive to microbial pathogens. The amount of surface areas upon which the oxidative reactions occur are directly related to efficacy. On every square inch of surface, chemical “clouds” of highly Reactive Oxygen Species continuously form. As ingested air passes through the device, it is constantly exposed to these oxidatively-destructive forces that form on all surface areas. The Air Guardian® devices have between 2,750 and 9,000 square inches of oxidative surface.

18) Air Guardian’s unique and proprietary design enables a level of continuous and extensive oxidation not found in any other solution. There are a few devices that add photo-catalysis in the form of filters embedded with nanoparticles, but they can only expose air to oxidation processes for sub-second periods - and they require frequent, often expensive filter replacement.

19) The Air Guardian® oxidation process uses rutile TiO^2 nanoparticles embedded in a permanent powder coating, which covers every square inch inside the fixture. Importantly it also accounts for the device’s ability to destroy harmful chemical compounds and particles that are often found in ambient air. These include PM1.0, PM2.5, PM10, volatile organic compounds, ozone, and pollutant chemicals and gases.

    That Air Guardian® can reduce and eliminate these compounds has been tested and certified by independent third-party laboratories.

20) Air Guardian® is available with a proprietary indoor air quality measurement system, Vertices™, which is a patented multi-sensor circuit-board for monitoring real-time and periodic measurement values. LED lights of the device offer visual cues on air quality for each room so that any material change in air quality can be immediately recognized.

21) The air quality measures include CO2, CO, TVOC, VOC, RH, PM1.0, PM2.5, PM10, smoke, temperature, and an aggregate AIQ measure. The user can monitor and control using a desktop application or an app that is approved for release in the Apple or Android app stores.

22) Air Guardian® includes multiple final stage, pre-vent filters that may be customized by use case and can include HEPA, Micron, MERV-6, and, usually, Charcoal. In some models, an additional charcoal absorber material may be used in pre-filtration.

23) Air is vented from multiple ceiling locations to create downward air displacement and to provide **protective zones of air** within the breathing strata - this also **dilutes all room air and ventilates** even in unventilated rooms

Air Guardian Plus

CleanWhite 405+470 antimicrobial white-illuminating LEDs Technology and Mechanism

illumiPure's CleanWhite™ technology is available as a separate luminaire or as an integrated component of the Air Guardian fixture.

The Immaculite fixture includes a patented form of visible light disinfection and illumination, called CleanWhite™.

CleanWhite 405/470 antimicrobial white-illuminating blue-light LEDs

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Thus, an important part of product comparisons should be whether wavelength energies from LED chips can pass through their fixture lens with full dose energies.

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Since MacLean's 405 delivery dose (from the study) is .01 Joules/cm2, the delivery rate is.01 joules/cm^2 per second. Therefore to reach 300 Joules/cm^2,

It is for this reason that many fixtures cannot deliver enough dose for reasonable disinfection over time. Because a) the Watts/cm2 energy is diminished by the lens and b) the energy needed for a reasonable kill time can only be delivered in purple-violet visible light.

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3. Assuming 40 Joules/cm^2/sec is delivered to the bacteria, we proceed to #4
4. The process of photo-catalyzation would then begin when the 405 nm wavelength photons reach the bacterial eukaryotic cell. Then, photo-excitation (catalysis) may begin, initiating an oxidation process, shown below, beginning at the cell wall and continuing in the DNA-containing organelles
5. In this example, 40 Joules/cm^2/sec would then need x amount of time to "saturate" the bacterial substrate, whether the bacteria is contained within an ORM (organic rich media), in surface colonies, or in biofilms
6. The saturation process varies by substrate, and thus one must add significant saturation time to allow for the full process to occur, at dose
7. For example, if 400 Joules is needed to achieve a 1 Log reduction of the specific bacterial species, one must account for the bacteria's presence in colony form on surfaces, within ORM, or within biofilm.
8. Thus, one cannot assume that within 10 seconds whole room disinfection will occur (40 Joules/cm^2/sec x 10 seconds = 400 Joules = I Log reduction). Rather, that should be considered **the point at which effective bactericidal saturation begins**; when a noticeable kill process begins.
9. Time must be allowed for saturation/oxidation to reduce the bacteria located on surfaces, in ORM, or in biofilms.
10. In this example, at 10 seconds, assuming #3 above, kill dose saturation begins.
11. Time to achieve a 6 Log reduction depends upon bacterial concentration and substrate location.
12. 405 nm is effective at completely reducing bacteria in ORM or biofilms, but additional time for saturation is required, which increases Log reductions, depending on the biofilm community or ORM solution.
13. For a bacteria that is susceptible to a 400 Joules/cm2 dose of 405 nm energy, the time to achieve 4-6 Log reductions will vary, depending on initial concentration, bacterial environment, and substrate.
14. To estimate time needed for a 4-6 Log reduction on all surfaces and media, a conservative approach should be used. illumiPure would calculate that projection using the following variable algorithm:

1- 10 seconds to achieve an effective kill-dose of 400 Joules/cm^2
2- Within 60 seconds of 405 nm saturation, the 405 nm energy begins to photo-catalyze porphyrins to produce reactive oxygen species, beginning at the cell wall
3- Further saturation migrates the oxidation processes to cell organelles
4- Based on studies that extrapolate on the MacLean et al. original experiments, 95 minute saturation periods are used to measure log reduction amounts. In this case, a 4 Log reduction could be projected at the 95 minute mark, which would provide adequate time to saturate bacteria present, in all forms, at the effective kill-dose energy levels

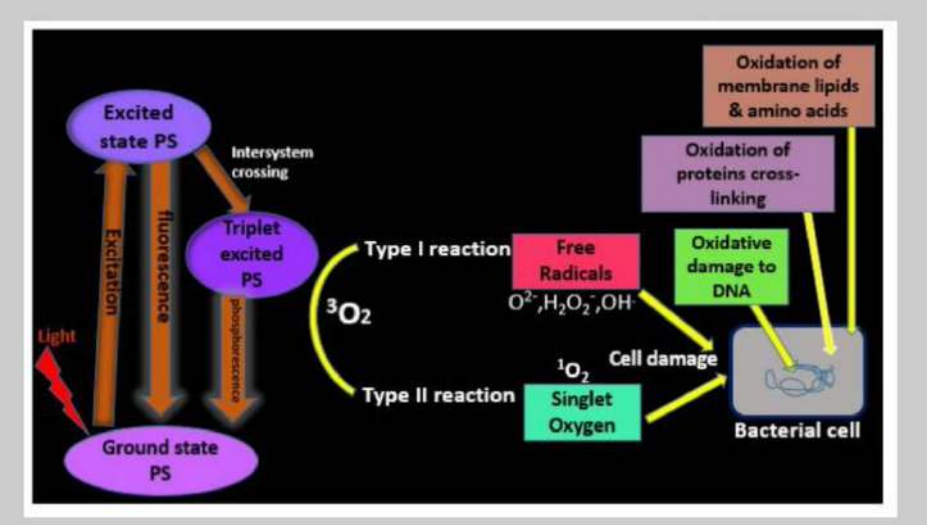
15. Thus, for a bacterial strain which has a 400 Joule energy dose, illumiPure could expect a 4-6 Log reduction within 95 minutes.

The above process is described, in detail, to illustrate the difference between experimental measurements and real world whole-room reductions. This is an important understanding when evaluating different solutions.

For example, if full dose energy can only be achieved in a purple-violet light, then the illumination of that light, with at least 40 Joules of energy, must be continuously used for that period. When the light is turned off (dose energy is below 40 Joules), bacterial re-growth can be expected from aerosolized sources or incomplete colony/biofilm reductions. That's why illumiPure's always-on capability is so important. The always on mode suppresses the formation of biofilms, CFUs on surfaces, and in ORM. With little existing presence, any new introduction of bacteria is saturated and killed much more efficiently then it would have if dose-energy had not been consistently present.

Other considerations when evaluating illumiPure CleanWhite 405/470 antimicrobial white-illuminating blue-light LEDs versus other aBL (antimicrobial blue light) fixtures:

1. Almost all competing fixtures use lenses in which 405 wavelengths bounce back into the fixture and reduce the actual emitted energy dose by up to 50%.
2. All competing fixtures will require illumination in shades of violet-purple to achieve effective energy doses
3. If dose-energy is reduced because of lens impedance or the ability of the LED chip to deliver actual dose versus rated Watts (25 Joules, for example) the time to kill-dose saturation is extended AND the incremental progression of saturation is slowed at lower dose
4. With reduced or lower energy doses, an extended period of purple-violet illumination will be needed to achieve proper levels of disinfection in all substrates. Based on the resiliency or susceptibility of the bacteria (e. coli, for example) purple-violet illumination could theoretically be required for several hours.



In other words, a fixture that cannot provide adequate dose levels without illumination in purple-violet light, and which does not have an impedance-free lens, is probably not going to be an effective solution, whether occupants are present or not. To overcome lens impedance and expected real energies emitted from the purple-violet LED chip, an extremely high level of Joule energy would be needed. Increased watts increases lumens, such that in a real-world room, purple-violet lights would be correspondingly bright, as high as 100-120 Watts.

Operating continuously, in surface dose energies between 30 joules/cm^2 and 80 joules/cm^2, illumiPure's single-chip technology 405+470 LEDs and patented lens material can deliver dose energies that can rapidly kill or inactivate bacteria, yeast, mold, and some viral species – even in biofilm form.

With illumiPure 405+470 LEDs, the time needed for high Log-reduction is four to twenty-four hours, depending on the initial colony counts within a given space. Many species of bacteria and microbes are reduced in high Log levels within 3-4 hours.

CleanWhite® 405+470

Air Guardian® Plus includes an integrated, fully controllable component of the Air Guardian® Plus device, which disinfects surfaces, called CleanWhite.

CleanWhite® is a patented surface disinfection technology that is not harmful to humans.

CleanWhite emits antimicrobial blue light (visible spectrum, near UV) in a white light illumination, which can constantly provide saturation at dose energies required to kill a vast species of microbes (containing cellular porphyrin) on any surface, substrate, ORM, or biofilm.

The mechanism proven in clinical studies is a 405+470-nanometer light-induced photodynamic process in which the wavelengths trigger a reaction within the cells and cell walls of the microbes – causing cellular destruction and preventing repopulation.

CleanWhite™

Continuous Surface Disinfection

CleanWhite provides continuous surface disinfection using patented, antimicrobial white-illuminating LEDs which destroy over 99% of surface microbes, including bacteria, spore forms, fungi, mold, and other harmful pathogens.

Air Guardian Plus™

Dual-Modality Air + Surface Disinfection Technology

Combines Air Guardian and CleanWhite in a single fixture to provide both surface and air disinfection. Both Air Guardian and Air Guardian Plus offer integrated, real-time monitoring of indoor air quality with mobile app and dashboard.

PART II
EVIDENCE AND DETAIL

Application of Science, Technology, and Research: Evidence

This section summarizes the research and literature that have led to the development and design of the novel Air Guardian fixture and its functional components, such as Air Guardian™ and CleanWhite™.

The evidence upon which Air Guardian has been designed, developed, patented, and registered, encompasses several different disciplines.

To form a complete picture of optimal safety and prevention, one must consider the peer-reviewed discoveries and knowledge found within each area. Contributions have been made by experts in Biotechnology, Cell Biology, Genomics, Ophthalmology, Dermatology, Oncology, Chemistry, Computational Biophysics, Photophysics, Environmental Biology, Microbiology, Airflow Dynamics, Engineering, Immunology, Virology, Infectious Disease, and regulatory agencies.

The variables that affect disease transmission, infection prevention, air quality, biosafety, and safety are found within the realms of these disciplines.

This is important because each physical space needs to be protected - and each space is different. Most spaces have a different use case or purpose. With that purpose, each space is its unique environment. And each room will have a myriad of possible variations, from airflow dynamics, ventilation, age, furnishings, occupants, previous occupants, building materials, proximity to other rooms, occupancy numbers, plumbing, adjoining rooms, etc.

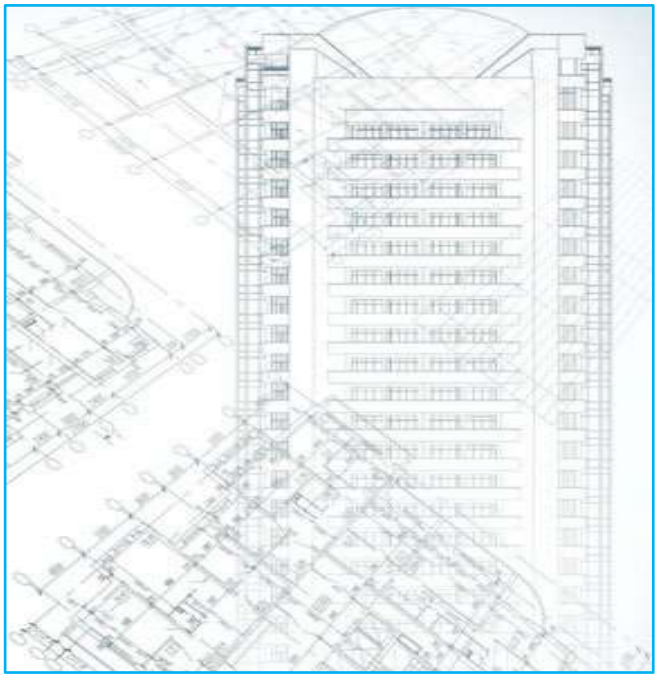
Each of these differences is a variable. Infection prevention specialists, indoor air quality experts, architects, plumbers, builders, microbiologists, chemists, engineers, and epidemiologists all recognize individual hazards and threats. Some hazards can be significant, perhaps unknown to tenants, occupants

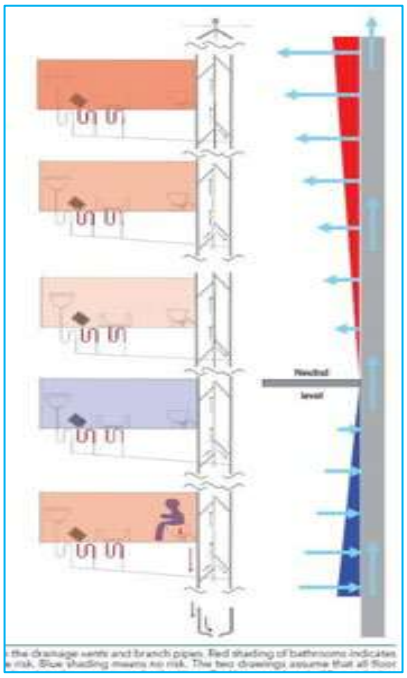
The goal is to solve for the variables.

In February 2020, in Guangzhou, China, researchers discovered that several people who had been socially isolating in their apartments were infected through fecal aerosols even though they were up to 12 floors apart in distance11. And, in 2003, in much the same fashion, fecal aerosols containing the SARS-Cov-1 virus were found to have infected more than 300 people in an apartment in Amoy Gardens[12].

[11] Probable Evidence of Fecal Aerosol Transmission of SARS-CoV-2 in a High-Rise Building
Min Kang, Jianjian Wei, Jun Yuan, Juxuan Guo, Yingtao Zhang, Jian Hang, Yabin Qu, Hua Qian, Yali Zhuang, Xuguang Chen, Xin Peng, Tongxing Shi, Jun Wang, Jie Wu, Tie Song, Jianfeng He, Yuguo Li, and Nanshan Zhong Annals of Internal Medicine 0 0:0

[12] 17. Yu IT, Li Y, Wong TW, et al. Evidence of airborne transmission of the severe acute respiratory syndrome virus. N Engl J Med. 2004;350:1731-9. [PMID: 15102999]





Higher floors were shown to be more prone to infectious fecal aerosols

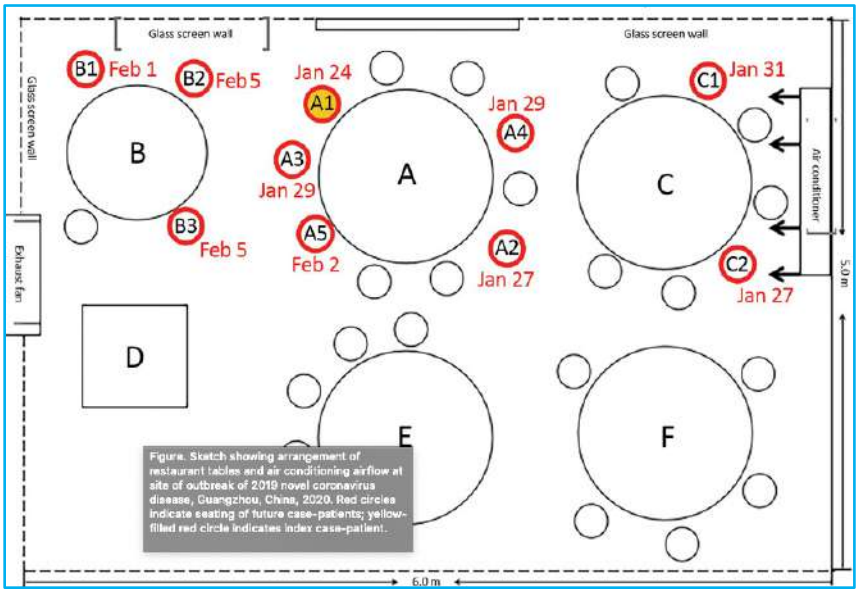
Solving for the variable that caused the infection required significant re-engineering and modification of plumbing, draining, venting, and HVAC systems. Only aggressive, fast, room air changes to remove all contaminated air from the space would provide a modicum of safety before the construction and engineering work was to be completed.

Airflow Dynamics

A major variable is airflow dynamics. This is possibly the most important but the least publicly understood variable. The dynamics are complex and include temperature convections, positive and negative pressures, HVAC venting location and pressure, door and window locations and use, object displacement, and other factors.

Complex airflow designs are often used in operating rooms, including positive pressure rooms, laminar airflows, separate air treatment systems with high MERV and HEPA filtered air, and even downward, highly treated airflow across the surgical space.

For example, in another well-known 2020 study, again in Guangzhou, China, it was demonstrated how airflow caused droplets and fine particles of shed virus to infect other customers at distances well beyond social distance recommendations. The figure below illustrates how HVAC airflow spread viral particles from two infected persons to tables on the other side of the room, infecting eight other people.



To solve this variable, it was proposed that increased distance was needed - as well as "improved ventilation."

To learn more about this case, as well as the study that followed, link to:

https://bit.ly/3uPUZ0q

In a related study, it was proposed that there are three key elements of ventilation related to the transmission mechanism and the risk estimation of airborne infection. It postulated that **ventilation rate, flow direction, and airflow pattern most strongly influence the risk of airborne infection**.[13]

This study is vital to better understand the airflow features of the Immaculight solution.

The ability to create safe, clean air was shown to be essential (similar to what was described in an operating theater), along with the aggressive ingestion of droplet nuclei and airborne particles in upper room air.

Hua Qiet al.t al, described the mechanism of airborne transmission relative to risk:

[13] Qian H, Zheng X. Ventilation control for airborne transmission of human exhaled bio-aerosols in buildings. *J Thorac Dis*. 2018;10(Suppl 19): S2295-S2304. doi:10.21037/jtd.2018.01.24

"Transmission of infectious diseases occurs when the pathogen or agent leaves the source and spreads by one or more routes of transmission to the susceptible. Droplet spread and airborne transmission are two main routes to transmit respiratory diseases.

Droplet spread refers to the passage of pathogens from a source to a susceptible [host] through large droplets. It was calculated that droplets of greater than 100 m in diameter released from a height of 2 m deposited on the floor within 3–6 s with less than 1.5 m in the horizontal distance at room air temperature and relative humidity of less than 60%, while droplets of less than 100 m evaporated within 3–6 s. [Therefore] droplet-borne transmission is a short-range process, with a distance less than 2 m due to the evaporation and high settling velocity of large droplets."

Airborne transmission refers to the passage of pathogens from a source to a susceptible host through airborne aerosols, resulting in infections. The vehicle of airborne transmission is droplet nuclei, the residues of dried-out droplets, which can suspend in the air for a long time and transmit over a long distance.

Liu et al. investigated the interpersonal exposure of exhaled droplets and droplet nuclei between two standing thermal manikins affected by different factors, i.e., distance, temperature, and humidity.

Results showed that the mechanisms of transmission for droplet-based, short-range infections and longer-range airborne infections are both possible, although short-range transmission probabilities were higher.

Thus, as is well understood by most researchers today (March 2021) while short-range transmission had a much higher risk than long-range transmission does, both must be mitigated as changing variables based, not only on airflow and ejection mode (breathing, shouting, sneezing, coughing, physical exertion, etc.) but also, in the case of SARS-CoV-2, on the type of viral variant. For example, the variant B.1.1.7 variant has been proven significantly more contagious and transmissible than wild-type SARS-CoV-2[14], in part because of the higher rate and volume or viral shedding.

Thus, social distancing alone cannot be relied upon as an effective mitigation strategy for these many transmission variables, such as airflow, ejection pressure, viral variant, and volume of viral shedding. The determination of droplet-borne or airborne infection should not be according to the transmitted range, i.e., 2 m.

The main variable is the optimal application of airflow dynamics. The secondary variables are the risk of infection, particle size, the viral load (contagion), inhalation, and time. From the Qian et al. study - results:

[14] Galloway SE, Paul P, MacCannell DR, et al. Emergence of SARS-CoV-2 B.1.1.7 Lineage — United States, December 29, 2020–January 12, 2021. MMWR Morb Mortal Wkly Rep 2021;70:95–99. DOI: http://dx.doi.org/10.15585/mmwr.mm7003e2external icon.

"The results indicated that the performance of downward ventilation to remove exhaled pollutants was close to that of mixing ventilation. However, when the infector faced horizontally, the exhaled jet [breath, cough, particle shed] could penetrate [travel] for a long distance and [could carry] a high concentration layer of exhaled pollutants … due to the thermal stratification lock-up" phenomena, which certainly added the risk of short-range airborne infection transmission.

And if the height of the lock up layer was located in the breathing zone; the risk of long-range airborne transmission would also be high. The length of [the] exhaled jet [breath, cough, sneeze, shed] and height of lock-up layer can be predicted, which is associated with a temperature gradient, exhaled momentum, and exhaled temperature difference with ambient air.

Preventing Airborne Transmission with Air Guardian®

While no one system will make for a "safe" space, Air Guardian® adds effective pathogen removal to any area, any room, in any environment - to help remove and eliminate harmful airborne microbes before they can be transmitted within a space.

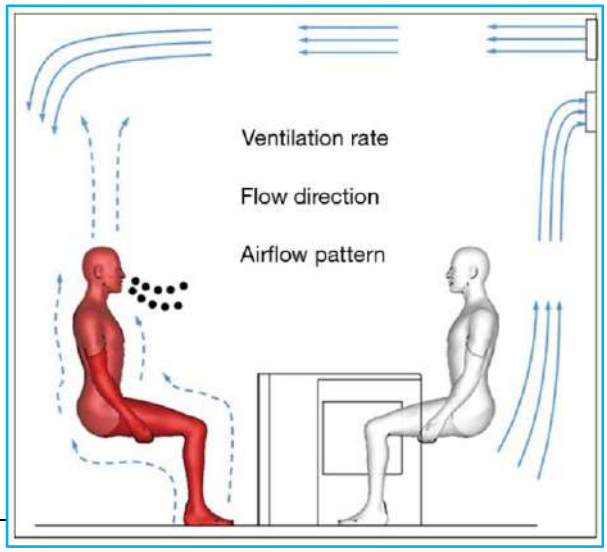
Regardless of the quality, purity, or disinfection level of air vented into a space from the HVAC system - or in spaces with little or no ventilation - Air Guardian® produces purified, disinfected air (between 2 Log and 6 Log reductions) in a protective displacement fashion (at pressure), and rapidly replaces all room air.

Air Guardian® provides the highest level of occupant safety, infection protection, and air quality within a given space.

More on this topic can be found later in this document.

Optimal Room Ventilation Methods while reducing cross-contamination airflow

Qian and Li[15] developed an improved downward ventilation system to show a better performance to remove fine droplet nuclei. They compared the ventilation performances when exhausts were at different levels using full-scale experiments and CFD simulations. Results suggested that upper-level exhausts were more efficient than floor-level and near-head exhausts in removing gaseous contaminants due to upward body plumes.



[15] doi:10.21037/jtd.2018.01.24

The low-temperature air was supplied vertically from the top and accelerated by gravity to deliver fresh air to HCWs directly, while the exhaust grill was also arranged at the top of the ward to remove the up-flowing exhaled fine droplet nuclei. The mechanism of removing large particles is due to deposition instead of ventilation. The significance of surface cleaning is then approved. The Immaculight Air Guardian® Solution is designed to do just that. Shown here is an example of the airflow, depicted in a classroom setting:

Photo catalyzed oxidation, ROS, and Advanced Oxidative Properties

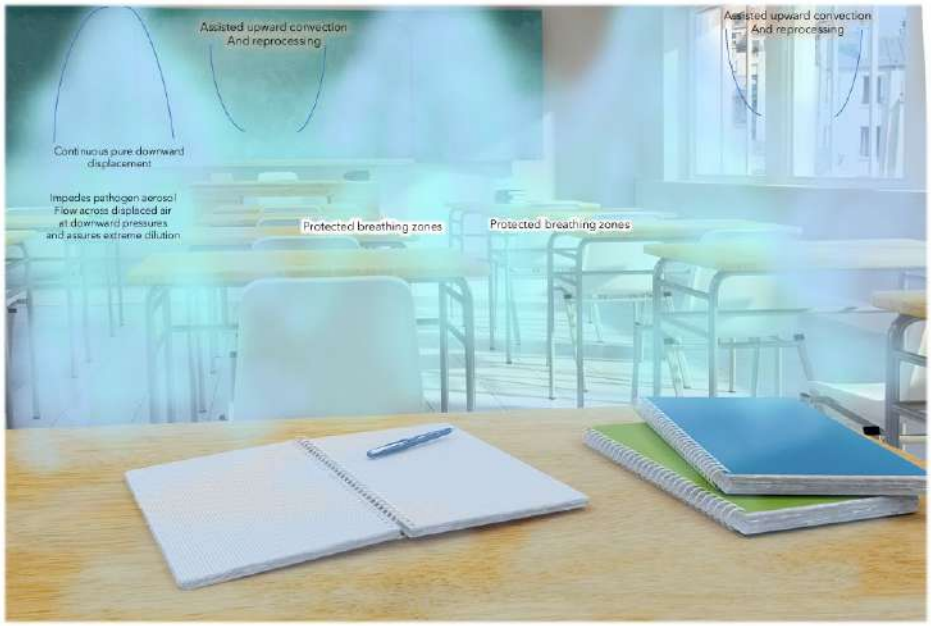
Since intense photo catalyzed TiO^2 oxidation is one of two forms of continuous microbiological, chemical, and particulate destruction (the other being direct UVA and UVC irradiation), it is important to describe the process and the efficacy of photocatalyzed oxidation.

From a 2015 study[16] on the viability of photocatalysis for air purification:

"The components of indoor air that affect the human condition are myriad and both particulate and gaseous. Within the set of all particles, ultra-fine particles have been directly linked to heart health. Bioaerosols can be allergens, asthmatic triggers, or mold spores [and some particles are benign. Within the set of gaseous products, some are carcinogens; some cause respiratory distress; some are toxic; some are odiferous, and some are benign. If we wish to treat indoor air to make it "healthy," one technology alone will not suffice to treat the wide range of particulates that may be encountered, as well as the wide range of gaseous components.[17]""

The Titanium Dioxide Nanoparticle

The use of Titanium Dioxide to facilitate photocatalytic ROS generation, and thus oxidation, has



been known - and used - for decades. In a 2003 study, TiO2 was described as an emerging

[16] Hay SO, Obee T, Luo Z, et al. The viability of photocatalysis for air purification. *Molecules*. 2015;20(1):1319-1356. Published 2015 Jan 14. doi:10.3390/molecules20011319

[17] Hay SO, Obee T, Luo Z, et al. The viability of photocatalysis for air purification. *Molecules*. 2015;20(1):1319-1356. Published 2015 Jan 14. doi:10.3390/molecules20011319

technique to add to traditional UVC light and filtration to treat air for reducing particulate materials, chemicals, and pathogens.

From Hay, SO, et al*: "Recently, there have been increasing numbers of people suffering from allergies, asthma, and bronchitis in Taiwan. Bioaerosols play an important role in these observed symptoms. Regarding the reduction in bioaerosol concentration, the commonly used methods include filtration, ultraviolet germicidal irradiation, and electrostatic precipitation. Currently, there is a new trend for pollutant control by photocatalytic oxidation (PCO) using TiO2. This process is referred to as heterogeneous photocatalysis or, more specifically, photocatalytic oxidation.*

The advantages of PCO are generally recognized as safe, less expensive with low power consumption, no consumption of oxidizing chemicals, and potentially long service life."

Regarding PCO, TiO2 is a semiconductor photocatalyst with a bandgap energy of 3.2 eV. When this material is irradiation with photons of <385 nm, the bandgap energy is exceeded, and an electron is promoted from the valence band to the conduction band. The resultant electron-hole pair has a lifetime in the space-charge region that enables its participation in chemical reactions. Hydroxyl radicals and superoxide ions are highly reactive species that could oxidize air pollutants adsorbed on the catalyst surface (Jacoby et al. 1996).

Particularly, the pollutants, volatile organic compounds (VOCs), are preferentially adsorbed on the surface and oxidized to carbon dioxide. Therefore, rather than simply changing the phase and concentrating the contaminant, the absolute toxicity of the treated airstream is reduced, allowing the photocatalytic reactor to operate as a self-cleaning filter relative to organic material on the catalyst surface."[18]

These early observations about adding the photo-catalyzed oxidation process to existing methods of air disinfection were important, in that the oxidation process could be leveraged in a multi-system environment designed to destroying particulate matter, pathogens, and reducing aerosolized chemicals to safe compounds - without the need for traditional filtration and by using three separate systems for particle, pathogen and chemical destruction.

Indoor Air Quality and Oxidation

Improving Indoor Air Quality includes more than just the destruction of infectious viral, bacterial, and vegetative pathogens. For example, from this same study[19], one finds:

"In normal indoor air, there are ca. 200 individual gaseous components, most in the 10-ppb range or lower, and most are volatile organic compounds (VOCs). The average tolerance index of the air found in office buildings by the BASE study is 0.884. In problem indoor air, the air that

[18] Chia-Yu Lin & Chih-Shan Li (2003) Effectiveness of Titanium Dioxide Photocatalyst Filters for Controlling Bioaerosols, Aerosol Science and Technology, 37:2, 162-170, DOI: 10.1080/02786820300951

[19] Hay SO, Obee T, Luo Z, et al. The viability of photocatalysis for air purification. *Molecules*. 2015;20(1):1319-1356. Published 2015 Jan 14. doi:10.3390/molecules20011319

has generated complaints and or illness, there may be a considerably higher total or higher concentrations of individual components, resulting in a significantly higher tolerance index

If our goal is to change air quality, we can simply rate an air purifier's effect based on its efficiency. However, in treating indoor air, our goal is to create cleaner or healthier air. This goal is somewhat nebulous as other VOCs can exhibit different effects. Some VOCs such as formaldehyde and benzene are carcinogens, some are toxic, some are odorous, and some are benign."

Oxidation Treatment Applications

Within the past two decades, the use of advanced oxidation processes (AOPs) has been extensively studied. In nearly every medium imaginable, there have been applications that have proven effective.

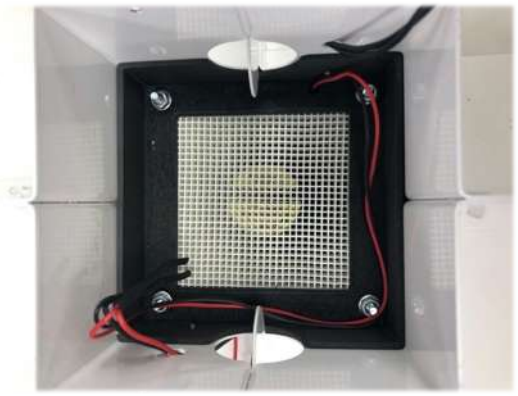
The studies have led to use-case applications in many areas, including water and effluent treatment, PCO and PECO air filtration, food storage, and protection. It has also been used in medical applications, including treatments that utilize photosensitizers absorbed by human tissue. New research into antibiotic-like drug development.

Advanced Oxidative Processes are now generally regarding as "the most encouraging method for the removal of pollutants, including organic, inorganic, and microbial contaminants, compared with traditional purification procedures[20].

An Immediate Oxidative Cloud with UVA irradiance

Within Air Guardian®, air first passes through a ceramic mesh of titanium dioxide (see figure 2), embedded with TiO2 nanoparticles, which are rutile-state reflective crystals. They are highly reactive to ultraviolet light. The ceramic mesh used is irradiated by powerful UVA 365 light, thereby forming a cloud of highly reactive electrons and subsequent ROS. The UVA light irradiance itself is also destructive, so dual toxicity begins immediately within Air Guardian®.

Air Guardian® Advanced Oxidizing Process:



- UVA 365nm light catalyzes nanoparticles (within Air Guardian® Titanium dioxide is used)
- Extreme levels of ROS are created as air enters the device, as UVA 365 is directed against a concentrated nanoparticle matrix of titanium dioxide
- Energy directed against Titanium dioxide causes outer valence electrons to shed as highly reactive oxygen species (ROS) like -OH, -O, and H2O2, which are produced in abundance within the enclosed chamber

[20] Review on heterogeneous photocatalytic disinfection of waterborne, airborne, and foodborne viruses: Can we win against pathogenic viruses? DOI link: https://doi.org/10.1016/J.JCIS.2020.07.047

- The ROS wash over the incoming air from the Air Guardian® intake
- The ROS species aggressively oxidize organic contaminants to CO2 and inorganic ions
- The ROS reduce (disassemble) inorganic contaminants and volatile chemicals to nontoxic ions throughout the pathway corridors - using UVC-photo catalysis of coated nanoparticle surfaces
- The ROS inactivate microorganisms, including viral pathogens
- The ROS oxidation process produces no noxious compounds

After air passes through the TiO2 mesh and is irradiated with UVA energy, it enters a pathway of corridors that are coated with Titanium nanoparticles. These TiO2-lined corridors represent 20 linear feet of "photocatalytic reactors", which are energized by powerful UVC irradiation at 265 nm. This means that the pathway corridors are also illuminated with UVC irradiant energy.

Airflow distance, time in-situ (time-dose), and turbulence under continuous oxidation

Within the Air Guardian® chamber (and along all pathway corridors, surfaces are powder coated with titanium dioxide particles. The corridor pathways are illuminated with UV-C 265-nm LED light, which creates constant oxidation as well as energetic UVC destruction along the linear length and surface of the corridors within the chamber.

The pathway corridor design of the Air Guardian® chamber (see fig. 3), contributes to air turbulence and agitation. The total length of all corridor pathways is 20 linear feet (2x4 device).

The airflow distance, vortices, and turbulence-inducing design contribute to the efficacy of a more complete oxidation process[21]:

The photocatalysis of gaseous species can be viewed as a multi-step process where adsorption of gaseous species onto the catalyst surface occurs first. All the interesting chemistry in this process occurs at the gas-solid interface between the photocatalyst, for example, solid titanium dioxide (TiO_2), and a contaminated airstream.

One way that the adsorption of molecules on a surface can be expressed … is to relate the surface concentration …to the collision frequency of the molecules with the surface, … and the retention time, …of the molecules with the surface.

Thus, turbulent, slowed airflow travels across a cubic area of 60.312 inches within each section of the chamber, for a total of approximately 20 linear feet. This is the "retention time with the surface," and it greatly enhances the efficacy of the destructive oxidation process within the sealed chamber.

[21] Hay SO, Obee T, Luo Z, et al. The viability of photocatalysis for air purification. *Molecules*. 2015;20(1):1319-1356. Published 2015 Jan 14. doi:10.3390/molecules20011319

The Air Guardian® design thus facilitates both surface contact and collision frequency using turbulence and other design elements to facilitate the collision of gaseous, particulate, and pathogenic contaminants.

Continuous UVC Irradiation

The Air Guardian® fixture is functionally categorized as a "UVGI" device. In its UVGI form, it can be additionally described as a "sealed, upper-room UVGI device."

Sealed UVGI systems are often recognized as effective in removing airborne pathogens, but room air must pass over the UV-C lamp enough times to inactivate or destroy not just SARS-CoV-2 - which UV-C readily inactivates at relatively low dose-time levels - but also other pathogens, such as mold, fungus, gram-positive, spore forms, and other difficult to kill microbes.

The highest level of UV-C energy found in any other any sealed, upper-room UVGI device today is 80,000 millijoules, with most systems ranging between 12,000 - 30,000 millijoules. With few exceptions, most UVGI fixtures use UV-C lamps (not LEDs), over which ingested air is passed within seconds or sub-seconds before being vented from the same fixture into the room. UV-C fluorescent-like tube lamps emit energy in a diffused fashion, as is illustrated below:

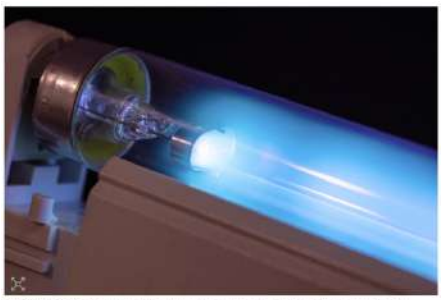
In addition to the fragile nature of the UV lamps, expected lifespans are low, and wave-shifting can occur in as little as 400 hours. Typical UV lamp lifespans are less than a year, depending on several factors.

By comparison, LED lamps that emit in the UV-C spectrum have several appealing commercial properties. They can be tuned to exact wavelengths and have a much longer lifespan (Air Guardian® VioLED chips have a 30,000-hour warranty).

VioLED High-quality chips are engineered with circuit boards such that even slight color shifting can be prevented. Multiple LED chips can be used within a single board, and multiple boards within a single device, far exceeding the UV energy which can be emitted from a single UV lamp.

Further, LEDs can be engineered to emit light in certain irradiance angles, which can focus and direct wavelength beam, rather than only diffusing light like that within a UV florescent-like tube lamp.

This has significant meaning for the Air Guardian® device, which uses VioLED chipsets manufactured by Seoul SETI. Within Air Guardian®, as air passes throughout chamber corridors which are 97% reflective, LED-emitted beams can be “bounced” against internal fixture surfaces.



Legacy technology UV fluorescent tubes are unwieldy and inefficient. An LED replacement would be cheaper, more tunable and longer-lasting, among other benefits. (Courtesy iStock/prosymender)

Within the narrow Air Guardian® corridors, computational physic studies calculate that a first “bounce” retains 40% of its initial irradiant energy.

The total ultraviolet energy emitted by chips within a 2’x4’ Air Guardian® device is currently 210,000 millijoules/cm^2. This does not include the total additional bounce energies, which are difficult to measure within the device.

For example, Lambertian reflectivity can be affected by surface type and angle and can be manipulated within the chamber to affect a direct or diffuse reflection, which in turn effects bounce (reflection) energy.

The following test result illustrates the efficacy of the SETI VioLEDs used to irradiate the Air Guardian® channels. The results show that VioLED (Air Guardian) UV-C chips, which total 100 millijoules/cm2, kill SARS-CoV-2 human coronavirus in 1 second or less:

KR Biotech Co., Ltd.
Institute of Infectious Disease Control
Neungdong-ro 120, Konkuk university
Bld#12, Rm 406, Kwangjin-gu, Seoul

Test Report

Client	Personnel	Jae Hak Jeong	Tel. No.	82-70-4391-8629
	Affiliation	SEOUL VIOSYS Co., Ltd.	E-mail	Jaehak.jeong@seoulviosys.com
	Address	65-16, Sandan-ro, 163beon-gil, Danwon-gu, Ansan-si, Gyeonggi-do, Republic of Korea		
Request	Virucidal Activity Test by UV Irradiation			
Product	UVC module (100mW)			
Purpose of Use on the Product	Sterilization			
Test Virus	COVID-19 (SARS-CoV-2)		Cell Line	Vero E6
Test No.	KR-2011-065-SVS-01		Test Period	2020.11.20-12.01
Treatment time	1, 3, 5 sec		Titration	CPE
Test Temperature	Room Temperature (Approx. 20℃)		Tester	Hansam Cho

Test Result

Product Name	Virus Titer $TCID_{50}$	Treatment time	Distance	Virus Reduction Rate	
				(log)	(%)
UVC module (100mW)	$2.15x10^7$	1 sec	2 cm	2.250	99.437 %
		3 sec		2.583	99.739 %
		5 sec		2.751	99.823 %

Result: As a result of the sterilization test for COVID-19 (SARS-CoV-2) by UV generated in the UVC module (100mW) of SEOULVIOSYS Co., Ltd., it showed 99.437%, 99.739% , and 99.823% virucidal effect in 1, 3, and 5 seconds, respectively treatment at a distance of 2 cm.

December 04, 2020

Test Manager: Young Bong Kim (Seal)

KR BIOTECH Co., Ltd.

* This test report is a result limited to the sample and sample name provided by the client and does not guarantee the quality on the overall product.
* This report cannot be used for PR, advertising and litigation purposes, and use of this report other for its original purpose is prohibited.

Test results have proven that VioLED chips at this dose kill the actual SARS-CoV-2 virus, with the studies performed within Biohazard Labs.

The reason Air Guardian® is engineered with dose energies up to 265,000 millijoules/cm2 is to be able to inactive or destroy more than just SARS-CoV-2.

It is the goal to capture and route air through corridors with intense UV-C irradiance (and secondary bounce energies) such that the following list of pathogens are also reduced at Log 4-6 rates within a single pass through the system:

Capturing air, airflow engineering, dose-time-energy

Only a few sealed devices have active air induction (versus passive induction via convection processes), and the typical fan speed for a sealed UVGI fixture is 50 cubic feet per minute. This is important because it reflects how capable the system is to move room air through the fixture and provide “air changes per hour”, or ACH.

By comparison, the Air Guardian® fixture moves air at 200 - 300 cubic feet per minute, which facilitates more complete room air changes. Air Guardian® is capable of moving 12,000 -18,000 cubic feet of air per hour, which enables up to 22.5 room air changes per hour.[22]

This air is vented, at distance, from the fixtures, and has been calculated, in terms of displaced downward air mass, as 500-700 kilograms of air per second.

This downward displacement creates single-pass purified air within the breathing zones and, effectively, creates a protective downward barrier to help shield cross-ventilated particles or pathogens. The displacement effect also helps to circulate and ventilate air in any space, moving air downward, then, with additional convective airflow, back to the Air Guardian® device to be reprocessed.

The Air Guardian® ability to process air over time within a “single pass”

No other device that works within a single room or space can ingest air and "hold" a volume of ingested air inside the device.

In devices that most other sealed UVGI devices use 50 - 100 CFM fans to ingest room air and blow that air across a UV-C lamp, consider the following:

- 100 cubic feet per minute = 14.1 miles per hour air speed
- 14.1 mph = 2481.6 inches per second
- Bulb length of UV-C lamp = 18 inches
- Time in seconds that 1 cm^3 of air travels over UV bulb emission = .0007 seconds

By comparison, Air Guardian® is able to maintain 1 cm^3 of air within a device for a period of six to twenty two seconds, depending on the device design.

Using fluid-dynamic-based engineering, vortices and turbulence are produced inside the device channels, which has unique effects upon the air movement and the particles suspended within the air.

[22] 10 x 10 x 8 room calculations available upon request; downward, dual vented, forced air displacement also facilitates room air changes

Note that particles floating within that 1 cm^3 do not always remain suspended in the same space and travel at equal speed.

Engineering studies of air movement within the Air Guardian® device shows the smallest particles do not uniformly travel with airflow in a linear fashion; rather, they move within vortices and turbulence, in Brownian-like actions, and are thus subjected to irradiance and oxidative effects for longer periods of time than what might be considered using a straight line projection based on linear airspeed through the device.

As a sealed fixture, Air Guardian® can safely irradiate at these extreme UV-C energy levels because it does not expose humans to UV light. All UV light is sealed within the Air Guardian™ fixture. Kill-switch safeguards are built into the Air Guardian® device should the sealed fixture be breached in any way.

Regarding the UV disinfection mechanism

As previously stated, this UVC irradiation provides the following utility, as described in, "The Study of an Ultraviolet Radiation Technique for Removal of the Indoor Air Volatile Organic Compounds and Bioaerosol":[23]

[UVC irradiation] is generally applicable in three areas, as follows: Inside the ducts used for mechanical ventilation, return air units, and any indoor area. The DNA of contagious airborne pathogens is damaged by the energy of UVGI (UVC) light, which interferes with its duplication, rendering the organisms noncontagious.

From "The Study of an Ultraviolet Radiation Technique for Removal of the Indoor Air Volatile Organic Compounds and Bioaerosols":

- The mechanism by which UV light removes air pollutants is photochemical dissociation.
- This process involves the absorption of photons by molecules, resulting in the excitation of their electrons enabling them to jump from low- to high-energy states.
- Excited electrons can break the chemical bonds, thereby altering the physical and chemical properties of the molecule.
- The elimination of air pollutants by UVC at wavelengths less than 290-nm involves direct photolysis, in which molecules that absorb light energy enter a chemically active state that breaks their chemical bonds,
- In Shie et al., it was indicated that UV light of shorter wavelengths is more efficient for the removal of formaldehyde (HCHO). Air Guardian® uses 265-nm UVC wavelength
- The efficacy of photolysis is dependent upon the energy, distance, temperature, and relative humidity

Filtration and precision venting

As a final step, Air Guardian® uses both charcoal and HEPA (99.97% of 0.3 micron particles, 85% of 0.1 micron particles) filtration, which is used as a safety step to eliminate any unwanted molecular or volatile organic byproducts, should they remain after passing through the active pathway corridors.

After the air is processed, it is vented from the Air Guardian® fixture by two separate exits, which are then exhausted through at least six feet from the fixture such that air can be dispersed into the lower third of the room. This process provides for the constant distribution of clean, disinfected, and filtered air at average human height, without creating aggressive biofilm aerosolization on floors or surfaces.

[23] http://dx.doi.org/10.3390/ijerph16142557

Generic fixtures that intake and exhaust within the same fixture cannot ensure reliable room air changes. Some UVGI systems recommend ceiling fans to circulate room air, which exposes the possibility for biofilm aerosolization. Air Guardian® vents in such a way that room air changes are more efficient and aerosolization is less likely. (see above section on Airflow Dynamics)
Air ingestion and venting to safe, clean zones.

Indoor Air Quality (IAQ) and disease

The air itself carries particles, pollutants, pathogens, and chemicals, all mixed within ambient chemicals we know as "air" - that is, H_2O CO_2, O_2, N, etc.

Indoor air quality is one of the major health challenges facing the world's population today. It is estimated that over 4 million people die each year from fine particle (PM 2.5) inhalation. The mortality is caused by cardiovascular disease, respiratory failure, pneumonia, and cancer.

Further, it is well-known that in environments where pollution (particulates) and contaminants are high, infectious disease is also found to be in greater incidence.

Recent studies[24] also link PM 2.5 particles to a greater incidence of Alzheimer's disease when children are exposed at a younger age.

Airborne chemical carcinogens, such as benzene, toluene, acetaldehyde, formaldehyde, and other compounds are known to be highly associated with many cancers, including lung cancer, lymphoma, and leukemia.

For example, ambient airborne Benzene has been definitively associated with cancer and can be emitted from certain household products made of plastics, resins, nylon, and synthetic fibers. Benzene is also used to make some types of lubricants, rubbers, dyes, detergents, drugs, and pesticides.[25]

Air Guardian's air purification process, consisting of oxidation and UVC irradiation, removes ambient airborne benzene.

The importance of this purification process can be emphasized by a review of this study:

Residential ambient benzene exposure in the United States and subsequent risk of hematologic malignancies[26]

For additional information on Air Guardian® science and research sources:
https://www.immaculight.com/science

[24] Li RL, Ho YC, Luo CW, Lee SS, Kuan YH. Influence of $PM_{2.5}$ Exposure Level on the Association between Alzheimer's Disease and Allergic Rhinitis: A National Population-Based Cohort Study. Int J Environ Res Public Health. 2019 Sep 11;16(18):3357. doi: 10.3390/ijerph16183357. PMID: 31514400; PMCID: PMC6765937.
[25] https://emergency.cdc.gov/agent/benzene/basics/facts.asp
[26] Lauren R. Teras W. Ryan Diver Emily L. Deubler Daniel Krewski 09 February 2019 https://doi.org/10.1002/ijc.32202

CleanWhite™ Antimicrobial Visible Light Solution

A detailed description of antimicrobial blue light technology

The utility, function, mechanism of action of antimicrobial blue light

Technology, and use Case examples

Validation of visible blue light efficacy

Extensive independent and laboratory testing has been conducted for more than a decade on the effects of 405 and 470 nm wavelengths on microbial disinfection. Research and literature on the subject have been exhaustive, and have included studies on microbial species, dose, periodicity, and wavelength requirements to inactivate or reduce bacteria, mold, fungus, and yeast.

The results of these numerous studies have enabled and promoted the use of 405nm and 470nm disinfecting light into mainstream healthcare and commercial use in both in vitro and in vivo disinfection.

An extensive listing of the literature is referenced within and at the end of this document.
Note that many studies derived results using lower doses of 405 nm and 470 nm energies, guided by standard scientific laboratory process. The doses used, often in mJ/cm^2, were often significantly lower than those used by the current dose emitted by the illumiPure® CleanWhite™ chipset, which is usually controlled to 44-60 Watts, or an equivalent of 44-60 J/cm^2. However, it can be precisely controlled to higher doses up to 120 J/cm^2.

illumiPure® used an independent lab to test generation 1 chipsets on specific species that represented known resistant pathogens, including:

Aspergillus brasiliensis BCRC 30506; ATCC 16404
Staphylococcus aureus subsp. Aureus (drug-resistant) BCRC 15211; ATCC 33591
Salmonella enterica subsp. Enteric (drug-resistant) BCRC 12947; ATCC 13311
The illumiPure® chipset used in the study was dosed at .6 J/cm^2. This independent, certified test validated the results expected with illumiPure® generation 1 chipset, based on the decades of study and testing mentioned above.

Over 97% colony reduction rates were observed for both Staphylococcus aureus subsp. Aureus (drug-resistant) and Salmonella enterica subsp. Enteric (drug-resistant) over 24 hours.

The testing also validated the expected result for Aspergillus brasiliensis, a spore-forming species known to be very resistant - except at higher 405-470 energy doses.

When the results are extrapolated to higher-energy illumiPure® ® 4th generation energy doses of 50-120 J/cm2 (between 83 and 200 times the dose used in the generation 1 chipset test), Aspergillus brasiliensis is shown to be highly susceptible to 405/470. However, the exact time to reach 2 Log reduction depends on colony size and dose.

Of further note, each species was tested in conditions of unusually high CFU counts, up to 9.0 x 10^4 (90,000 CFU's per square centimeter).

Thus, the existing literature and specific testing of the illumiPure® chipset confirms the utility and performance of the technology, even at low doses. Today's illumiPure® 4th generation

chipsets are between 83 and 200 times more energy-dose efficient than those used in initial tests.

405 / 470 Technology and Mechanism

illumiPure's CleanWhite™ technology is available as separate luminaire or as an integrated component of the Air Guardian fixture.

The Air Guardian® Plus fixture includes a patented form of visible light disinfection and illumination, called CleanWhite™.

In its utility, it emits sharp spikes of 405-nm and 470-nm wavelengths, which represent two specific, safe wavelengths known to energize an oxidative process, which is described in a study by Ramakrishnan et al. in 2016[27]:

"The mechanism of the bactericidal action, and the occurrence of mammalian cell toxicity beyond a threshold exposure level (Ramakrishnan et al., 2014), has not been fully elucidated, but it is thought to involve the photo-excitation of endogenous porphyrin molecules, a process which generates reactive oxygen species (ROS). ROS, including singlet oxygen (1O2), superoxide anion (O2•−), hydrogen peroxide (H2O2) and hydroxyl groups (•OH), are chemically reactive free radicals that play a crucial role in cell signaling and homeostasis, but overproduction becomes toxic to cells and alters redox balance causing significant damage to cell structures via oxidation of cellular macromolecules such as proteins, lipids, nucleic acids, NADH/NADPH and soluble thiols (Devasagayam et al., 2004). Since mammalian and bacterial cells contain intracellular porphyrins, during violet-blue light exposure, these porphyrins may become photosensitized leading to an overproduction of ROS (Kotelevets et al., 1988; Lavi et al., 2004; Lubart et al., 2011).

As with traditional photodynamic inactivation reactions, which involve the use of exogenous photosensitive dyes or porphyrins (Gayl, 2001), photosensitization using violet-blue light is thought to cause cellular damage via two different pathways: Type I and Type II. With the Type, I mechanism, the electronically excited sensitizer (e.g., endogenous porphyrin) reacts directly with the cellular component resulting in free radical formation (e.g., O2•− and •OH). These free radicals propagate further free radical chain reactions. In the Type II process, the excited photosensitizer reacts directly with molecular oxygen resulting in the formation of 1O2 (Pattison and Davies, 2006). Both pathways culminate in significant oxidative damage to exposed cells."

This mechanism is facilitated by Air Guardian's integrated (Clean-White™) patented, single circuit light-emitting diodes (LEDs) that spike, as described in precision 405-nm and 470-nm wavelengths.

The wavelength energy has been tested to caused significant damage to bacterial and vegetative pathogens, as well as some known viral strains[28], such as norovirus, although few viral strains have been found susceptible to 405/470 damage, except when suspended within a bacterial biofilm or organic matter, upon which their damage is thought to be attributable to ROS-driven oxidative actions occurring within bacteria in biofilm or organic matter.

[27] Cytotoxic responses to 405nm light exposure in mammalian and bacterial cells: Involvement of reactive oxygen species
DOI link: https://doi.org/10.1016/J.TIV.2016.02.011 Published: 2016-06

[28] See R.M. Tomb et al., "New Proof-of-Concept in Viral Inactivation: Virucidal Efficacy of 405 nm Light Against Feline Calicivirus as a Model for Norovirus Decontamination," Food & Environmental Virology, Vol. 9(2), pp. 159-67 (2017).

Fungal Light Sensitivity

Biologists have been aware since at least 1887 of visible blue light's capacity to stimulate phototropism—ability plants possess to orientate themselves toward a light source (Sachs 1887). Visible blue light, it has also been noted, performs as a cue for fungi to perform important developmental tasks, such as metabolism, growth, pigment development, spore production, and tropism (Siegel et al. 1968; Casas Flores et al. 2006; Purschwitz et al. 2006). A particular type of red bread mold called Neurospora crassa has been shown to contain blue light receptors that respond significantly to changes in light intensity. Of its receptors, one type controls recognition of transitions between light and dark, while a protein it contains (VVD) aids in regulating its light controlling system.

Blue light, whose position in the spectrum exists in a range between 400 and 500nm, provides a cue for fungi to perform their asexual development and reproduction. However, when combined with photosensitive dyes, the light has a fungicidal effect. Candida is particularly susceptible to the combination of light and such dyes as phenothiazinium, dimethyl methylene blue, and toluidine blue O.

Bacterial Light Sensitivity

Under controlled laboratory circumstances, bacteria have also shown sensitivity to blue light. Building on the knowledge that light at higher frequencies can destroy microbes, researchers have recently been interested in the effects of the higher frequency bands of visible light on the integrity of bacterial cells as well as on other microorganisms. The reports on these studies claim that light inhabiting the blue area of the spectrum (with wavelength ranging from 400 to 500 nanometers) retains some of the ability to harm these microbes while relinquishing the harmful effects of its higher frequency (ultraviolet) counterparts (<400nm in wavelength). Some have shown, for example, that blue light acts as a phototoxic to the P. gingivalis and F. nucleatum groups (Feursteinet et al. 2004). Similarly, light from argon lasers emitted at low fluencies and existing within a band of 488 – 514nm have a phototoxic effect on the Gram-negative anaerobic and porphyrin-producing bacteria Porphyromonas and Prevotella spp. Bacteria that thrive in the oral cavity and which, exhibiting black pigmentation, is derived from dental plaque, have been destroyed by blue light emitted at an intensity level of 4.2 J $cm^{-2,}$ and P. melanogenic, despite requiring the higher intensity of 21 J cm^{-2}, was nevertheless also destroyed by the blue light.

Also inactivated by blue light emission were Propionibacterium acnes, and this occurred without any added exposure to photosensitizing substances that would induce increased light sensitivity. That is, the blue light by itself was enough to eliminate the viability of P. acnes. Salmonella aureus, too, which has no pigment, is sensitive to visible light, and the optimal wavelength for eliminating its viability has been pinpointed within a bandwidth of 10 nanometers. The lower part of the visible light spectrum—400 to 420nm—has been identified as that having the greatest bactericidal effect, with its peak effect occurring within the smaller 400 – 410 band (i.e., 405nm ± 5nm).

Many other studies have shown the effective parts of the spectrum to reside around the 405nm mark, with little effectiveness occurring at bands higher than 430nm.

However, other more recent studies have identified sanguine effects on the inactivation of bacteria and other microbes (Maclean et al. 2008). Guffey and Wilborn, for instance, show that S. aureus is inactivated using visible light of wavelength 470nm. Certain bacteria that inhabit the digestive system, such as the Helicobacter pylori, were also sensitive to visible light of a similar wavelength.

Of particular interest are those especially infective types Escherichia coli, Staphylococcus aureus (anaerobic bacillus that shown significant resistance to methicillin, an antibiotic), and Pseudomonas aeruginosa (PA). In

vitro experiments have shown significant reductions in their viability as a result of blue light exposure (Guffy and Wilborn 2006). The light excites photosensitive porphyrins inside the bacteria, which causes them to exhibit the bactericidal effect upon exposure. However, it was also found that those bacteria without such light-sensitive compounds can also be killed by combining the exposure to blue light with the use of non-toxic dyes that themselves activate upon exposure to light. Examples of such dyes are the cationic phenothiazinium types. Together, the photo-activable dye and the blue light cause the production of reactive oxygen species (ROS).

Reactive Oxygen Species

Reactive oxygen species (ROS) have also been induced by bacteria's exposure to light. Included in these species are oxygen radicals, peroxides, and singlet oxygen—usually tiny molecules whose high reactiveness comes from the fact that they contain shell electrons of unpaired valence. Biological cells have negative responses to high quantities of ROS, and this property has been useful in such photodynamic treatments used in cancer and antibacterial therapies (Lubart et al., 2011).

Photodynamic therapy (PDT) usually uses exogenous photosensitizers added to the cells, to which the light source (set to an appropriate wavelength) is subsequently applied. The molecules used as photosensitizers give off energy to the surrounding molecules of oxygen, and this leads to ROS formation.

Visible light also can stimulate ROS in vivo once the light has been absorbed by the cell's endogenous sensitizers (e.g., porphyrins, flavins, cytochromes). These endogenous sensitizers can absorb light from a wide spectrum of its visible range, with maximum absorption occurring from the blue band. Bacteria, too, has endogenous photosensitizers, and Lubart et al. (2011) explores the possibility that blue light of high intensity could cause significant ROS in bacteria and thereby lead to their destruction. Bacteria such as Propionibacterium acnes, which do contain significant amounts of endogenous photosensitizers, readily die as a result of light exposure. Strains of the same bacteria whose difference manifested in their porphyrin content were shown to react differently under exposure to visible light (Lipovsky et al., 2009).

Light Wavelengths

Varying the wavelength of the light while it is being used in conjunction with the chemicals has also been shown to improve the effectiveness of the bactericidal and fungicidal treatments. Even polychromatic white light, when used in conjunction with the bisamino phthalocyanine BAM-SiPc (unsymmetrical), has been demonstrated to lower the viability of Candida albicans (So et al. 2010). The effectiveness is made more apparent when white light is coupled with cationic fullerenes: this combination renders Candida albicans ineffective with just 10 minutes of exposure (Tegos et al. 2005).

Methylene blue, BAM-SiPc, and BCA all act as an adjuvant to the effects of red light against C. Albicans. The combination of red light with methylene blue inhibits the growth of C. Albicans as well as the formation of its germ tube, and this occurs as a result of an increased permeability granted the organism by the effects of both actants together. The food dye erythrosine (Red no. 3) is among the chemicals with photosensitizing properties that enable them to combine with light to increase fungicidal effects.

Contemporary research into 470nm blue light

De Lucca et al.' sal. 's 2012 research into the effects of blue light at a specific wavelength of 470nm uses:

Two LEDs with the blue light that peaks at 470nm
An incubation mechanism to test the effects of ambient temperatures on fungi or bacteria after exposure to LED

Two separate methods of using electromagnetic radiation via light-emitting diodes (LED) have been generally in use. Photodynamic therapy (PDT) uses the light of a particular wavelength (here 470nm) to stimulate a photosensitizer supplied by the researcher as a third ingredient. PDT shows great therapeutic promise and is used to generate reactive oxygen species (ROS), which eliminate the microorganism to which it has been applied whenever the ROS reaches toxic levels. The second approach allows the light to locate, directly within the microbe, photosensitizers intrinsic to its cells. These will react with the light without intermediation by a third compound and provides a simpler and therefore more transparent process of bactericide and fungicide that supports examination and research.

The research done by De Lucca et al. (2012) closes gaps in the scientific community's knowledge about the effects of filamentous fungi on monochromatic light used in conjunction with photosensitizing chemicals. It also contributes to an understanding of blue light's effects on filamentous conidia of the non-germinated and germinating types, with distinctions made between blue light's use both in and out of the presence of erythrosine. Fungi used in the study are Penicillium digitatum (PD) and Fusarium Graminearum (FG). Citrus exposed to PD evince rot and FD, which naturally occurs in environments where wheat is stored, renders grain unsafe for consumption after harvesting whenever storage conditions allow for the growth of the fungi.

Leuconostoc mesenteroides is a soil-borne bacterium that contributes to the deterioration of beet and cane sugars in U.S. agriculture, and Bacillus atrophaeus is used as a proxy for the more aggressive Bacillus anthracis. Pseudomonas aeruginosa (PA) causes serious infections to burn wounds, contaminates medical equipment, and leads in many cases to dermatitis upon contact with skin.

Effects of 470nm blue light on bacteria

2006 in vitro study, which determined that 470nm light kills S. aureus and P. aeruginosa, was designed based on the apparent variability of the bacteria's behavior and dose (intensity) and wavelength of the light used. The S. aureus and P. aeruginosa were treated using lights that peak at 405 and 470nm. For the 470, energy levels ranging from 3 to 15 J cm^{-2} were used. The bacterial colonies were counted in preparation for comparison to control populations, which were not treated with light. The 470nm blue light rendered P. aeruginosa invalid (96.5% reduction) for every dose given. For S. aureus, however, the effective doses were limited to 10 and 15 J cm^{-2}, with the highest reduction in colony count being 62%. The indication by these results is that blue light is indeed effective in killing bacteria, but the effect is dependent on the dosage for most (Guffey & Wilborn 2006).

In De Lucca et al. 2012 study, AR1 (the first light array, which was of an impure blue constitution) had the effect of significantly reducing the growth of Leuconostoc mesenteroides (LM). Their colony-forming units (CFU) began exhibiting reduction at an intensity of 150 J cm^{-2}, and when intensities grew to 180 J cm^{-2}, the CFU reduction and loss of viability reached 80%. Treatment with AR2 (the second light array which resided in the pure blue range) resulted in no reduction in the levels of LM. After treatment, LM levels increased only in an incubation environment of 25°C and remained dormant at other temperatures.

AR2'sAR2's lack of bactericidal effect on LM was atypical of the experiment's general results. Both AR1 and AR2 reduced the levels of CFU in Bacillus atrophaeus (BA), with AR1 reducing the colonies significantly at light intensity levels of 40 J cm^{-2} and killing all colonies and bacilli at 80 J cm^{-2} in conjunction with incubation at 25°C and 30°C. AR2 did achieve viability reduction beginning at 100 J cm^{-2} but required a much higher intensity of 300 J cm^{-2} and incubation temperatures of 37ºC and to achieve results comparable to those of AR1. AR2 achieved approximately 100% reduction and zero growth only at 300 J cm^{-2}. This is a much higher light intensity level than required by AR1 at 100 J cm^{-2}. The indication from these results is that blue light requires traces from other wavelengths to produce its more effective anti-bacillus effects.

Post-AR1 exposure to 60 J cm^{-2} of impure blue light intensity, BA cells were incubated at 25ºC, 30ºC, and 37C. Those that were incubated at the higher the highest temperature (37ºC) showed lower viability loss than those exposed to the lower temperatures of 25ºC and 30ºC. However, the differences were not statistically significant. Unlike those cells treated by AR1, AR2 cells did not exhibit a difference in viability loss between those exposed to 25ºC, 20ºC, or 37ºC temperatures.

The most sensitive of the various bacteria to blue light was the Pseudomonas aeruginosa

(PA), which responded to both AR1 and AR2 with significant reductions to viability. At just 8 J cm^2, PA showed the highest reduction of CFU, which amounted to 84% at incubation temperatures of 25ºC. When the energy levels were increased to 10 J $cm^{-2,}$ and PA's optimal incubation levels of 30ºC and 37ºC were used, the respective reduction rates were 58% and 54%. Interestingly, AR2 had a better effect on viability loss for PA at an intensity of 8 J cm^{-2}. The CFU reduction at these levels was 96% at a post-light treatment incubation temperature of 37ºC —which is the optimal growth level for this particular bacterium. Exposure to the lower temperatures of 25ºC and 30ºC resulted in viability reductions of 62% and 57%, respectively. The lethal effects of the blue light were increased for PA in direct relation with the increase of light intensity. Its behavior suggests that pure blue light is more effective at reducing its viability than impure blue alloyed with other wavelengths.

Effects of 470nm blue light on fungi

Penicillium digitatum

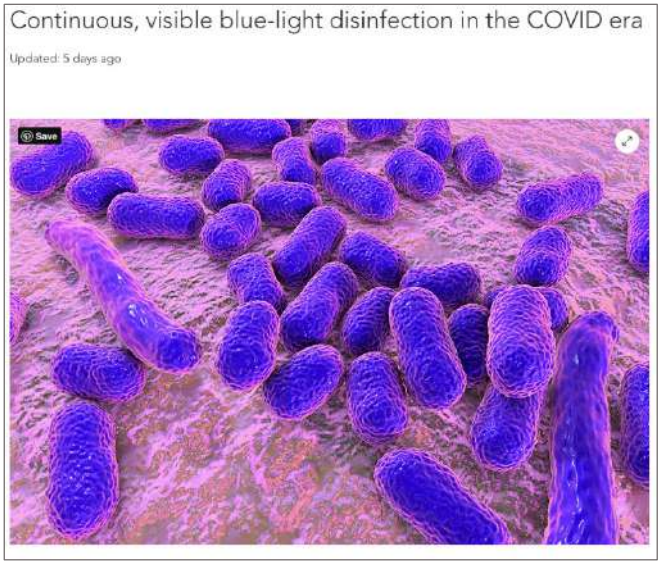
For Penicillium digitatum's germinating conidia, the study showed no significant reduction in CFU when exposed to ERY and blue light when compared with the control group, exposed neither to light nor ERY. Yet, the germinating conidia showed significantly higher susceptibility to the combination of blue light and ERY than their non-germinated counterpart. The decreases in viability were about 80% to 98% when blue light of intensity levels 40-100 J cm^{-2} was combined with 11.4 µmol l^{-1} of ERY, which represented a greater reduction than that shown by the control exposed to no ERY or light. When the ERY levels were doubled to 22.8 µmol $l^{-1,}$ and blue light levels lay at 40 and 100 J cm^{-2}, the reduction in CFU rose to 95% and 98%, respectively. When the light was combined with ERY in this way, it also caused a significant reduction in CFU as compared with the results from control groups exposed to blue light alone or ERY alone.

Fusarium graminearum

Blue light alone was enough to significantly reduce the levels of CFU for germinating conidia. This occurred at energy levels 40, 80, and 100 J cm^{-2} and respectively granted 36, 42, and 47% reductions in CFU levels. The viability losses increased to approximately 90% and 100% when these conidia were exposed to blue light of respective intensities of 40 and 80 J cm^{-2} in combination with 11.4 µmol l^{-1} of ERY. The blue light of intensities 20 and 40 J cm^{-2}, when combined with ERY of twice the concentration (22.8 µmol l^{-1}), led to a larger viability reduction of 80% and 100%. (Note the much lower intensities for blue light.)

The blue band of the light spectrum, 405–470 nm, has a bactericidal effect on Pseudomonas aeruginosa (PA) and on S. aureus, which has shown resistance to methicillin (Guffy and Wilborn 2006). The results of this research by De Lucca et al. show that a similar reduction in viability occurs for LM and BA in the presence of blue light. AR2 peaked at 470nm, and the blue light it emitted was purer than that emitted by AR1, which showed traces of light lying within three ranges of the spectrum: 420–450 nm (indigo), 500–510 nm (cyan), and 520–535 nm. Thus, the study shows in general that blue light produced with no adulteration of light from outside the 405–470 nm band was less effective at reducing the viability of bacteria than that which did contain traces of other types of light, particularly indigo, cyan, and green.

For more information on CleanWhite™ technology and its important role in the Covid era, see our blog, "Continuous, visible blue-light disinfection in the COVID era." Which can be found at https://www.immaculight.com/post/continuous-visible-blue-light-disinfection-in-the-covid-era



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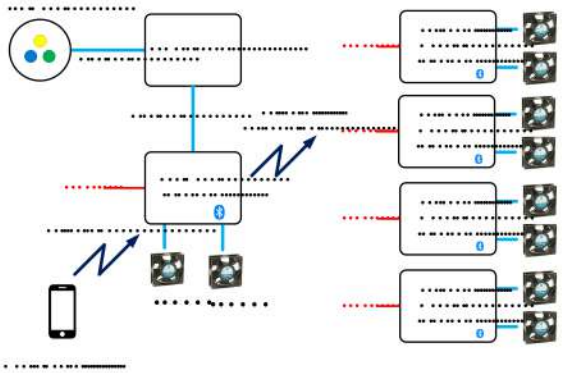
Vertices AQS System

- Standalone or network configuration
- Bluetooth 5.0
- Mobile app and dashboard real-time monitoring
- Configured control threshold values and fan speed value through Bluetooth communication
- Data logger function



Treat pathogens at their source

Our patented technology solution for better air quality and cleaner, safer environments provides surface disinfection, air disinfection and purification, as well as precision airflow and ventilation for any individual space or room.

*All viruses are known to be affected by UVC; however, inactivation time varies by type of virus.
**Room air changes can occur every several minutes depending upon variations of room size and fixture selection.

VERTICES AQS
BY illumiPure
Air Guardian | Air Quality

Main Unit (Hub or Peripheral)

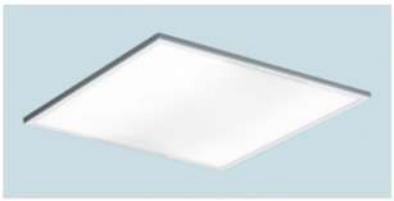
- Two 24V FAN output with PWN control
- One 0-10V Analog output
- One controlled 24V output
- Real-time clock and battery back-up
- 24Vdc input power
- RS-485 connection to sensor node

Sensor Node

- C02 sensor
- Particulate matter sensor
- Humidity + temperature sensor
- TVOC sensor
- Occupancy sensor
- CO sensor (Optional)
- RS-485 Communication to Main Unit (Hub)

LED Module Feature

- Yellow, green, and blue color LED for status indicator



CleanWhite™

Continuous Surface Disinfection

Air Guardian®

Air Treatment Technology

Air Guardian Plus™

Dual-Modality Air + Surface Disinfection Technology

Protect patients from illnesses and pathogens in your most vulnerable healthcare spaces:

Ambulatory Surgery	Assisted Living	Dental Offices	Dialysis Clinics	
Hospitals	Long Term Care Facilities	Medical Offices	Nursing Homes	Urgent Care Centers

illumiPure

Learn more at illumipure.com

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Suite 250
Houston, TX 77014

(281) 227-2208

sales@illumipure.com

the PORTABLE by AIR GUARDIAN Mobile Enclosed UVC Disinfection Air Chamber

AIR GUARDIAN 4-TIER PROTECTION:

1. Air is first inducted through a UV-A catalyzed TiO_2 embedded ceramic filter inlet and exposed to extreme oxidation.
2. Air then passes into a proprietary coated chamber filled with high dose UV-A irradiance and additional oxidation reactions.
3. Air is then forced through a series of proprietary coated linear chambers filled with intense, continuous UV-C irradiance and oxidation.
4. Purified air is then dual-filtered through (HEPA-like) super-micron and carbon filters before precision venting.

FEATURES:

• Convenient, portable unit protects human health without the use of harmful chemicals or materials. Heterogenous filtration eliminates odorous molecules and improves overall air quality by removing particulates, pathogens, and pollutants.

• Emits **no ozone**, VOCs (Volatile Organic Compounds), or any harmful by-product; Multi-level filtration may help people in relieving symptoms of allergies to dust, mold, spores, and other environmental irritants.

• Filter and chamber effectively inactivates/kills all airborne pathogens (including SARS-CoV-2, the virus that causes COVID-19), spores and any other living organism which pass through. Effective against **MRSA, C. difficile, Salmonella, E. coli**, and other pathogens.

• 24hr rechargeable battery available

CERTIFICATIONS:

- CE, ETL, RoHS
- Patent pending
- FDA Facility #10077990
- EPA Establishment # 98105-TX-1
- FDA Medical Device Classification Device Class 1 Listing #D420497

WARRANTY:

- UV-A & UV-C LED Circuits: 30,000 hrs
- Driver, Fans: 5 years
- Chamber Housing: 25 years

APPLICATIONS:

Suitable for most commercial and institutional applications.
IoT available (Internet of Things)

- Hospitals | Healthcare
- Office and Retail
- Schools | Universities
- Labs and Clinics
- Government Facilities
- Nursing | Assisted Living

SPECS:

Air Guardian Chamber:
- Amps: 75 (±10%)
- Wattage: 38
- Decibels: 51*
- Voltage:122 ~ 277

Snorkel: (Air Intake w/ Adjustable Lock):
- Lowers down to 7' 4"
- Extends up to 10'

Weight: 29.15lb **Base:** 36"

**Variable speed available. Adjustable option affects decibel level.*

Total exposed surface area of TiO_2 (UV-C disinfection) within Air Guardian:
- 2 x 2: >19 sq. ft.

UV-C excited disinfection chamber length in which air is passed through Air Guardian:
- 2 x 2: >18 linear ft.

** All viruses are known to be affected by UVC, however, inactivation time varies from virus to virus.*

EPA Est #: 98105-TX-1 | Region: 06 | Facility #10077990

illumiPure

Learn more at illumiPure.com

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MANUFACTURED IN THE UNITED STATES

(Rev. 05-21)

MANUFACTURING

Breathe pure, safe air. Continuously.
Disinfect surfaces. Continuously.

An innovative new air and surface disinfection solution that makes every space safer

Manufacturing of illumiPure Products
June 2021

This document is a description of manufacturing for Air Guardian®, CleanWhite™, and Air Guardian Plus™

This document has been prepared for **prospective clients** for review
Air Guardian® and Air Guardian Plus™ devices, Including CleanWhite™ technology

Manufacturing

All illumiPure products are manufactured, assembled, tested, and shipped from our own high-tech facility in Houston, Texas. This vertically integrated laboratory-to-manufacturing process delivers scalability and ensures the highest level of quality control. Research and Development is always on the forefront to oversee production lines and monitor facility conditions while enhancing and protecting our company's intellectual property. illumiPure's team of engineers and developers provide an unmatched ability to react quickly to changing demands in the market and deliver highly innovative technologies and solutions to our customers.

AIR GUARDIAN®
AERODYNAMICS

Breathe pure, safe air. Continuously.
Disinfect surfaces. Continuously.

An innovative new air and surface disinfection solution that makes every space safer

Clean Air Delivery Quality and Air Changes per Hour
June 2021

This document is a high-level description of the Clean Air Delivery after a single pass through the Air Guardian

This document has been prepared for **prospective clients** for review
Air Guardian® and Air Guardian Plus™ devices, Including CleanWhite™ technology

Calculating Clean Air Delivery Quality and [Room] Air Changes per Hour

Clean Air Delivery after a single pass through the Air Guardian®

Calculating the quality and rate of clean air delivery

The following elements are important in calculating quality and rate of disinfection and purification

1. The movement of air, in cubic feet per minute, as measured by the fan speed of the device
2. The residency of n volume of cubic air within the device
3. The fluence, or dose delivered to the n volume of cubic air during its residency time spent in the device
4. The amount of fluence delivered to n volume of air (for example, 1 cm^3) in order to destroy, kill or inactivate the microbial species at 4-6 Log, is calculated as a cumulative amount of energy absorbed as a fluence dose. For example, if 30 Watts of fluence dose is required to kill a specific bacteria at 6-Log, the 30 Watts can be delivered at 6 Watts within 5 seconds or 10 Watts within 3 seconds.
5. Because of the importance of dose/times, a key aspect of the Air Guardian® is the ability for n amount of air (in our example 1 cm^3) to receive the appropriate dose under fluence over time.

Room Air Change Rates per Hour (ACH)

The following elements are important in calculating how many times each hour the air is replaced [changed] in the room by the Air Guardian® device

1. The movement of air, in cubic feet per minute, as measured by the fan speed of the device
2. The cubic volume of the room, as measured by width x feet x height
3. The Cubic Feet per Minute x 60 minutes = Cubic Feet per Hour
4. The Cubic Volume of the Room divided by The Cubic Feet per Hour = ACH (air changes per hour)

The quality of the CADR and the ACH are a critical differentiators between Air Guardian® and all other systems. ACH with high quality clean air single pass delivery are unique to Air Guardian®. Even at high ACH levels, if single pass reduction rates (in the level of pathogen kill and inactivation as opposed to filtration) are not disinfecting and purifying at high levels, the ACH number is less important. With quality CADR and high ACH, Air Guardian® is unmatched by sealed, upper-room UVGI systems.

1. **Residency Rates for Cubic Volume n of A**

CFD AIR RESIDENCY SUMMARY						
	VOLUMETRIC RESIDENCY		BROWNIAN and SLIP/DRAG EFFECTS		VOLUMETRIC + BROWNIAN	
			0.3			
	Chamber	TOTAL	Chamber	TOTAL	Chamber	TOTAL
2x2 DEVICE	1	4	1	4	1	4
50 CFM	5.80	23.20	1.74	6.96	7.54	**30.74**
75 CFM	3.92	15.68	1.18	4.704	8.62	**20.38**
2x4 DEVICE	1	2	1	2	1	2
105 CFM	4.0800	8.1600	1.2240	2.448	5.3040	**10.6080**
120 CFM	3.4400	6.8800	1.0320	2.064	4.4720	**8.9440**

2. **The ACH rates for a 10' x 12' x 9' room**:
   As shown below, a 200 CFM device will have more than 14 ACH per hour

ACH CALCULATOR	6/16/21

ALLIANCE EXAMPLE		
ROOM DESCRIPTION -->		
	LINEAR FEET	
Length in linear feet	**10.00**	SQUARE FEET
Width in linear feet	**12.00**	120
Ceiling Height in linear feet	**9.00**	
Cubic feet room volume		1080.00
Cubic feet net air volume		842.40

DEVICE SPECS		FAN SPEED	FAN SPEED
DESCRIPTION	DEVICE	TOTAL CUBIC FEET / MIN	CUBIC FEET / HOUR
Four 50 CFM = 200 CF FAN TOTAL	2 x 2	200	12,000
TOTAL ACH CALCULATIONS BASED UPON DEVICE COUNTS			
ROOM OR SPACE DEVICE SELECTIONS	NUMBER DEVICES	CUBIC FEET / HOUR	AIR CHANGES/HOUR
AIR GUARDIAN 2 x 2 - 200 CFM	1	12,000	14.245
		NET AIR CUBIC FEET	
		842	

illumiPure®, Corp.
Air Guardian® and Air Guardian® Plus
Testing and Efficacy Summary Statement
May 3, 2021

Summary statement:

The Air Guardian® is the only commercially available, room-based, air disinfection and purification device that can remove nearly all infectious pathogens within a single pass through the device.

Air Guardian® achieves complete inactivation, cell destruction, and disassembly of cellular and chemical byproducts of microbial species before the air reaches the filtration process.

Air Guardian® provides 4-6 Log reductions for bacteria, viruses, spores, mold, and fungal species. Microbes are inactivated or destroyed within seconds or sub-seconds. Subsequent oxidation and UV-C energy reduce fragmentary byproducts into harmless molecules found in ambient air. Oxidation and filtration also help remove particulates, pollutant compounds, and odors.

Microbial reductions are achieved using several mechanisms, including extended air residency times in-device, extreme UV-C oxidation (up to 170,000 millijoules), intense photoelectrochemical oxidation, and final filtration.

These results have been validated through third-party laboratory whole room testing and single-pass pathogenic destruction models.

More detailed messaging

Competitive:

While there are recent-to-market UVGI fixtures with adequate UV-C energies in fixture lamps, air only spends from .2 seconds (50 CFM) to .05 seconds (100+ CFM) receiving a UV-C dose. Thus, multiple, continuous passes are needed to inactivate or "kill" pathogens (including SARS-CoV-2).

Adding HEPA or MERV filtration to these sealed fixtures may skew single pass results or room reductions without removing pathogens. Filtration does not cause cell apoptosis or destruction. Infectious pathogens can remain trapped in MERV or HEPA filters.

UVGI systems actively kill and inactivate pathogens with UV-C energies, ideally and specifically in either 254 or 265 nm wavelengths, with 265 nm proven to be more effective at elimination.

Air Guardian

Air Guardian efficacy was tested in a nationally recognized, independent laboratory for its ability to inactivate and remove MS-2 Bacteriophage virus ATCC-1157-B1 as a proxy for SARS-COV-2 human coronavirus. The testing was performed under whole-room conditions, in conformance with ISO testing standards and procedures. Certified results show that Air Guardian eliminated 99.99% of all viral particles aerosolized into a whole room sealed chamber.

Notably, this study was performed without micron filters; thus, true UV-C and oxidation energies accounted for ALL viral inactivation and destruction. No active viral particles were trapped in filters during the test.

In addition, Air Guardian's UV-C LEDs have been tested against SARS-CoV-2 in a BSL-III lab at Korea University and achieved a 4-Log (99.99%) reduction of the SARS-CoV-2 virus.

Air Guardian® has been additionally tested and modeled in certified laboratories. Results include dose-time destruction/removal studies of over 80 microbiological species, including gram-positive, gram-negative, vegetative bacteria, mold, fungus, influenza, salmonella, candida, c-diff, and several spore forms (including C-Diff, fungal, yeast, and mold forms).

It has been shown that Air Guardian® achieved single-pass reductions between 99.9% and 99.9999% of all microbiological pathogens (excluding tobacco mosaic and anthrax spores) tested.

SARS-CoV-2 and MS-2 Bacteriophage (Escherichia coli strain) were completely eradicated (not just filtered) within 1 second under time-dose modeling within the Air Guardian® device.

Time in device for inducted air is ~ 9 seconds per 2 x 4 chamber (there are two) and 12-20 seconds for micro-particles (see mechanisms of the action below). These processes and airflow residency rates have been certified by molecular, airflow, and CFD engineers.

Mechanisms of action:

Intense UV-A in oxidizing pre-chamber
Intense UV-C in residency chambers
Total UV energy - 170,414 millijoules
265 nm UV-C
365 nm UV-A
29 feet of energy exposure
Energy source - Viosys led
Intense oxidation 63 ft^2
Rutile nanoparticle TiO^2
Powder-coated photo-catalyzed oxidation on 63 square feet surface area
Continuous ROS oxidation across all surfaces
Induced turbulence enhances oxidation
Air vortices enhance oxidation
Airflow capture and processing
Air volume residency time in the device - 9 seconds per chamber, two chambers
Microdroplet residency in chambers 12 to 20 seconds per chamber, two chambers
Induced turbulence airflow impedance
Air vortices - corridor design

Dual filtration
Super micron filters
Charcoal filters
Airflow and induction
Air induction speed 285 cfm
Dual exhaust vents separate from the fixture
Downward airflow 950 kg/sec each vent
In-plenum design or ceiling mount

AIR GUARDIAN®
VENDOR COMPARISON

Breathe pure, safe air. Continuously.
Disinfect surfaces. Continuously.

An innovative new air and surface disinfection solution that makes every space safer

June 2021

This document is a high-level comparison of the novel air purification of the Air Guardian®
with UV Angel and other competitors

This document has been prepared for **prospective clients** for review
Air Guardian® and Air Guardian Plus™ devices, Including CleanWhite™ technology

illumiPure®, Inc.
Air Guardian® and Air Guardian® Plus
Comparative Efficacy and Design

A closer, science-based examination of Air Guardian® and UV Angel

Test Results, Efficacy, Claims, Mechanisms and Design Elements
June 18, 2021

Air Guardian® Science, Efficacy, and Design Summary

1. Air Guardian® is the only commercially available, upper-room sealed UVGI device that will remove - not just filter - nearly all infectious pathogens in an ingested cubic volume of air.
2. Air Guardian® can be installed either in the ceiling plenum or mounted on the ceiling surface, and is available in multiple form factors, including 2x2, 2x4, and portable form factors.
3. Air Guardian® devices are pre-configured to be controlled as either a single device or in tandem with up to four other devices from a single controller. Aspects of the Air Guardian® device can be controlled by the end user, via the controller itself or the Vertices™ integrated IAQ sensor system (described below). The controllable aspects are on/off, dose energy, and fan speed.
4. Third-party Computational Fluid Dynamic testing has certified Air Guardian® ambient air ingestion rates, air residency rates within the device, and the volume (in kg/second) and spread of downward airflow - all produced from patented design elements.
5. Air Guardian's innovative induction fan design, including angle, speed, and location is uniquely effective at drawing room air, which helps stimulate upward air movement around the downward columns of vented and dispersed air within the breathing zone.
6. Upward air movement is also generated by Air Guardian® through convection forces, which is created when cool air (approximately four degrees cooler than ambient room air) is vented from the multiple supply sources, which are positioned well away from air induction locations. This is a function of exposing resident air to a titanium dioxide surface area equal to twenty to sixty-three square feet.
7. The air temperature gradient between ingested and vented air is due to the known effects[1,2] of TiO2 surface reflection and thermal absorption. Thermal cooling is supplemented by fluid dynamic forces (airflow), near-zero surface friction, and the thermal shielding on the exterior of the Air

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[1] B. Givoni, M.E. Hoffiman, Effect of building materials on internal temperatures, Research Report, Building Research Station, Technion Haifa, (1968).

(i) H. Taha, D. Sailor, H. Akbari, High albedo materials for reducing cooling energy use, Lawrence Berkeley Laboratory Report 31721, UC-530, Berkley CA, (1992). DOI: 10.2172/7000986

(ii) A. Seneca, A. Santamouris, W. Miller, A. Livada, A comparative study of the thermal performance of reflective coatings for the urban environment, in Proceedings of the International Conference Passive and Low Energy Cooling for the Built Environment, Santorini, Greece, (2005).

[2] https://www.scientific.net/KEM.545.95

Guardian® device shell, which enables the gradient between ambient room air and the interior of the device chambers.

8. The sum of Air Guardian® design elements, including the numerous Multi-focal Reaction Chambers, enable more rapid ingestion of room air, enhanced upward air movement and convection, and thus more frequent - and complete - room air changes (ACH) while using fewer devices than any other solution.
9. Air Guardian's high kill-curve reduction rates and particle/chemical dissolution capability mean that each room air change (ACH) is of higher value than an equivalent ACH from any other sealed UVGI solution. Thus, room air change rates from other vendors may be a misleading measure of infection prevention and improved air quality and must be carefully considered.
10. With Air Guardian's innovative and patent-protected design, a cubic volume of ambient room air, is forced through a residency period within the device, for a period of 6.6 to 23 seconds (depending on device model). During residency, ingested air volume is exposed to powerful ultraviolet and nano-particle reactor energies generated by proprietary UV diodes.
11. Air Guardian's Multi-focal Reaction Chambers are powered by 55 - 210 Watts of UV energy, and airflow containing microbial, particulate, and chemical contaminants and hazards is continuously exposed to the mechanisms and properties within the sealed chambers.
12. Because of Air Guardian's proprietary diode and circuit design, the UV-C dose wavelength is 265nm, which has been proven in multiple studies to be the optimal wavelength for microbial destruction and fastest kill-curve Log reductions.[3]
13. Warranties - Air Guardian® uses long-lasting proprietary LED diodes, the warranty for the diodes is 30,000 hours, or more than three years of constant use. It is warranted from drifting or degrading off the 265nm wavelength during that time. The device itself, excluding LEDs and fans, is warranted for 25 years. The fans have a 50,000-hour warranty. These warranties reflect the superior grade of materials, manufacturing techniques, quality control, assembly, and design.
14. Maintenance - Air Guardian® has recommended periods for filter replacement, which depend on use case. The filter replacement process is simple and device-accessible, and is described in the installation and maintenance guideline document, which can be found at https://www.immaculight.com/installation-guide.
15. It has been proven that the sum of the Air Guardian® applied science mechanisms and design elements kill, inactivate, or destroy microbial pathogens within seconds or sub-seconds while resident within the cubic volume of air which passes through the proprietary internal structures of the device. These elements include intense UV energy and continuous photo-catalyzed oxidation.
16. The high UV kill-curve in single-pass Log reductions is a result of the Multi-focal Reaction Chambers and their intense mechanisms applied over dose-time, rather than distance traveled within the chambers. The proprietary CFD design elements within the chamber increase the time under dose.

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[3] https://www.cdc.gov/niosh/nioshtic-2/20034387.html

17. Nano-reactors include crystalline photo-catalyzed oxidation, which is also highly destructive to microbial pathogens, pollutants, and harmful chemical compounds. The amount of surface areas upon which the oxidative reactions occur are directly related to efficacy. On each square inch of surface within Air Guardian®, chemical "clouds" of highly Reactive Oxygen Species continuously form. As ingested air passes through the device, it is constantly exposed to these oxidatively-destructive forces that form on all surface areas. **The Air Guardian® devices have between 2,750 and 9,000 square inches of oxidative surface area.**

18. Air Guardian's unique and proprietary design - including airflow elements within the Multi-focal Reaction Chambers - enables a level of continuous and extensive disinfection and purification not found in any other solution. There are but a few devices that add oxidation mechanisms. They are limited to filters or mesh embedded with nanoparticles. However, they only expose air to oxidation processes for sub-second periods - and they require frequent, often expensive filter replacement.

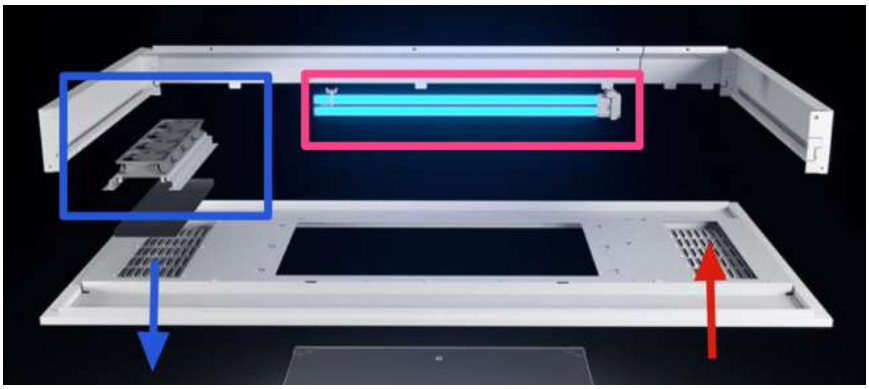
19. The Air Guardian® oxidation process uses rutile TiO^2 nanoparticles embedded in a permanent powder coating, which covers every square inch inside the fixture. Importantly it also accounts for Multi-focal Reaction Chambers' ability to destroy harmful chemical compounds and particles that are often found in ambient air. These include PM2.5 and PM10 particles, volatile organic compounds, ozone, and pollutant chemicals and gases. That Air Guardian® can reduce and eliminate these compounds has been tested and certified by independent third-party laboratories.

20. Air Guardian® is available with a proprietary indoor air quality measurement system, Vertices™, which is a patented multi-sensor circuit-board for monitoring real-time and periodic measurement values. LED lights of the device offer visual cues on air quality for each room so that any material change in air quality can be immediately recognized.

    The recorded measures include CO2, CO, TVOC, VOC, RH, PM2.5, PM10, Temperature, and an aggregate AIQ measure. The user can monitor and control using a desktop application or an app that can be found in the Apple or Android app stores.

Comparative Statements regarding UV Angel:

1. The UV Angel is an upper room sealed UVGI device that has 80 Watts of power. Of this, 60 Watts is used for the UV-C lamps, which leaves 20 Watts available for use by the light source in the middle of the device.
2. The device can only be installed in the ceiling plenum and appears to be available only in a single 2 x 4 form factor, although this has not been confirmed.
3. UV Angel has 50CFM of air induction. The induction is facilitated passively by being pulled through the device from the air output vent, which is located on the same UV Angel device, shown here:
4. CFD engineers have stated that the proximity of the UV Angel vents for both induction and output, along with the relatively low CFM rates, may create competitive airflows or slight vortices, which could, theoretically, affect the efficiency of room air changes.
5. Because the UV Angel uses a lamp bulb, vented air will likely be warmer than ambient air inducted into the device. Thus, more downward airflow pressure is needed to force air into the breathing zone, since the cooler air gradient in the lower room will form a layer of resistance. Since the UV Angel air must also pass through a HEPA filter before venting, it is very possible that vented air may be less than the kg/sec volume of a 50CFM fan.



6. The whole-room studies conducted at the MicroChem laboratory on UV Angel shown the device positioned atop a ladder, not on the ceiling. Thus, the results would not represent the actual installation configuration of the device, which is in the ceiling plenum. The ladder itself also offers separation between the two vents on the UV Angel device, which would help prevent the above-mentioned fluid dynamic issues with close-proximity intake/output vents.
7. The whole-room studies conducted at the MicroChem laboratory on UV Angel do not necessarily prove kill-curve Log reductions, since a HEPA filter was used on the UV Angel device during the test. Whole-room reductions may measure filter efficiency as opposed to real pathogenic kill-time curves. If that were the case, the filters would contain captured microbes that could still be pathogenic; trapped within the HEPA filter.

   HEPA filters can become overloaded with microbial content if not changed frequently. When changed, they should be considered environmentally hazardous. Studies have shown that many organisms can survive for almost a week within HEPA filters, and some microbes have shown viability after 210 days.[4]
8. The airspeed of a 50CFM fan is 572 linear feet per minute. Assuming that the UV-C lamp length is 12 inches, the time air spends over the dose within the UV Angel device is .1049 seconds. The conclusion on what may account for efficacy and test results may be based more heavily on HEPA filtration than the efficacy of UV-C irradiation.

   However, if one assumes that the full 60,000 millijoules in the UV Angel device irradiates the microbe for .1 seconds and only 6-10 millijoules are required for the "inactivation" of RNA in a SARS-CoV-2 virus, then it is possible that the sub-second exposure could inactivate SARS-CoV-2.

   However, that would assume the full 60,000 millijoules are dosed. It is well known that only about 10-15% of the Watt-energy of the UV-C lamps emit UV-C dose energy, thus the actual dose would only be about 7200 millijoules, dosed for .1049 seconds, or 755.28 millijoules.

   From https://www.waveformlighting.com/uv-c-led/how-to-determine-uv-c-irradiance-requirements-for-disinfection-applications

   *"Caution: Don't confuse irradiance watts with electrical watts! While it can be tempting, it is not enough to rely on the electrical rating of a **UV lamp** for two reasons. First, the wattage rating of an electrical lamp*

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[4] https://www.liebertpub.com/doi/10.1177/153567601101600305

refers to the amount of electrical energy it consumes. This is different from how much UV energy it produces ("radiometric watts"). A 20-watt UV lamp, for example, may only produce 2 watts of actual UV-C energy (i.e., it has an efficiency value of 10%). Secondly, even if we know how many radiometric watts a UV lamp produces, we do not know how and where the UV energy is distributed. Irradiance is strictly a measure of UV-C at a particular position and distance from a UV lamp.

9. <u>UV-C dose/time needed for other pathogens</u>: Even if 0.1 seconds of dose/time in UV Angel at 755.28 millijoules can inactivate a SS-RNA virus like SARS-CoV-2, the time and UV-C dose needed to kill bacteria, molds, fungus, and some other viral species are much, much higher. Again, if UV Angel testing shows efficacy in achieving reductions, it would almost certainly reflect filtration rather than UV kill-curve reductions.
10. <u>Quality room air (ACH) changes</u>: Additionally, it is unlikely that (excluding HEPA filtration) that, even if UV Angel can affect full-room ACH reasonably well with low-speed fans, Air Guardian® will have considerably higher quality ACH because of dose/time values, air residency times, wavelength specificity, and intense, continuous oxidation.

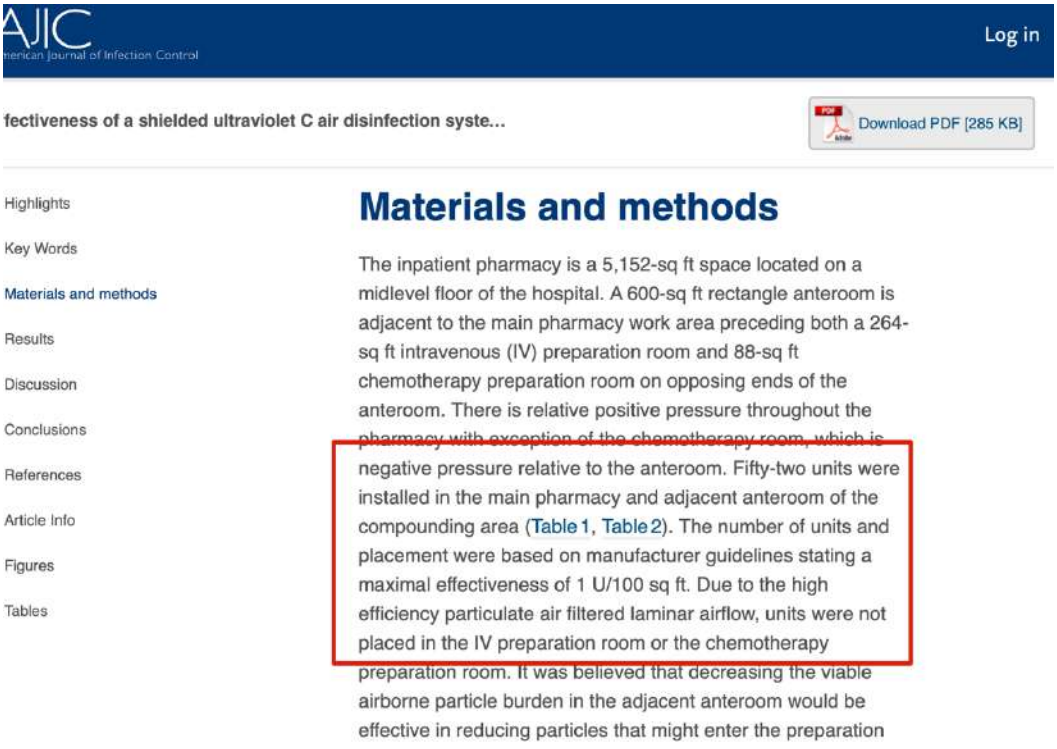
DEVICE TYPE	UV ANGEL 2x4
CHAMBER DIMENSIONS	
FAN SPEED IN CFM	50.00
linear feet per minute	572.00
REDUCTION, CFD EFFECTS	0.00
REDUCTION, CHAMBER VORTICES	0.00
NET LINEAR FEET PER MINUTE	572.00
Total inches traveled in device	14.00
Percentage of inches exposed to UV-C	NA
Total UV-C exposed inches traveled in device	12.000
LINEAR SPEED INCHES PER SEC NET	114.40
Seconds spent in device chamber under UV-C	0.1049
Assumes 12-incch UV-C Lamp or Lamps	

11. UV-C lamps: UV Angel's use of UV-C lamps also effects the performance of the device, since the lamps cannot emit a precise, exclusive 254 nm dose. In addition, lamp degradation can occur in as little as 3,000 hours, which further reduce the effective UV-C dose of the lamp, and thus the overall value proposition of UV Angel as a sealed UVGI device. As lamp dose-energy degrades, HEPA filtration becomes more of a primary mechanism for air quality. Careful consideration should be given to the concept of whether UV Angel is a primary UV-C disinfection device or a HEPA filtration device with a certain degree of UV-C pathogen reduction.
12. Since UV Angel does not have continuous intense photo-catalyzed oxidation, it must rely on UV-C dose energy for the destruction and disassembly of chemical compounds, pollutants, and particulates. Although UV Angel also uses a charcoal filter, which can absorb some compounds, air passes across the thin charcoal layer very quickly.

    Again, time and dose over the energy source is a limiting factor in UV Angel's ability to affect indoor air quality. In terms of ability to oxidize harmful compounds, particulates, and pollutants and improve indoor air quality, UV Angel and Air Guardian® are essentially not comparable.
13. Real-world studies of UV Angel - in a study[5] frequently cited by UV Angel, performed in the pharmacy of a children's hospital, the study protocols should warrant special attention from any prospective UV Angel customer. In a 5,000 square foot pharmacy, 52 devices were required by the vendor, and they were only placed at the periphery of pharmacy, since a central positive pressure

[5] DOI: https://doi.org/10.1016/j.ajic.2017.07.026

airflow system was in use. Why 52 devices? Were the results based on UV-C time/dose mechanisms or HEPA filtration every 10 feet?



14. Warranties and maintenance - the typical UV-C lamp has a limited warranty period because vendors tell customers that they should expect annual bulb replacements. For UV Angel devices, one would expect rather frequent HEPA and charcoal filter changes since it is likely a significant element of the removal mechanisms. The filters will contain viable pathogens, microbial fragments such as endotoxins, particles, dust, and absorbed chemicals in the charcoal layer. If the filters are categorized as a biohazard, frequent replacement of filters at scale would be costly and problematic.

UVGI vendor Or vendor type	Air Guardian® Air Guardian® Plus	HealthE Air fixture	UV Angel Company	UV Fan Company	American Ultraviolet®	Light Progress UV Flow	Bovie	Energy Harness (Purdue)	Sanitaire	Big Ass Fans
Located in the upper third of the room or on ceiling or in plenum	✓	✓	✓	✓	✓	✓	✓	✓	✓	?
Provides addition surface disinfection technology	✓	—	—	—	—	—	—	—	—	—
Room Air Changes via induction greater than 100 CFM Fan	✓	—	—	—	—	—	—	✓	—	—
UV dose energy in millijoules/cm^2	126,000	60,000	60,000	80,000	36,000	75,000	24,000	18,000	26,000	5,000
Includes TiO2 catalyzed oxidation	✓	—	—	—	—	—	—	—	—	—
Includes HEPA Filter or HEPA-grade filter	✓	—	✓	✓	—	—	✓	✓	—	—
Kills Sar-Cov-2 at 2-6 Log with single pass-through the device	✓	↗	↗	↗	↗	↗	↗	?	↗	—
Kills Gram - bacteria 2-6 Log with single pass-through the device	✓	↗	↗	↗	↘	↘	↘	—	—	—
Likeliness to kill Gram+, Spore, Fungi single pass 2 -4 Log	✓	—	—	—	—	—	—	—	—	—
Pm 2.5 removal to lowest ppb measures in single pass	✓	—	—	✓	—	—	↗	↗	—	—
Can dissemble to lowest ppb VOC in single pass	✓	—	—	↘	—	—	—	—	—	—
Has Mobile app to for monitoring IAQ and controls	✓	?	✓	?	—	?	✓	?	—	—
Protective precision downward airflow	✓	—	↘	—	—	—	—	—	—	↘

Yes ✓
No —
Possible or likely ↗
Possible but unlikely ↘
Unknown ?

AIR GUARDIAN®
INSTALLATION & INSTALLS

Breathe pure, safe air. Continuously.
Disinfect surfaces. Continuously.

An innovative new air and surface disinfection solution that makes every space safer

June 2021

This document is a high-level descriptive guide on installation instructions for the Air Guardian, including examples of installs

This document has been prepared for **prospective clients** for review
Air Guardian® and Air Guardian Plus™ devices, Including CleanWhite™ technology

Installation and Operation Instructions

CE, ETL, RoHS
FDA Facility #10077990
EPA Facility Establishment # 98105-TX-1
FDA Medical Device Classification:
Device Class 1 Listing #0420497

For additional information on the Air Guardian® product registration information, hazards, and handling of the device, please refer to the labeling information included on the device and in the packaging materials.

Installation of the Air Guardian® should be performed by qualified personnel only, and in accordance with local guidelines that may govern the installation of electrical devices.

For questions regarding installation of the Air Guardian®, please contact the local supplier or retailer from which the Air Guardian® was purchased. CalyxPure is the manufacturer of the device and will provide guidance and support to the local vending supplier if needed.

The following instructions should be followed to ensure the safe and efficient operation of the device.

Table of Contents

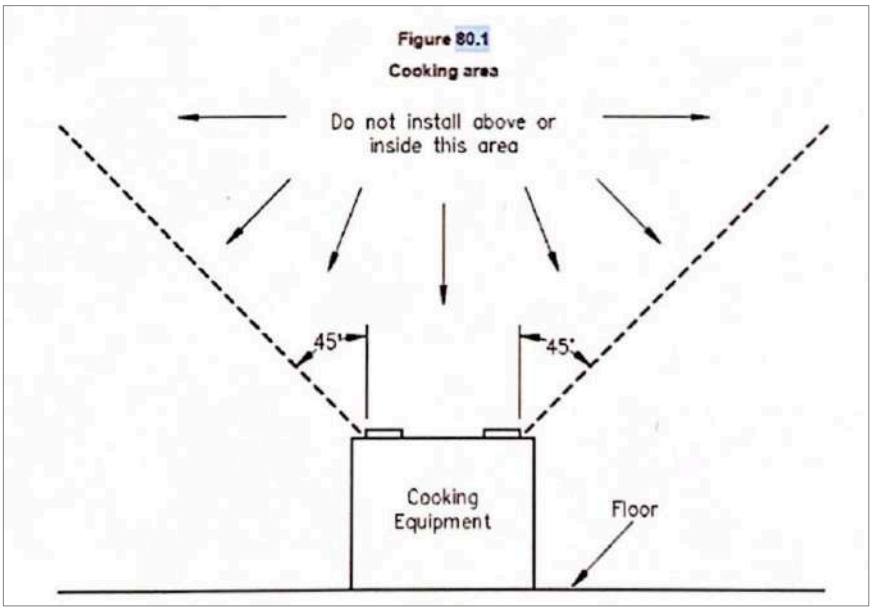
Use Warnings

TO REDUCE THE RISK OF FIRE, ELECTRIC SHOCK, OR INJURY TO PERSONS, OBSERVE THE FOLLOWING:

A. Use this unit only in the manner intended by the manufacturer. If you have questions, contact the manufacturer of the device. Contact information can be found at www.illumipure.com

B. Before servicing or cleaning unit, switch power off at service panel and lock the service disconnecting means to prevent power from being switched on accidentally. When the service disconnecting means cannot be locked, securely fasten a prominent warning device, such as a tag, to the service panel.

DO NOT INSTALL IN A COOKING AREA
NE PAS INSTALLER PRES D' UN APPAREIL DE CUISSON
See figure 80.1 below for device placement restrictions for cooking area
See installation instructions



Air Guardian® Ceiling Tile and Device Installation

Step 1: Remove ceiling tile from the ceiling grid.

Figure 1 - remove tile from grid

Step 2:
Measure the ceiling tile for the fan-box cut out by placing the 2x2 Air Guardian® in the center of the tile. This will be the opening for the intake fan on the Air Guardian®.

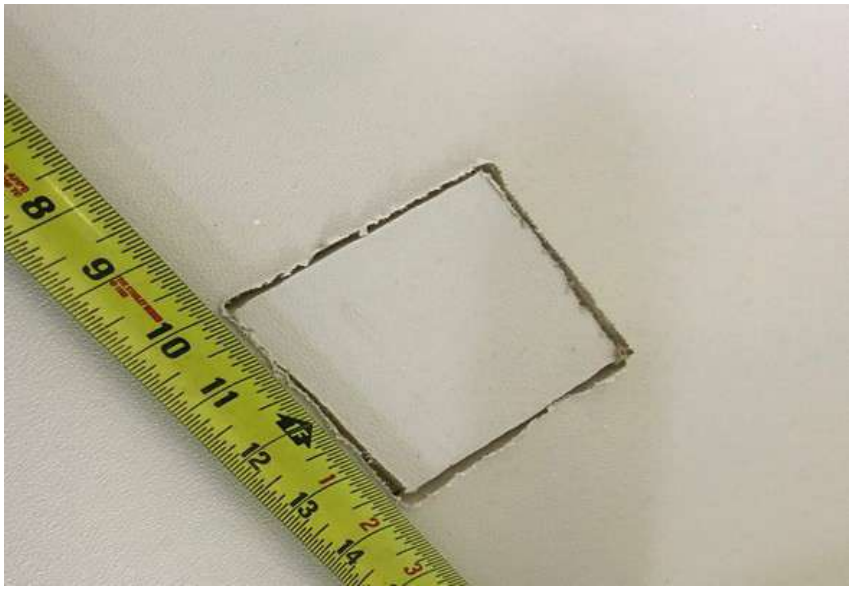


Figure 2 - Measure ceiling tile for the fan-box cut out

Step 3:
Using the measurements, cut out the fan-box hole in ceiling tile. (A Hard Tile Precut is also available)

Figure 3 - cut fan box hole in ceiling tile

Step 4:
Remove the "finger guard", which is included in the Air Guardian® packaging, as shown.

Figure 4 - remove finger guard from packaging

Step 5:
Replace ceiling tile into ceiling grid.

Step 6:
Lay the Air Guardian® fixture onto the ceiling tile such that the fan housing slots into the cutout that was made in the ceiling tile.

Step 7: Safety Secure
Loop the tie wires through the Air Guardian Mounting Hooks & secure them to the ceiling grid as shown.

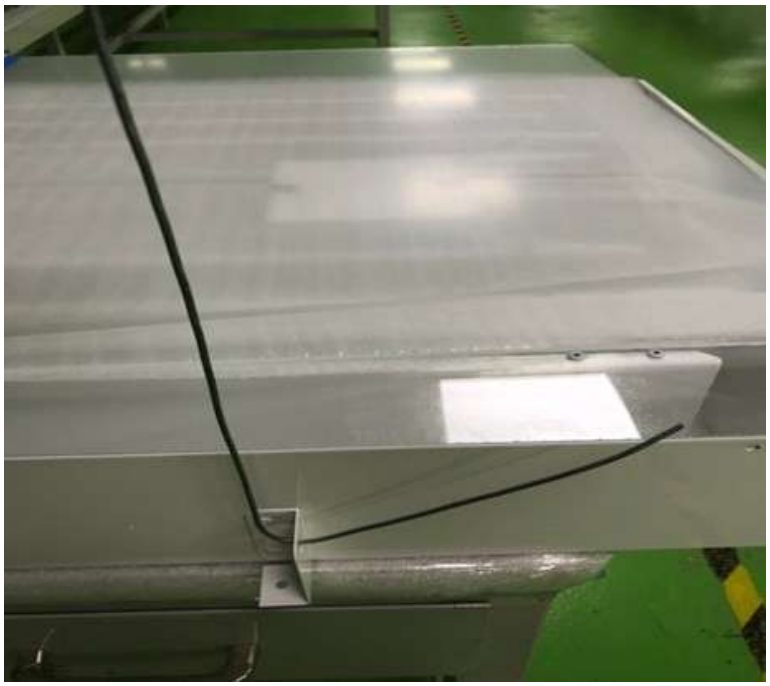


Figure 5 - loop the tie wires as shown

Secure with provided hardware.

Figure 6 - safely affix tie wire and secure per plenum design

Step 8:
Attach electrical source. (Refer to the following **Wiring Guide** section for wiring instructions)

Screw Sizes legend

1. **Finger Guard** 6/32 2.) Fan M3 x 50mm
2. **Exhaust Finger Guard** 8x32x1
3. **Switch** M3 x 15mm
4. **Fan Driver** M3 x 12mm
5. **UVA Drivers and Fan Housing** 3M x 7mm
6. **1 Up Board Screws** #5 x 5/32

Figure 7 - screw sizes legend

Air Guardian® Wiring Guide

Step 1:
Remove the Air Guardian box electrical panel cover by removing screws, popping out of tabs, and sliding down.

Figure 9 - remove Air Guardian electrical panel

Figure 8 - access to electrical panel

Step 2:
Identify correct wires – Green = Ground, Black = Line, White = Neutral

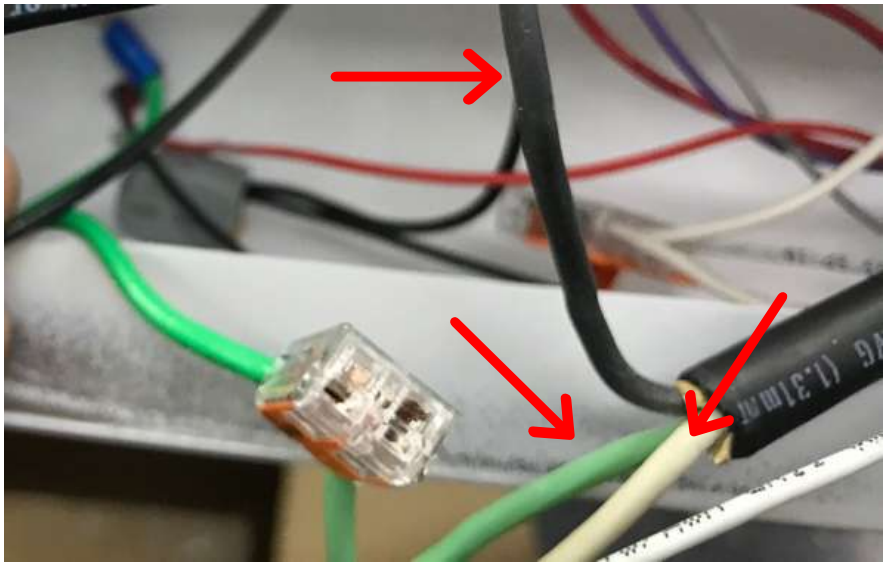


Figure 10 - identify proper wires

Step 3:
Install Wire Input Guide Fitting into wiring opening.

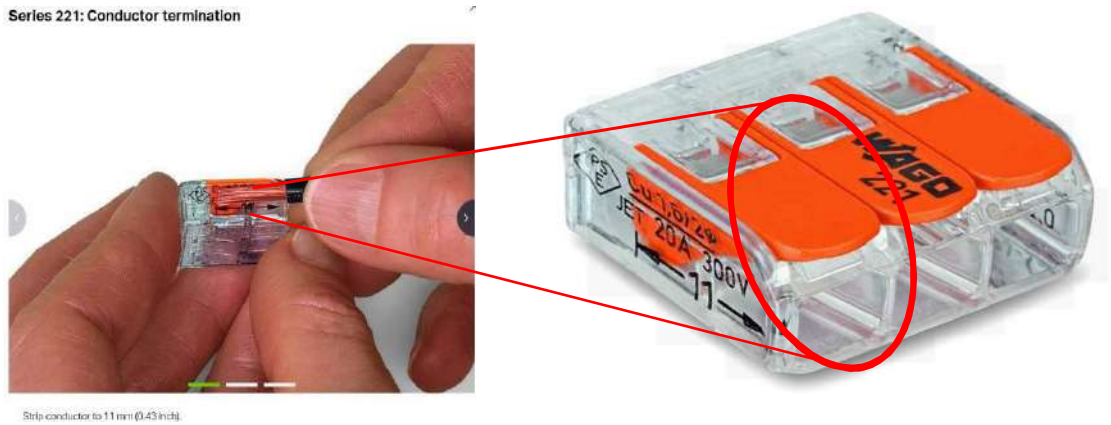
Figure 11 - install the wire guide fitting into the wiring opening on Air Guardian box

Step 4:
Connect Input Wires to Wagos (Refer to Wago wiring instructions below).

Step 5:
Replace electrical panel on the fixture.

WAGO 221 Series Lever-Nut TM User Instruction Sheet

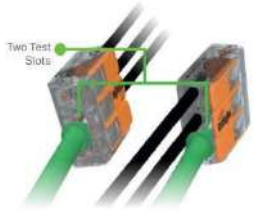
Step 1:
Strip your wire conductor to the proper length. Use the Wire Strip Gauge on the side of the connector as your guide.

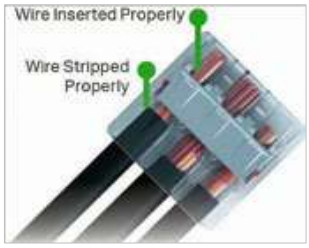


Step 2:
Flip-up Lever(s) and FULLY INSERT WIRE AS SHOWN BELOW. Use clear sight case to verify proper insertion.

Step 4:
Test your circuit (if required).

Test port is located under the lever with the WAGO name on it.





Hose Assembly & Installation

Step 1:
Insert hose through clamp.

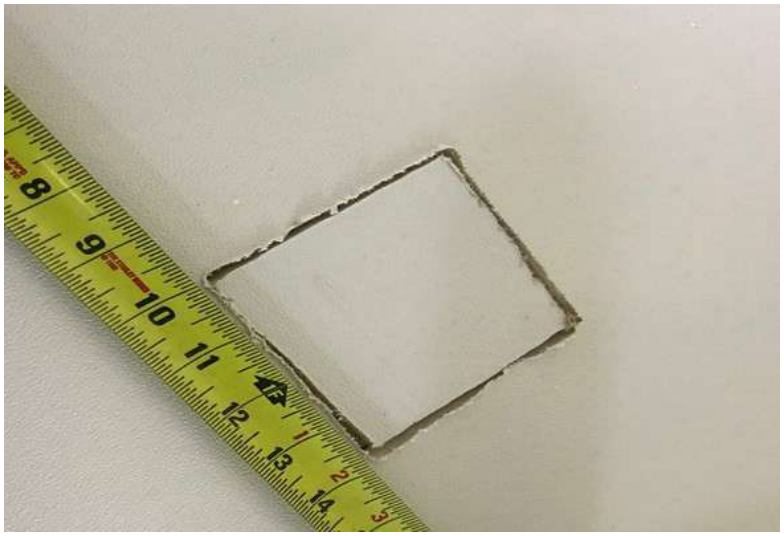
Step 2:
Attach hoses to sides A & B.

Step 3:
Tighten hose clamp until snug.

Step 4:
Ensure hose is firmly secured to the Air Guardian.

Fan Return Assembly & Installation

Step 1:
Measure ceiling tile for the fan-return cut out by placing the fan box in the center of the tile.



Step 2:
Cut out fan-return hole in ceiling tile. (A Hard Tile Precut is available)

Step 3:
Insert hose through clamp.

Step 4:
Place back of fan return into cut out and connect the fan return finger guard on the other side of the tile.

NOTE:
Must install fan return unit at least 6 feet away from Air Guardian®, if possible, in the space. For best air displacement, a staggered alignment is recommended.

For any positioning in tile, please refer to the cutting list.

Air Guardian® Carbon Filter Replacement

Step 1:
Remove glove from bag and wear before handling. Remove new filter and set aside.

Step 2:
Remove old filter by sliding out using the finger hole.

Step 3:
Place the old filter into the bag and seal securely.

Step 4:
Slide the new filter into place using the finger hole to insure complete installation.

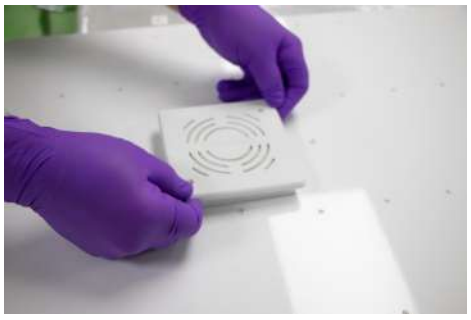
Air Guardian® TiO2 Filter Replacement

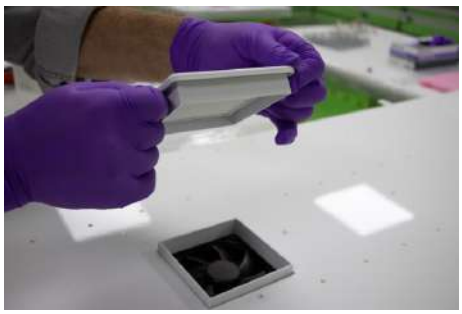
Note: Turn off all power to the unit before starting.

Step 1:
Remove gloves from bag and wear before handling. Remove new finger guard with installed filter and set aside.

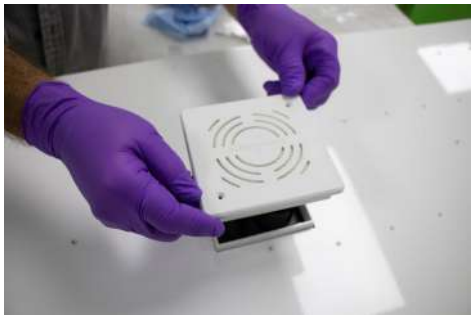
Step 2:
Remove the two screws from the finger guard unit.

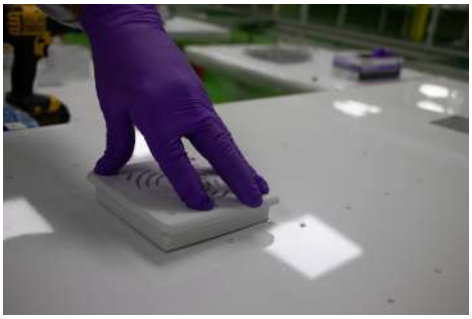
Step 3: Carefully remove the old finger guard fan unit.
Step 4: Place the old finger guard unit into the bag and seal.



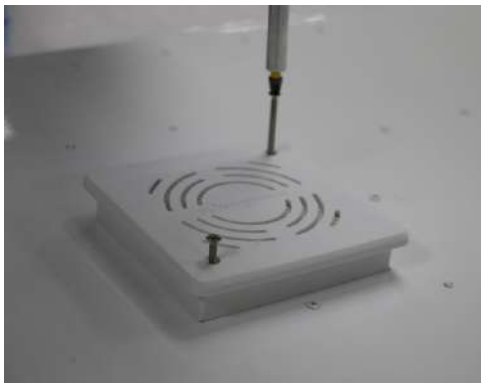


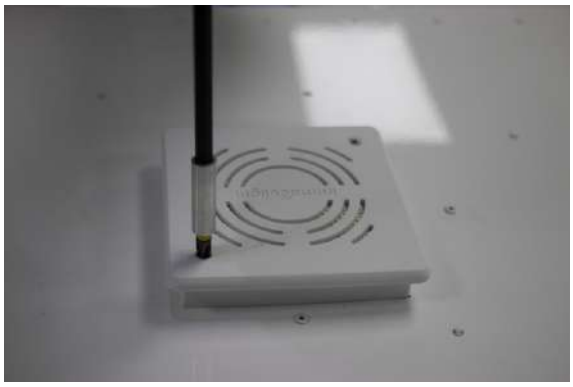
Step 5: Set the new finger guard into place over the fan unit and press into a snug fit.





Step 6:
Set the torque no higher than 3 on your electric screwdriver. Start with one corner and screw in to about 3/4 of the way. Make sure to line up with all holes in the fan housing unit. Then fully screw in the other corner, also making sure to line up with all holes in the fan housing unit. Then finish original corner.





Contact your supplier for return instructions for old finger guard.

Operating Instructions

illumiPure® RECOMMENDS THAT YOU FOLLOW ALL SAFETY INSTRUCTIONS DURING OPERATION OF THE AIR GUARDIAN® FIXTURE.

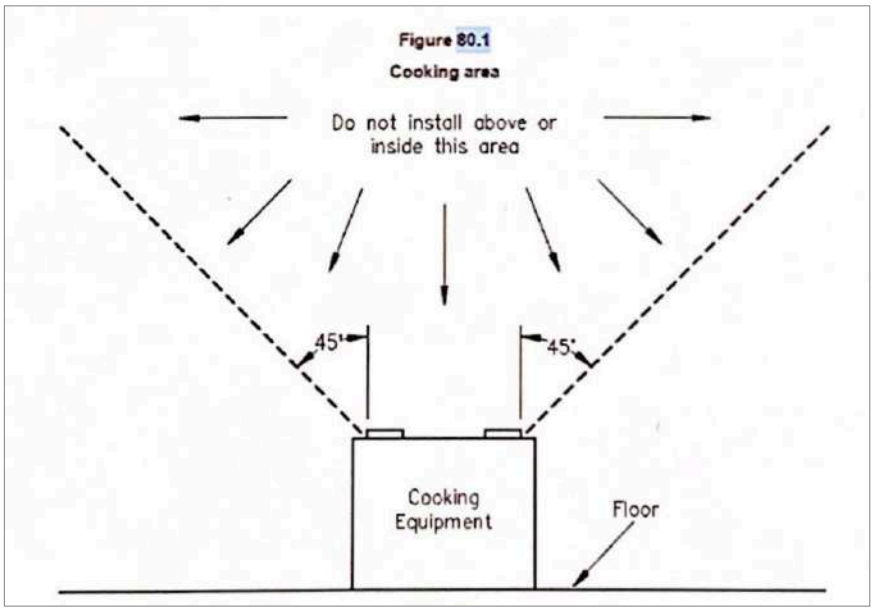
SAVE THESE INSTRUCTIONS, REVIEW WITH THE OWNER AND DELIVER TO THE OWNER AFTER QUALIFIED INSTALLATION.

USE AND INSTALLATION

- To reduce the risk of death, personal injury or property damage from fire, electric shock, falling parts, cuts/abrasions, and other hazards **please read all warnings and instructions** included with and on the fixture box and all fixture labels.
- Pay attention to and **follow precautions provided on the warning and hazard label**s on the packaging and on the Air Guardian® fixture.
- All power to be connected to the fixture should disconnected and turned off in order to prevent electrical injury or death. Power supplied to the device should be connected, by a qualified and licensed electrician or licensed and trained lighting technician, to the control system preferred by the owner.
- The Air Guardian® fixture should be installed consistent with the wiring instructions in the installation portion of this manual.
- There are several commercially available controllers, with options for on/off operation, that are available to the owner and operator. Any questions about the suitability or conformance of the controller should be referred to the licensed electrician or technician, to the manufacturer of the controller, or to illumiPure® or its distribution agents.
- For optimal Air Guardian® air purification performance, venting outlets should be placed such that clean air is vented into the airspace at a distance from the Air Guardian® air intake vent(s). Distance may vary depending on the room space, but vents should be positioned such that vented clean air is not immediately re-ingested.
- Some customer use cases may benefit from customized operating instructions, which are available from qualified manufacturer (illumiPure®) representatives or distribution agents.
- Should further information be desired, or should particular problems arise which are not covered sufficiently for the purchaser's or owner's purposes, contact illumiPure® or the distributor for further instructions or guidelines.
- Do not impede or block airflow intake vents into Air Guardian® fixtures.
- Do not restrict the ventilation of air released from Air Guardian®.
- TO REDUCE THE RISK OF FIRE, ELECTRIC SHOCK, OR INJURY TO PERSONS, OBSERVE THE FOLLOWING:
- Use this unit only in the manner intended by the manufacturer. If you have questions, contact the manufacturer of the device. Contact information can be found at www.illumipure.com
- Before servicing or cleaning unit, switch power off at service panel and lock the service disconnecting means to prevent power from being switched on accidentally. When the service disconnecting means cannot be locked,

securely fasten a prominent warning device, such as a tag, to the service panel.

- DO NOT INSTALL IN/NEAR A COOKING AREA.
  NE PAS INSTALLER PRES D' UN APPAREIL DE CUISSON
- See figure 80.1 below for device placement restrictions for cooking area.



HAZARDS

- Do not install a visibly damaged product.
- This device has been properly packed so that no parts should have been damaged during transit. Inspect to confirm. Any part damaged or broken during or after assembly should be replaced.
- Do not try to open the device access panel or any part of the device during operation.
- Do not immerse the Air Guardian® device in liquids of any kind as it may cause hazardous results, including injury and warranty violation (see Terms and Conditions in the CalyxPure Agreement).

INSTALLATION AND SERVICE

- Before installing, servicing, or performing routine maintenance upon this equipment, follow all precautions listed here and those consistent with any interaction with a powered electrical device.
- Installation and service of the Air Guardian® device should be performed by a qualified and licensed electrician or licensed and trained lighting technician.

MAINTENANCE

- Maintenance of the Air Guardian® should be performed by person(s) familiar with the fixture's design which allows for access and maintenance. Such person shall also be familiar with the operation of the fixture and any associated operating, operating, or electrical hazards involved.
- The device is intended to be operated continuously, for maximum air purification and infection prevention.

CLEANING

- Inspect the device regularly for any noticeable dirt or particles that may be found inside the device chambers.

- Inspection should occur every month for 90 days. Based upon any particles or dirt found during these regular initial inspection periods, inspection and cleaning, if needed, should be performed a minimum of every 6 months.
- It may occasionally be necessary to clean the outside of the intake and exhaust vents. Frequency of cleaning will depend on the level of dirt or particles in the ambient air.
- Should vent assembly become visibly dirty on the outside surface, wipe surface with non-caustic cleaning agents as necessary. If vent appears obstructed or clogged in any way, remove vent per installation guide process and clean obstructions as needed.
- Micron and Charcoal filters should be replaced as shown in the installation guide, as needed, and replacement requirements will vary by use case. It is recommended that replacement should be no less than every 90 days. Replacement filters are available from illumiPure® representatives or licensed distribution or sales agents. Replacement costs are nominal.
- TiO2 honeycomb filters should be periodically inspected, based on use case, and are designed for easy access by qualified technicians per the installation guidelines herein.
- TiO2 honeycomb filters are designed for an extended lifespan but, as needed, may be cleaned, and re-used after rinsing using a mild, highly diluted solution of distilled water and bleach, in solution no greater than .25 ml per gallon of distilled water.
- Follow installation instructions and hazard warnings during filter removal and replacement.
- Inspecting, cleaning, and maintenance services are available from your local seller or distribution vendor. Or can be arranged through illumiPure.

REGARDING UV RADIATION AIR-CLEANING APPLIANCES

- This appliance contains a UVC emitter.
- Unintended use of the appliance or damage to the housing may result in the escape of dangerous UVC radiation.
- UVC radiation may, even in little doses, cause harm to the eyes and skin.
- Replacement of the UVC emitter must only be performed by a licensed professional who has been certified by CalyxPure for UV emitter/board replacement.
- Please see product specific installation instructions for additional warnings or any applicable FCC or other regulatory statements.

FAILURE TO FOLLOW ANY OF THESE INSTRUCTIONS COULD VOID PRODUCT WARRANTIES.

Product: Air Guardian: Enclosed UVC disinfection Air Chamber 2 feet x 2 feet
Weight: 10.85 pounds
Produced by:
IllumiPure, Incorporated
14340Torrey Chase
Houston, Texas 77014
EPA Product Establishment Number: # 9810S-TX-1
This product is a device that does not contain any pesticidal ingredients and does not require an EPA registration number
Hazard and Precautionary Statement: this device uses electrical current for its operation and should only be installed by qualified personnel. The Immaculight™ device should remain sealed at all times and should never be opened, except by qualified personnel during maintenance or servicing procedures. All electrical power should be disconnected or disabled during and maintenance or service operation. Failure to follow these instructions can be hazardous and may invalidate the product warranty.
Directions for use: This device should be installed and operated in compliance with the written instructions included in the Operating Manual provided in the product packaging. The Operating Manual is also available at www.Immaculight.com.
Use Classification: Medical Device Class 1 Listing #0420497
FDA Facility #10077990

Installation Images

Examples of Installs Images

BARBERS HILL
Independent School District
P.O. Box 1108 · 9600 Eagle Drive · Mont Belvieu, TX 77580
281.576.2221 · bhisd.net

RE: Air Guardian & CleanWhite Anti-Viral & Anti-Microbial Disinfection Lighting

Who would have thought 2020 would leave such a scar on our country as it has. K-12 schools have had to re-think safety standards to protect both staff and students on top of newly emerging education and challenges. My name is Ricky Shelton and I am the Energy Manager for Barbers Hills Independent School District in Houston Texas. I serve as the Vice President of TEMA "Texas Energy Managers Association", an organization created from the State Energy Conservation Office "CECO" in Austin Texas, which is designed to guide schools and public entities to not only reduce energy consumption, but also build safe learning environments.

Barbers Hill ISD was introduced to the new Immaculight UV Air Guardian product a month after the Covid pandemic shut the city of Houston down. I am writing this letter on behalf of a new product line from Illumipure / Calyx for their Air Guardian UV Fixture and their CleanWhite LED Light fixture where the company is located in Houston, Texas. We have been using the CleanWhite Light technology for several months before Covid and have been delighted with the Microbial Disinfection evident from its use. There is no chemical spraying or waste of custodial man-hours to do a less than stellar job. We started the installation process in the athletic departments, nurse's stations, and administration offices as an introduction which proved to be very successful. Because of the success, we have two new Intermediate Schools that will be opening 2021-2022 with the intentions of installing units in each classroom.

I thought bad people with guns was a the most substantial issue we would face, but Covid has changed our educational processes in ways we never could have imagined. School started back in mid-August of 2020 for in school learning, but before students arrived, we put new policies in place. We installed on each desk a three-sided shield, students and staff wear masks as normal daily routine. We installed hand sanitizer stations, and there is nightly cleaning and disinfecting. The district's original attendance numbers started at 87% in the classroom and 13% online, six weeks later we were at 93% in the classroom. Our staff feels Immaculight products play an important role in keeping people safe, knowing it is cleaning while class is in session.

After reviewing several different UV product lines, numerous scrubbers and filters, we are extremely proud with our choice to move forward with the IllumiPure products. Just knowing the district is doing all it can to keep people safe is comforting to the parents, students, and our community within our district. I feel it's my responsibility to our community and state as a whole to inform other districts deciding on purchasing products which affect people's lives. Please feel free to reach out to me for any questions you may have before making decisions on how to protect your schools and spend your local taxpayer dollars.

Ricky Shelton

Energy Manager
Barbers Hill ISD
832-784-2496

Just Breathe

Take a breath. It fills you, sustains you, nourishes your mind and body. So simple, yet so vital to life.

The world has never needed a deep, cleansing breath of fresh air more than we do in this moment. It is our mission at illumiPure to deliver just that—the cleanest, healthiest indoor air possible. After all, the air we breathe may be the single most precious resource we have on this planet. At illumiPure we see it as our calling to use our technology to protect it, purify it, and make it accessible. To improve the health and lives of people everywhere.