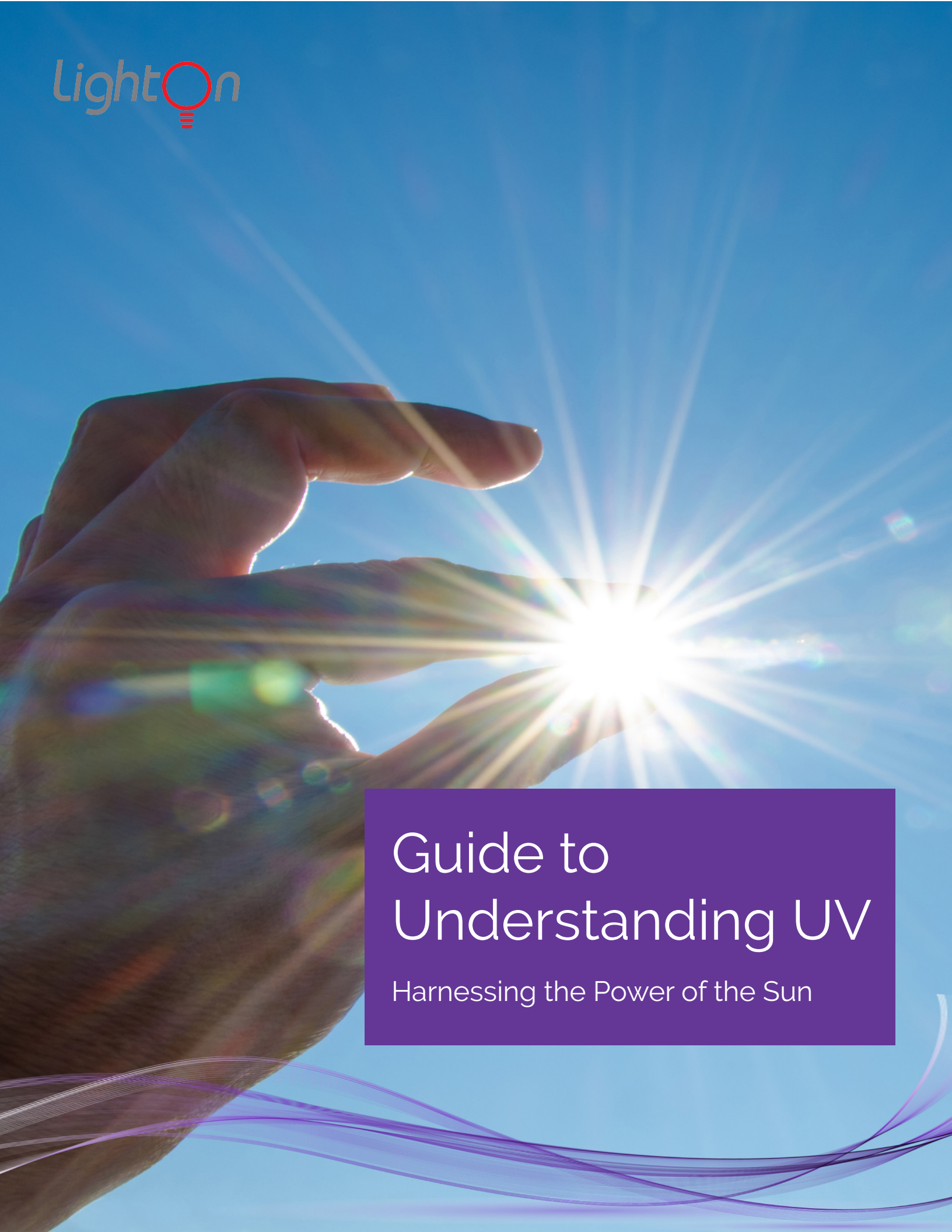


Guide to Understanding UV

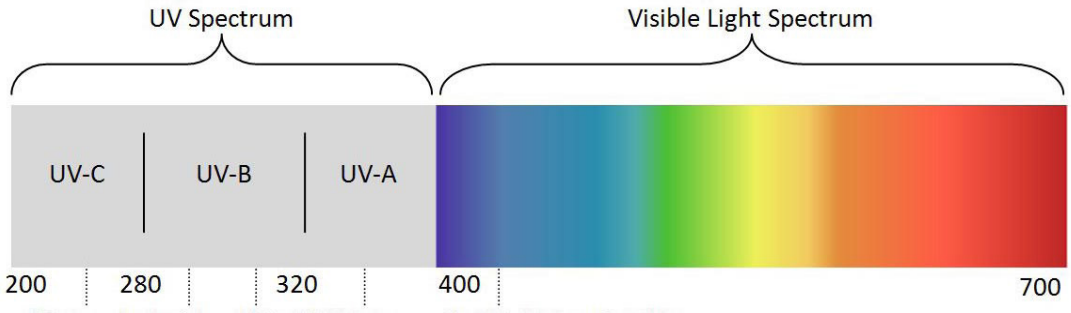
Harnessing the Power of the Sun

Introduction

Ultraviolet light is naturally present in sunlight and actually makes up about 10% of the total light generated by the sun. UV is a form of electromagnetic energy with a wavelength from 10 nm to 400 nm, though for germicidal purposes we focus on the wavelengths of UV-A, UV-B, and UV-C light.

The atmospheric ozone absorbs energy of wavelengths less than 290 nm, such that most of UV-C and UV-B is blocked by the planet's ozone.

Weather, geographic region, altitude, and time of year can all impact the amount of UV in a certain location. In areas where there is less atmospheric ozone, such as higher altitudes or during summer months, more UV-B and UV-C are able to make it through.



Key Terminology

wavelength: the distance between successive crests of a wave, especially points in an electromagnetic wave.[1] Visible light corresponds to a wavelength range of 400-700 nanometers (nm).

spectrum: a band of colors, as seen in a rainbow, produced by separation of the components of light by their different degrees of refraction according to wavelength.[1] The ultraviolet spectrum of light consists of wavelengths from 100-400 nm.

disinfection: the process by which most or nearly all microorganisms are killed through use of chemicals, heat, or ultraviolet rays[2]

dose: the measure of how much UV energy is delivered to microbes is the product of intensity of the light times the length of exposure. Different types of organisms require a different dose of UV to be inactivated or killed.

inactivate: to stop the activity of certain biological substances. As viruses are molecules, it is customary to refer to them as being inactivated rather than killed.

intensity: the measurable amount of UV energy produced, measured in milliwatts per square centimeter.

electromagnetic spectrum: the entire spectrum, considered as a continuum, including microwaves, infrared light, ultraviolet light, X-rays, gamma rays, and visible light

pathogen: any microbe that can cause infections in humans and animals, including viruses, bacteria, and fungi

UV-A: light in the UV spectrum from 320-400 nm. Black lights emit UV-A light.

UV-B: light in the UV spectrum from 280-320 nm and is most commonly associated with sunburn or freckling, but also produces germicidal effects

UV-C: light in the UV spectrum from 200-280 nm known for its germicidal effects

Violet-blue light: light with wavelengths of 400-470 nm with antibacterial effects

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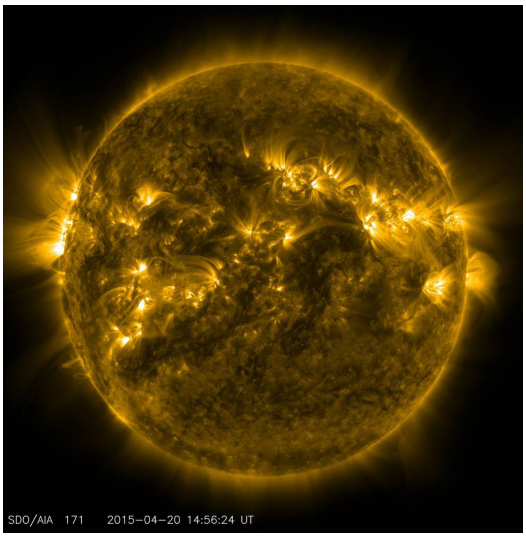
A Brief History of UV



It's been 140 years since Downes & Blunt discovered the antibacterial effects of sunlight. They determined that shorter wavelengths of the solar spectrum were more effective at neutralizing bacteria. Just 15 years later, Professor Marshall Ward determined that it was violet-blue and UV portions of the spectrum that are able to destroy microorganisms.

With further validation of the ability of the UV spectrum to kill germs, a variety of applications of this technology began to emerge - ranging from the first UV quartz lamp by Lorch in 1904 to the first overhead UV system for hospitals in 1936. In 1942, the military adopted UV for inclusion in barracks for the protection of soldiers in the Army and Navy.

Studies such as one conducted by Riley in 1957 showed effectiveness in using control for tuberculosis. In spite of the positive adoption rates and studies proving its effectiveness, UV wasn't as widely adopted as would be expected, largely in part due to the rise of the use of antibiotics. Now given the growing concern of antibiotic-resistant strains of "superbugs," UV has tremendous momentum as microbes cannot acquire resistance to the germ-killing power of UV.

In 2000, the Army recommended Ultraviolet Germicidal Irradiation (UVGI) for the isolation of disease and just three years later, the CDC endorsed the use of UVGI in hospitals and FEMA approved the use of bio-defense systems based on UVGI for buildings. The field of using UV light for germ elimination continues to grow as new ways to deploy this powerful light are discovered.

How UV Works

To understand how UV kills bacteria and viruses, a basic understanding of their structure is needed. DNA & RNA is the genetic material that makes up all living organisms, controlling their growth, development, functioning and reproduction. DNA chains are made up of nucleotides which are comprised of deoxyribose (sugar), phosphate, and nucleotide bases. These bases come in four chemical forms: adenine, cytosine, guanine, and thymine.

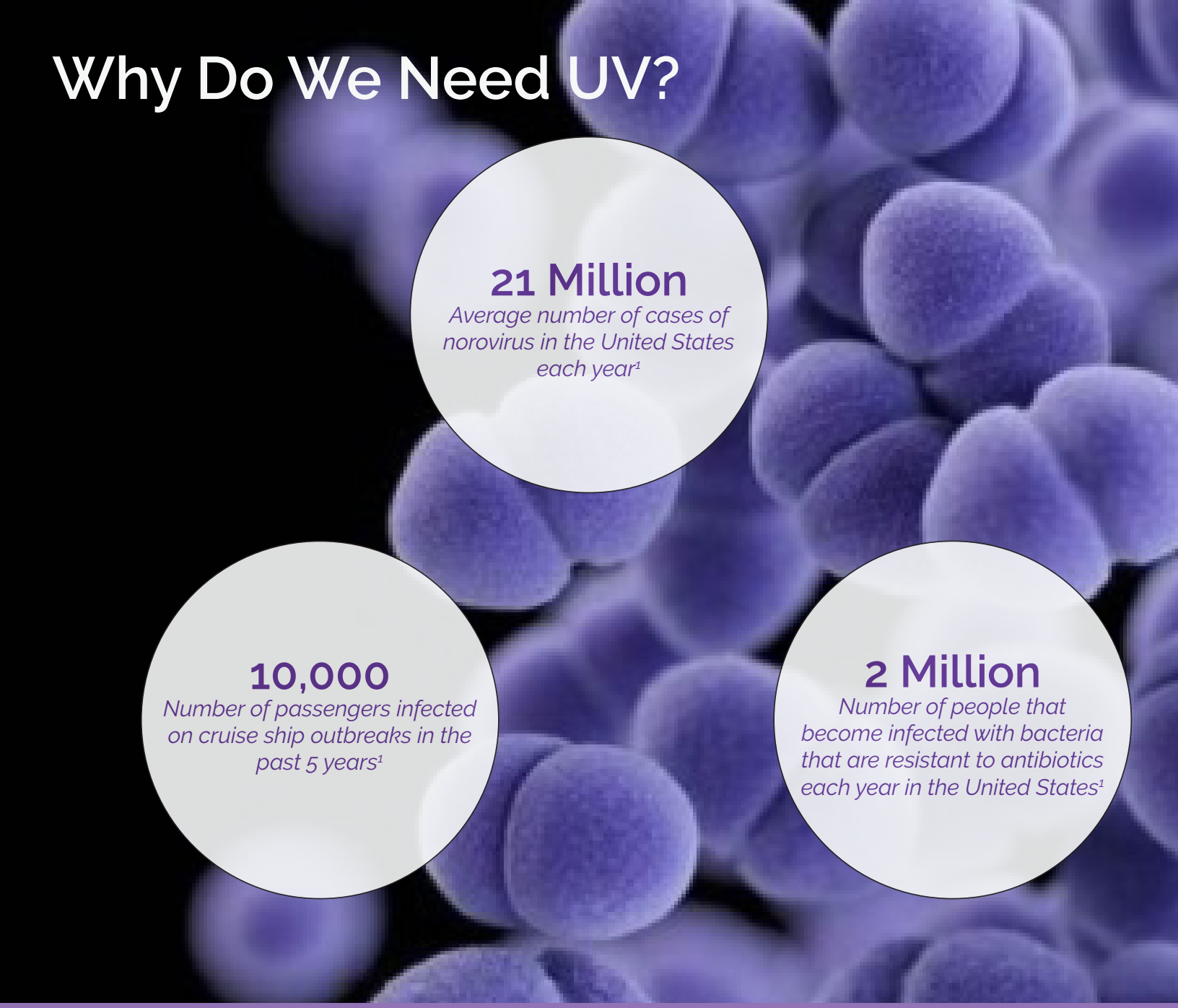
DNA and RNA are the blueprint for cellular development. The DNA code gets transcribed to RNA (ribonucleic acid) that carries information or instructions and controls the synthesis of proteins. In some viruses, RNA has the genetic information.

DNA is the most sensitive target of an organism. Radiation at 200 nm is absorbed by molecules of ribose and phosphate while nucleotide bases peak absorption is at the 265 nm wavelength. The UV light actually modifies the genetic material of microorganisms. The electromagnetic energy destroys the ability of microorganisms to reproduce and by causing photo-chemical reactions in nucleic acids. The UV energy triggers the formation of specific thymine or cytosine dimers in DNA and uracil dimers in RNA, which causes the inactivation of microbes by causing mutations and/or cell death as well as failure to reproduce.[1]

UV-B and UV-A light causes oxidation of proteins and lipids causing cell death. Broad spectrum UV lamps have also been shown to inhibit photoreactivation, the process that can result in self-repair of damaged microbes. Furthermore, UV-A light when distributed using pulsed UV systems can cause additional cell wall rupturing from sudden heating. Therefore, pulsed UV systems combine not only the germicidal effects from delivering a lethal UV dose, but also thermal disintegration from the speed and intensity of photonic delivery. [2]

1 - Kesavan, Jana and Jose-Luis Sagripanti. Disinfection of Airborne Organisms by Ultraviolet-C Radiation and Sunlight. Rep. Edgewood Chemical Biological Center, July 2012.
2 - Kowalski, Wladyslaw. Ultraviolet Germicidal Irradiation Handbook: UVGI for Air and Surface Disinfection. Springer. 2009

Why Do We Need UV?



21 Million
Average number of cases of norovirus in the United States each year[1]

10,000
Number of passengers infected on cruise ship outbreaks in the past 5 years[1]

2 Million
Number of people that become infected with bacteria that are resistant to antibiotics each year in the United States[1]

Each year, millions of people acquire illnesses from bacteria and viruses in common places - ranging from restaurants to hospitals to just about any space.

While strategies such as hand-washing are a critical part of our defense against getting sick, they are not enough to keep the millions of germs at bay. Many germs, including norovirus can survive on surfaces for weeks. For many years, antibacterial products were prevalent based on people looking for an additional layer of protction.

However, the FDA eventually ruled that products with certain ingredients, such as triclosan, could no longer be marketed as manufacturers had not proven their products to be safe or that they were actually any better than plain soap and water. Some tests have even suggested that chemicals such as these were actually contributing to the antibiotic resistance problem.

Other chemicals that may help clean surfaces are often not used as directed, which can require extended time durations, thus limiting their effectiveness.

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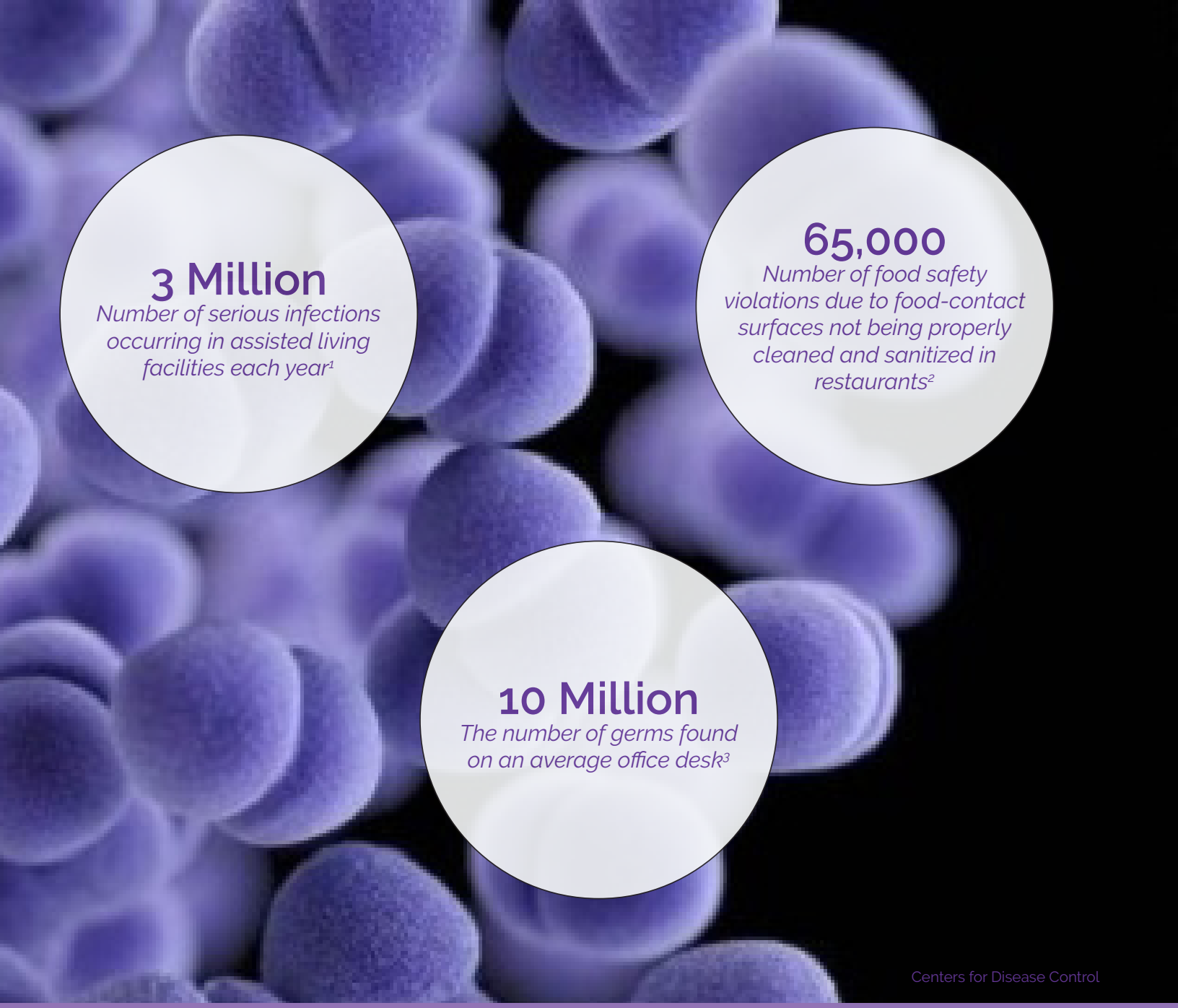

The CDC has labeled 18 bacteria as drug-resistant threats that require additional prevention and control mechanisms due to their resistance to treatment with antibiotics. Recently, a specific strain of Klebsiella pneumoniae was found to be resistant to all 26 antibiotics used in the United States.

Over time, bacteria have changed their structure to resist the antibiotic effects, produce enzymes called beta-lactamases that actually destroy penicillin, or acquire drug-resistance from other bacteria.

However, UV can kill all bacteria, including drug-resistant bacteria because UV light is actually attacking the DNA and RNA of microbes. While the amount of UV needed to kill a microbe may vary as there is a relationship between the size of DNA molecules and the effect of UV radiation, there have been no reports of microbes demonstrating an ability to build an immunity to light-based methods.

1 - Centers for Disease Control & Prevention
2 - Florida Department of Business & Professional Regulation, 2015-2016s)
3 "Germs and the Office Equal a Costly, Sickly Mix." B4 Brands. Food Industry, Hand Hygiene, Healthcare, Hotels - Casinos, Office Buildings, Private label, Schools-Education.

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Finding the Right Disinfection Solution

In terms of controlling the spread of germs, there are several options available, but there are pros and cons to each of them. When health and wellness are on the line, it's essential to find a solution that is easy to use to ensure proper usage every time.

Not only does the solution need to have proven results, but does it effectively kill the pathogens you are most concerned about and want to target? Look closely at the results to assess the length of time needed to disinfect pathogens of greatest concern, including the distance tested for UV solutions.

When determining if a solution will be cost-effective, be sure to consider not only the initial costs, but ongoing expenses, including labor costs, ongoing supply purchases, and/or maintenance costs.

ALTERNATIVES TO UV

Hand Washing

Hand washing is among the most common strategies recommended to help fight the spread of germs because so many are spread from touching surfaces or objects and then putting hands in your mouth.

However, many diseases are spread due to people improperly washing their hands. It is recommended that people wash their hands with soap for at least 30 seconds - the bubbles and friction are needed to help remove the pathogens from your hands effectively.

Chemicals

Chemicals are one of the most common methods for disinfecting spaces. However, many of the most effective chemicals such as bleach are harmful to humans and the environment. The more eco-friendly and safer chemicals may not be effective against viruses or certain bacteria.

For full effectiveness, chemicals also require surfaces to remain wet for 30 seconds to 10 minutes before being wiped down. Research has shown that nearly 70% of hospital surfaces aren't sufficiently disinfected.

Aerosol Misting Systems

Hydrogen peroxide aerosol/missting systems are another alternative, particularly for hospitals when you need a high kill rate. Due to the distribution method, when a room is properly sealed, this method can potentially ensure all surfaces in a room are reached.

However, these systems require extensive room preparation, including sealing all HVAC grilles, doorways, etc. The cycle time can be lengthy requring up to 120 minutes to operate. These units also produce water as a by-product, which may harm metals (i.e. rust) as well as sensitive electronics.

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The Difference

Violet Defense's technology provides safe, effective, germ-killing for everyday spaces.

INTELLIGENT CONTROL MAKES IT EASY TO USE

Violet Defense systems feature an intelligent control system that can automatically adapt cleaning cycles to help maintain a level of cleanliness over time. Units can be programmed to deploy in various methods to integrate seamlessly into daily operations of a business. Products include both installed and mobile solutions.

The units are programmed to automatically activate when a room is unoccupied. Redundant safety systems are in place to ensure the units de-activate when someone enters the room. The cleaning cycle will automatically resume again when it's safe to do so.

POWERFUL UV YIELDS RESULTS

Violet Defense's technology utilizes powerful, broad spectrum, pulsed Xenon light, including violet-blue, UV-A, UV-B, and UV-C to effectively kill bacteria, fungi, mold, and viruses.

Independent testing has proven that the pulsed Xenon products can kill up to 99.9% of bacteria and viruses, including *E. coli*, *Salmonella*, MRSA, and Norovirus at distances of up to 3 meters.

COST-EFFECTIVE SOLUTION

UV disinfection units powered by Violet Defense's technology are designed to easily retrofit into existing spaces. Once installed, the units require no ongoing maintenance or labor costs.

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