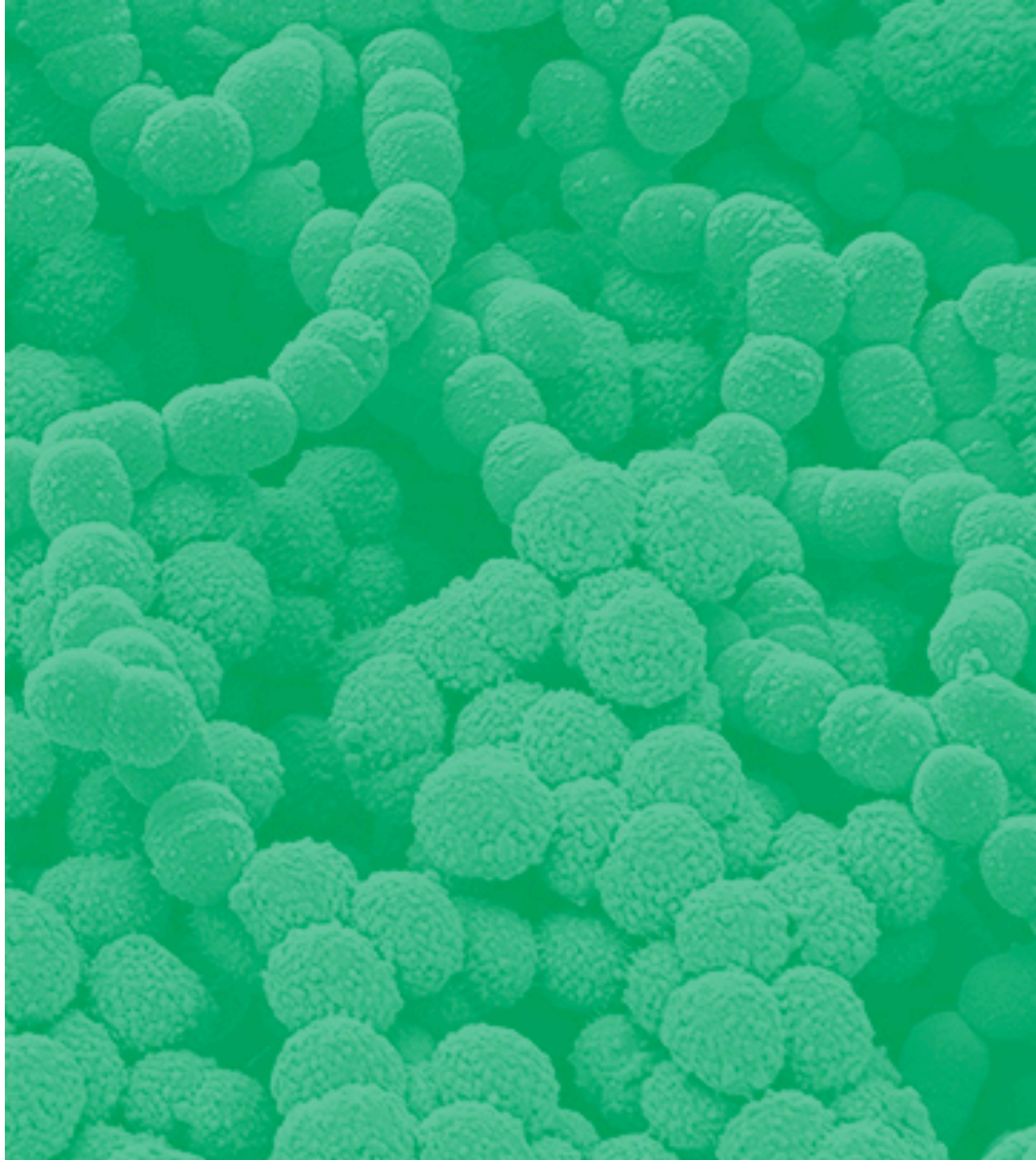
UV-C disinfection for air, surfaces and water

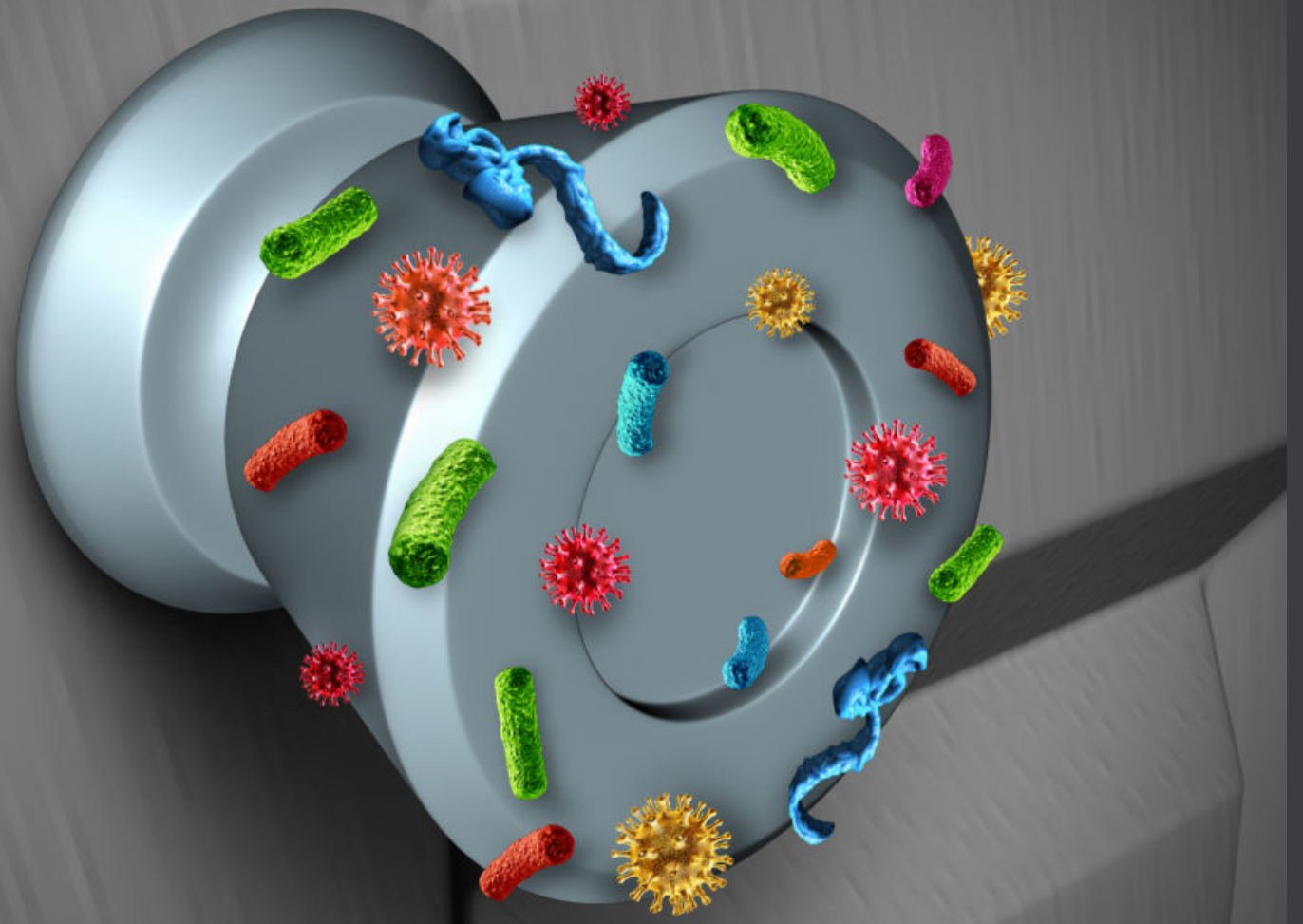
UV-C market, applications and offering

June 2020

Content



Bacteria and viruses are present in the air, on food, plants and animals, in soil and water — and on just about every other surface…

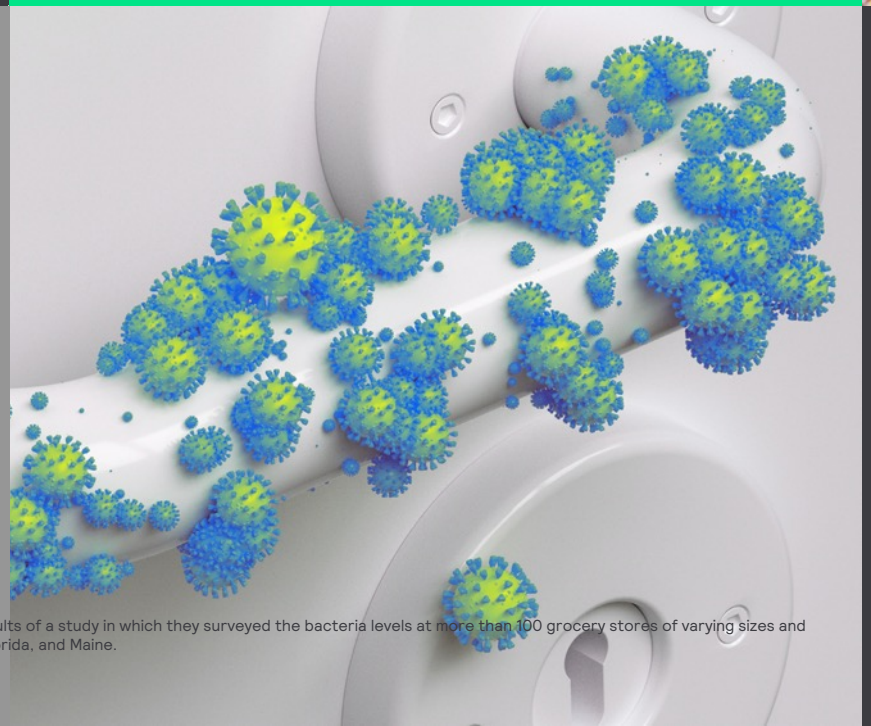



Most bacteria and viruses won’t harm us. However, some germs are difficult enemies because they're mutating to breach our immune system’s defenses.

Some everyday encounters with germs

Traditional grocery store shopping carts have 361 times more bacteria than a bathroom doorknob.

Supermarket fridge doors have 1,235 times more bacteria than the surface of your cell phone.



50% of self-checkout touchscreens sampled had fecal bacteria on them.

Source : Reusethisbag.com, an online retailer for reusable shopping bags, released the results of a study in which they surveyed the bacteria levels at more than 100 grocery stores of varying sizes and price levels in 10 states across America. The survey covered New York, California, Texas, Florida, and Maine.

Coronavirus will fundamentally change the way we live, work, shop, eat, and are entertained

- Only 5-10% of population has had exposure to SARS-CoV-2.
- A vaccine is still likely 12-18 months out.
- Prior exposure is not proven to confer future immunity.
- Herd immunity may not be reached for years
- CDC warns that coronavirus may become a seasonal epidemic.
- Biosecurity will become standard in nearly all public places.

Wash your hands.
Use a tissue for coughs.
Avoid touching your face.

That's why
disinfecting air, surfaces and water
is important for our health & well-being

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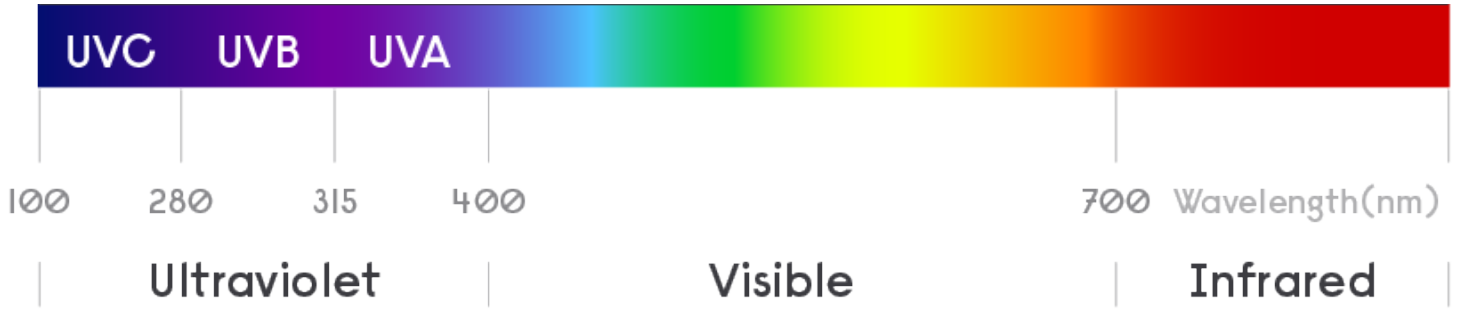
UV-C light has the power to disinfect

What is UV-C and how does it work?

What is UV radiation?

Ultraviolet (UV) light is invisible to human eyes. It can be subdivided into three categories:

UV-C from 200 to 280 nm	UV-B from 280 to 315 nm	UV-A from 315 to 400 nm
For disinfection purposes and germicidal application	For medical use (i.e. phototherapy to treat skin conditions, including psoriasis)	For use with curing, suntanning and insect traps



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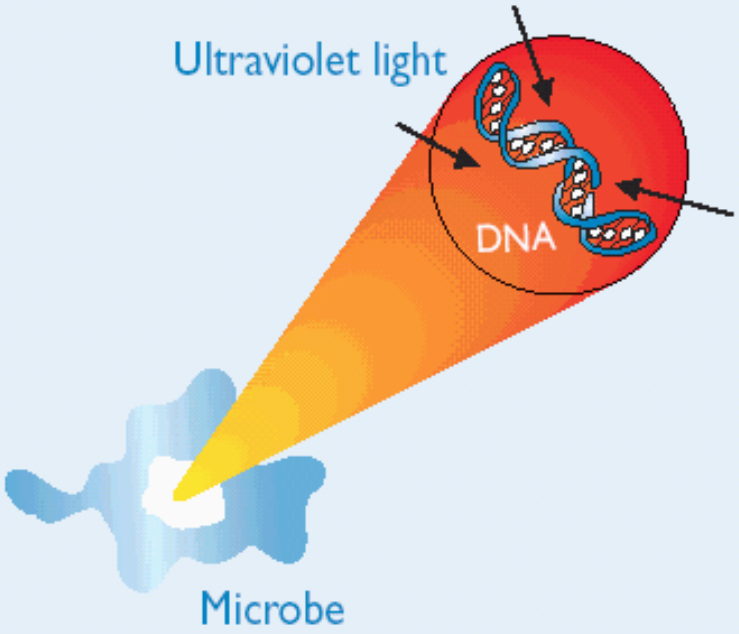
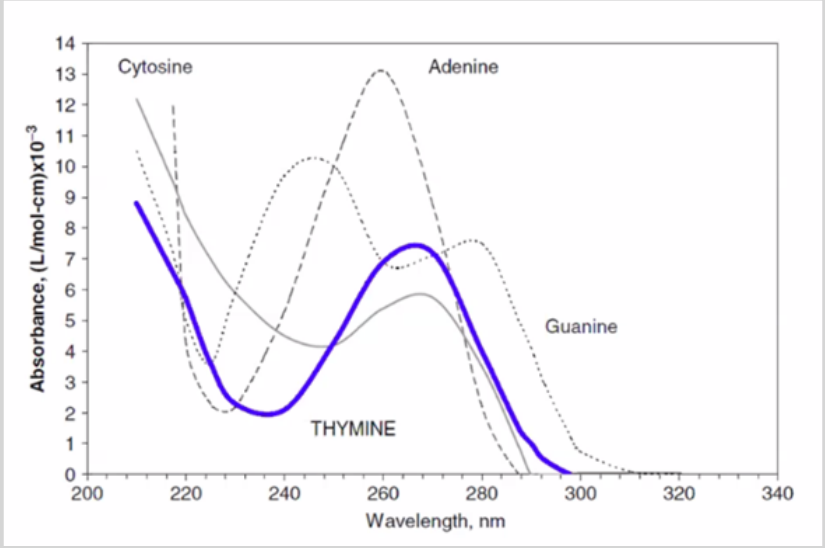
How does it work?

- UV-C radiation can break the DNA and RNA of bacteria, viruses and spores, meaning that they leave them harmless. There are no known micro-organisms resistant to UVC.[1]
- UV-C technology has been used safely and effectively in hospitals and governmental buildings for more than 40 years[2]
- Most UV-C solutions utilize conventional lighting, with LED now improving in efficiency
- The peak output of our germicidal lamps (253.7nm) is close (80-85%) to the maximum effectiveness of UV-C (265nm)
- Smaller UV-C wavelengths (222nm) are being explored as alternative. Also 405nm wavelength solutions are being investigated for inactivating bacteria (not viruses)



Effectiveness of UV-C on DNA building blocks

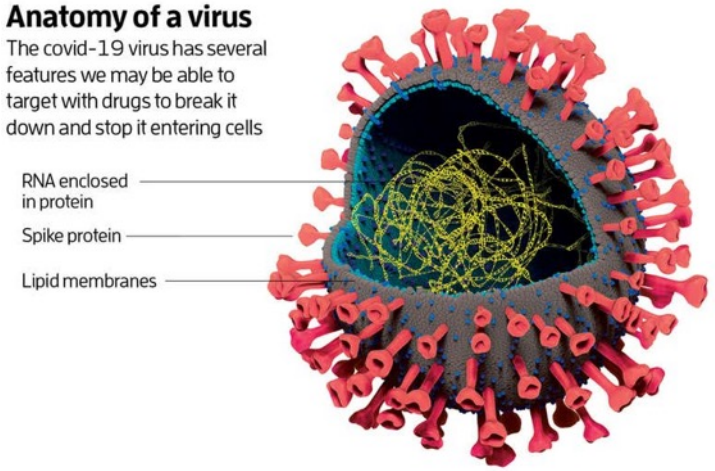


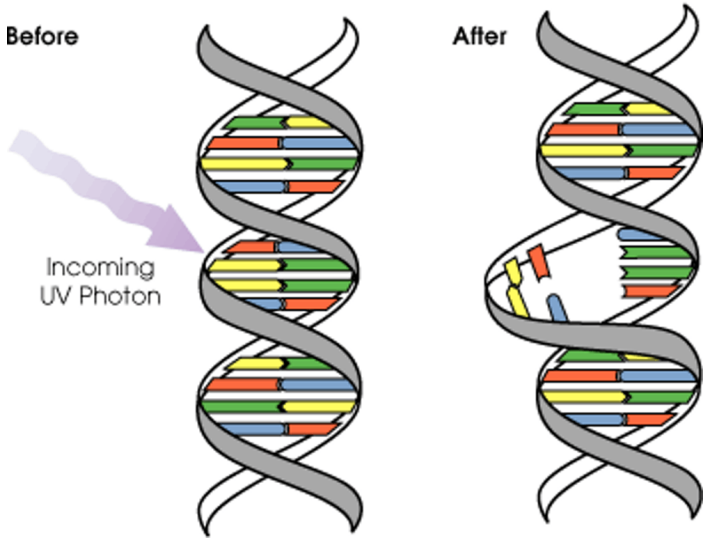
[1] Fluence (UV Dose) Required to Achieve Incremental Log Inactivation of Bacteria, Protozoa, Viruses and Algae Revised, updated and expanded by Adel Haji Malayeri, Madjid Mohseni, Bill Cairns and James R. Bolton. With earlier contributions by Gabriel Chevrefils (2006) and Eric Caron (2006) With peer review by Benoit Barbeau, Harold Wright (1999) and Karl G. Linden

[2] EPA Report, "Building Retrofits for Increased Protection Against Airborne Chemical and Biological Releases" Pg. 56

Facts on UV-C and COVID-19

- UV-C has been used extensively for more than 40 years in disinfecting drinking water, wastewater, air, pharmaceutical products, and surfaces against a whole suite of human pathogens
- All bacteria and viruses tested to date respond to UV disinfection at the appropriate doses.
- UV-C has proven to inactivate at least two other coronaviruses that are near-relatives of the COVID-19 virus: SARS-CoV-1 and MERS-CoV
- COVID-19 infections can be caused by contact with contaminated surfaces and then touching facial areas; additionally it can also be transmitted through air
- COVID-19 can live on plastic and steel surfaces for up to 3 days
- There are published studies that prove the effectiveness of UV-C on Sars-CoV-2 (the virus causing COVID-19), however these have not been peer-reviewed





Source: IUVA – International UV Association http://www.iuva.org/COVID-19

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Applications

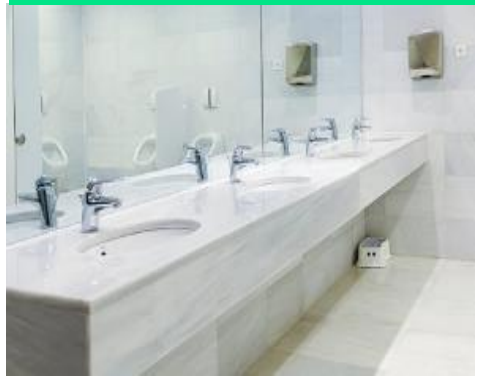
Applications

Looking at just surface and air, there are numerous real-world segments where UV-C lighting is a viable disinfection solution

Retail

Work surfaces

Restrooms



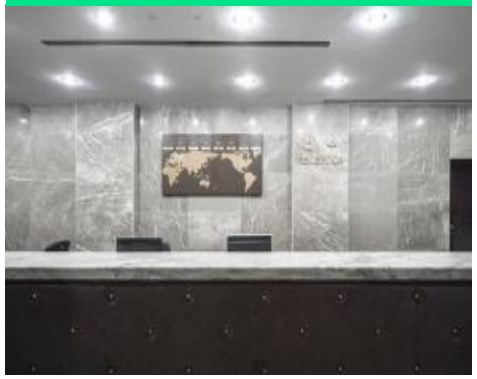
Food

Transportation

Labs

Offices

Hospitality



Entertainment

Custom chambers

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Applications

Air – Upper air, cooling coil cleaning and HVAC

Upper air disinfection

Example luminaires

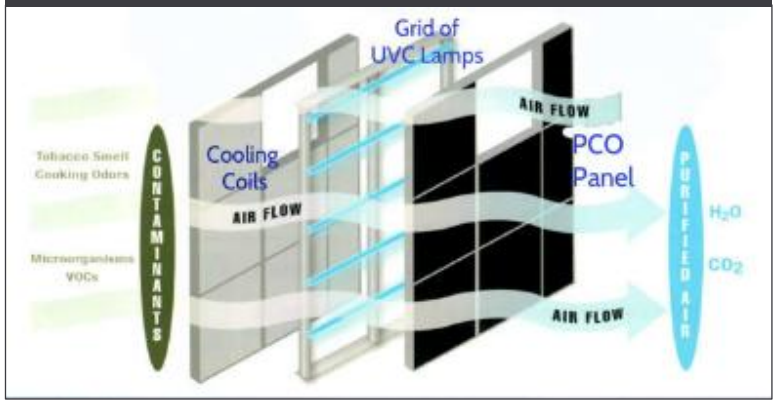
These systems are usually installed at a height of 2.5m and work with natural convection of air. As air passes above, it gets disinfected.

Cooling coil cleaning system

Example system

In air conditioning systems, high output (HO) UV-C lamps will keep the cooling coil free from biofilm.

HVAC cooling coil cleaning



Example system

UV-C lamps can also be applied in the ducts of the air conditioning system. Due to high air speed, the required UV-C dose will usually be high.

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Applications
Surface – Moveable carts / robots, open luminaires, cabinets

Moveable cart / robot

Example luminaire

Robots equipped with multiple high power UV-lamps to disinfect rooms within minutes.

No people should be present in the room when the system is in use.

Open luminaire

Example luminaire

UV-C luminaires for disinfection| of both surfaces and air.

No people should be present in the room when the system is in use.

Cabinets

Example cabinets

Primary uses are for disinfection and sterilization of objects

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Safe usage of UV-C

PHILIPS

While the UV-C lamps on the market look like traditional products, functionally they are much more unsafe

Residential - air and water disinfection

YourSource UV module 5W-13W

TUV PL-S and driver 5W-13W

TUV PL-L and driver 18W-95W

TUV TL Mini and driver 4W-25W

NaturalTrust UV-C LED module

Municipal and industrial - water disinfection

TUV Amalgam XPT system 130W-800W

TUV T5 and driver 40W-140W

DynaPower system 230W, 260W, 335W

Professional - air disinfection

TUV T8 and driver 10W-75W

TUV PL-L and driver 18W-95W

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UV-C is harmful to eyes

UV-C is harmful to skin

Safety concerns

Motion/presence detection and auto switch off sensors

Operate only with proper protection equipment and shielding

It is visible whether UV-C lighting is on/off thanks to blue hue during operation

UV-C has limited penetration (walls, glass <3mm)

Safeguards

The best safeguards are proper application design in combination with dedicated installer and user training

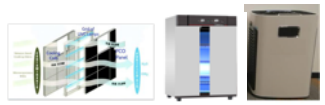
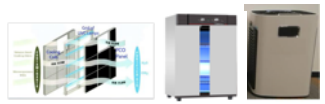
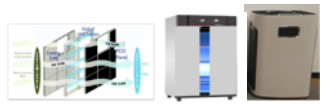
Using UV-C in a safe way

- Like any disinfection system, UV-C lamps and devices must be used properly to be safe.
- UV-C light can cause a severe sunburn-like reaction to your skin and similarly, could damage the superficial tissue of eye (photo keratitis), if exposed … this is very painful. It is, therefore, key that lamps are always shielded from direct radiation.
- All products need to follow the standard product safety releases and approbations.
- All products require at least –

    1. An Instructional Safeguard and…
    2. A Time Safeguard, or an Equipment Safeguard, or a Containment Safeguard

- We strongly suggest our OEM customers communicate clearly the warnings on their website and applications, as we do on our leaflets. Disclaimers may apply.

Which safeguards are needed

	UV-C safeguard	Upper air disinfection	Open luminaires	Carts & robots	Cabinets, closed air/ HVAC disinfection units
	Instructional safeguard				
And	Time safeguard	Recommended only for Risk Group 1 and 2 (low exposures) Signify products do not fall in these groups. Timers may be secondary safeguards in all applications			
Or	Closed enclosure	–	–	–	
Or	Partially closed enclosure		 In combination with a reflector	–	–
Or	Presence detection: Detects static as well as dynamic presence	–			–
Or	Controlled access locations + training				

Instructional Safeguard is always required. Combination safeguards is allowed and will improve the safety, but at least one is strictly required
Further details can be found in GLA UV-C safety guide.

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UV-C dose calculations

Micro-organisms effective resistance to UV-C radiation varies considerably. Moreover, the environment of the particular micro-organism greatly influences the radiation dose needed for its destruction.

Calculate irradiance from UV-Lamp specs

Philips TUV T8

UV-C Power

Type	Cap-Base	Dim. No	Technical Lamp Wattage (W)	Lamp Voltage (V)	UVC at 100h on EM gear (W)	Lamp Current (A)	Useful life on EM gear (h)	Depreciation at useful lifetime (%)	Packaging type	Packaging configu-ration	Ordering number 12 NC
10W T5*	G5 to G13	1	9.0	48.5	–	0.220	9000	15	1FM	25	927801304011
15W	G13	2	15.5	55.0	4.9	0.335	9000	10	SLV	25	928039004005
T8 F17	G13	3	16.7	72.0	4.5	0.265	9000	15	SLV	25	927941904020
25W	G13	2	25.0	48.0	7	0.600	9000	15	SLV	25	928039404005
30W	G13	4	30.0	102.0	12	0.370	9000	10	SLV	25	92809504005
36W	G13	5	36.0	103.0	15	0.440	9000	10	SLV	6	928048604003
55W HO	G13	4	54.0	86.0	18.5	0.770	9000	10	SLV	6	928049504003
75W HO	G13	5	75.0	110.0	25.5	0.840	9000	10	SLV	6	928049404003

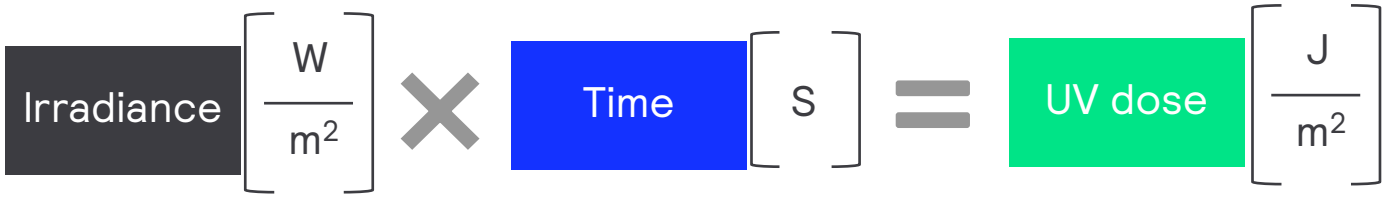
*With T5 to T8 adapters

Efficiency (%) can be calculated as:

$$\frac{UVC\ at\ 100h\ on\ EM\ gear\ (W)}{Power\ of\ lamp\ (W)} = \frac{18.5}{54} = \sim 34\%$$

Define dose and time required to eliminate the targeted pathogens

Dose is based on intensity and time:



- Micro-organisms need a different dose to be neutralized by UV-C. (see table)
- Micro-organisms on surfaces that are not directly exposed to UV-C radiation (hidden or 'in shadow) will not be disinfected.

UV dose to obtain 90% killing rate		
Bacteria	**Dose**	**k**
Bacillus anthracis	45.2	0.051
B. megatherium sp. (spores)	27.3	0.084
B. megatherium sp. (veg.)	13.0	0.178
B. parathyphosus	32.0	0.072
B. suptilis	71.0	0.032
B. suptilis spores	120.0	0.019
Campylobacter jejuni	11.0	0.209
Clostridium tetani	120.0	0.019
Corynebacterium diphteriae	33.7	0.069
Dysentery bacilli	22.0	0.105
Eberthella typhosa	21.4	0.108
Escherichia coli	30.0	0.077
Klebsiella terrifani	26.0	0.089
Legionella pneumophila	9.0	0.256
Micrococcus candidus	60.5	0.038
Micrococcus sphaeroides	100.0	0.023
Mycobacterium tuberculosis	60.0	0.038
Neisseria catarrhalis	44.0	0.053
Phytomonas tumefaciens	44.0	0.053
Pseudomonas aeruginosa	55.0	0.042
Pseudomonas fluorescens	35.0	0.065
Proteus vulgaris	26.4	0.086
Salmonella enteritidis	40.0	0.058
Salmonella paratyphi	32.0	0.072
Salmonella typhimurium	80.0	0.029
Sarcina lutea	197.0	0.012
Seratia marcescens	24.2	0.095
Shigella paradysenteriae	16.3	0.141
Shigella sonnei	30.0	0.077
Spirillum rubrum	44.0	0.053
Staphylococcus albus	18.4	0.126
Staphylococcus aureus	26.0	0.086
Streptococcus faecalis	44.0	0.052
Streptococcus hemoluticus	21.6	0.106
Streptococcus lactus	61.5	0.037
Streptococcus viridans	20.0	0.115
Sentertidis	40.0	0.057
Vibrio chlolerae (V.comma)	35.0	0.066
Yersinia enterocolitica	11.0	0.209

UV dose to obtain 90% killing rate		
Yeasts	**Dose**	**k**
Bakers' yeast	39	0.060
Brewers' yeast	33	0.070
Common yeast cake	60	0.038
Saccharomyces cerevisiae	60	0.038
Saccharomyces ellipsoideus	60	0.038
Saccharomyces sp.	80	0.029
Mould spores		
Aspergillus flavus	600	0.003
Aspergillus glaucus	440	0.004
Aspergillus niger	1320	0.0014
Mucor racemosus A	170	0.013
Mucor racemosus B	170	0.013
Oospora lactis	50	0.046
Penicillium digitatum	440	0.004
Penicillium expansum	130	0.018
Penicillium roqueforti	130	0.018
Rhizopus nigricans	1110	0.002
Virus		
Hepatitis A	73	0.032
Influenza virus	36	0.064
MS-2 Coliphase	186	0.012
Polio virus	58	0.040
Rotavirus	81	0.028
Protozoa		
Cryptosporidium parvum	25	0.092
Giardia lamblia	11	0.209
Algae		
Blue Green	3000	0.0008
Chlorella vulgaris	120	0.019

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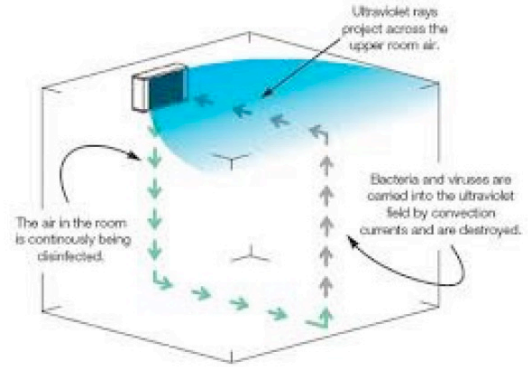
Upper air disinfection calculations (theoretical guideline)



1 Rules of thumb for radiation:

- 0.2-0.5 W UV-C/m^2 floor space
- 0.15 W UV-C/m^3

2 Other factors to take into consideration:

- Lamp maintenance (EOL output)
- Temperature (lamp efficiency)
- If humidity > 50%, then increase of UV-C power by 25%)
- 8-hour exposure limit in the lower room: 0.2 W/cm^2 (ACGIH)

3 Calculation (Example)

Requirements

- Surface: 100m^2
- 0.2 to 0.5 UV-C W/m^2
- EOL: 80%
- Humidity: 60%

Calculation

(100m^2 * 0.35 W UV-C/m^2 * 1,25)/0.8
= 54.7 Watt (UV-C)

➔ **3 lamps**
... if we choose the 55W HO (G13) lamp that has a UV-C power of 18W (18W x 3 = 54W)

Disclaimer: This is a theoretical calculation. Final irradiance should always be measured in practice.

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Surface disinfection calculations (theoretical guideline)

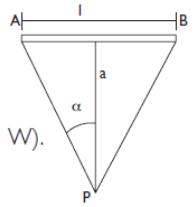
Irradiance $\left[\frac{W}{m^2}\right]$ × **Time** $[S]$ = **UV dose** $\left[\frac{J}{m^2}\right]$

- Dose depends on type of virus and bacteria
- Irradiance depends on the distance between UV source and object (surface): the longer the distance, exponentially lower irradiance (formula of Keitz)

$$E = \frac{\varphi}{2.\pi^2.l.a}(2\alpha + \sin 2\alpha)$$

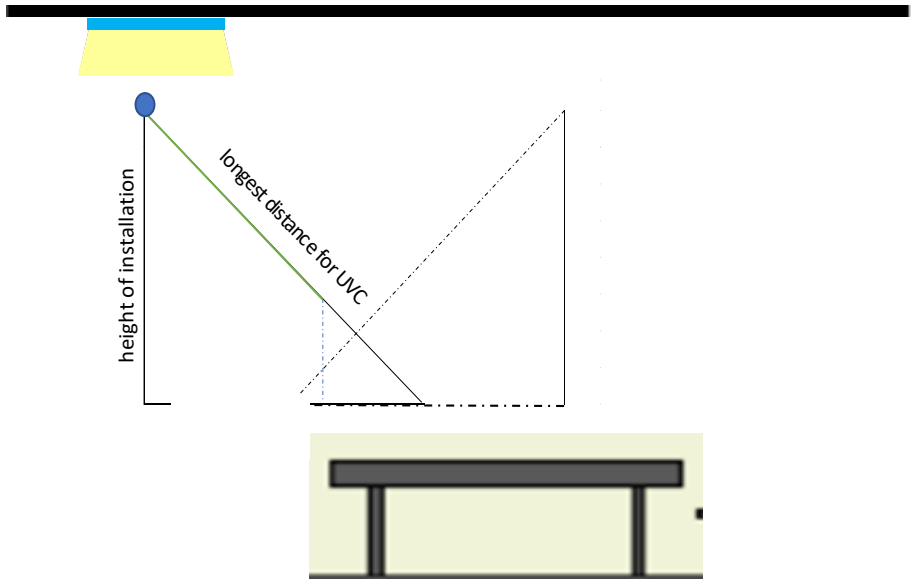
φ is the total radiation flux (in W).

radiation source AB of length l



1 Step 1

Calculate longest distance between UV-source and object (surface).
Based on a known height and fixture with 2x 45 degr. angle



2 Step 2

Case 1. Distance is known and UV-power of lamp / luminaire efficiency is known.
-> we can calculate required exposure time to achieve required dose

Case 2. Distance and Preferred disinfection time is known
-> we can calculate required power of lamp

- Depending on luminaire performance, # of luminaires & lamps to be used to disinfect can be calculated
- Overlap is needed as UVC output reduces fast when distance increases.

Disclaimer: This is a theoretical calculation. Final irradiance should always be measured in practice.

Where to find more information?

Where to find more information?

Visit the Signify UV-C page

www.signify.com/global/lighting-academy/browser/webinar/uvc-disinfection-for-air-surfaces-water

Q&A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