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Far-UVC Systems Pocket Guide on the use of Far-UV 222nm technology

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Date: 10th September 2021

Version: 1.1

SUMMARY

Ultraviolet radiation covers the wavelength range between 100-280nm, and has a known germicidal (bacteria and virus inactivating) effect. UVC radiation is already a well-established technology for the destruction of bacteria and viruses, being employed widely across multiple industries, such as healthcare and food. ¹

Most UVC disinfection systems currently use wavelengths between 240-280nm, with 254nm being the most prevalently used. Unfortunately, exposure to 254nm UV has been shown to cause damage to skin and eyes in humans, and therefore cannot be employed as a solution for the inactivation of bacteria and viruses in public spaces when people are present.

However, recently published scientific studies have shown that a different wavelength of UV light, of 222nm, when properly filtered, has the same bacteria and virus inactivating ability of 254nm UV, without the damage to skin or eyes. This new to the market “Far UV” (from wavelengths 200 to 235nm) technology can therefore be a bacteria and virus inactivating solution, both airborne and surface based, that can be deployed in public spaces while people are present.

This Far UV 222nm wavelength is the technology we utilise in our products. Our solutions of Far-UVC are available as a range of dual-use, retrofitted LED lamps, as well as disinfection wands, and walkthrough decontamination gates; actively decontaminating spaces when occupied, decontaminating people on entry to an environment, and deactivating both airborne and surface-based pathogens. We also sell the patented Lumenizer 300 on behalf of Lumenlabs, capable of inactivating 99.9% of pathogens, including Covid-19, within an occupied room in seconds. We are further looking to develop our own in-vehicle and public transport-related solutions that we hope to be available in the near future.

¹ Eadie, E., Barnard, I., Ibbotson, S. and Wood, K., 2021. Extreme Exposure to Filtered Far- UVC: A Case Study *†*. *Photochemistry and Photobiology*, 97(3), pp.527- 531.

IS IT SAFE?

Multiple studies have been conducted into the safety of the use of Far-UV at 222nm, generally emitted from krypton-chloride (Kr/Cl) lamps, to inactivate bacteria and viruses. The consensus has been that, “to date, the evidence is overwhelmingly in favour of using filtered Far-UVC as a safe, effective germicidal technology”.²

A 2021 study by Eadie et al at NHS Tayside found that no visible skin changes were observed when individuals exposed their inner forearms to large radiant exposures of 1500 mj/cm² from a Far-UV lamp³. A dose of 1500 mj/cm² is far above the 23mj/cm² limit of exposure given in the internationally used guideline that our products follow, by the International Commission on Non-ionizing Radiation Protection (ICNIRP)⁴.

In a 2020 study of 20 healthy volunteers irradiated with 222nm UVC at 50-500 mj/cm² (remember our products will be at a maximum of 23mj/cm² over an 8-hour period of work), no erythema (redness of the skin) was observed⁵. It was concluded from the study that irradiation of 222nm UVC at 500mj/cm² is safe, and has a bactericidal effect on the human skin. A further study found that, with radiant exposure of 265 times the current exposure limit value of 23mj/cm² at 222nm, appropriately filtered Far-UVC is unlikely to present a carcinogenic (cancer causing) risk through DNA damage⁶.

It is clear, therefore, that there is a substantial evidence base for the safety of Far-UV technology at 222nm, with our products starting to be utilised in public spaces such as Costa Coffee outlets and dental practices, with the potential to be used across many industries.

2 Hickerson, R., Conneely, M., Hirata Tsutsumi, S., Wood, K., Jackson, D., Ibbotson, S. and Eadie, E., 2021. Minimal, superficial DNA damage in human skin from filtered far- ultraviolet C. *British Journal of Dermatology*, 184(6), pp.1197- 1199.

3 Eadie, E., Barnard, I., Ibbotson, S. and Wood, K., 2021. Extreme Exposure to Filtered Far- UVC: A Case Study †. *Photochemistry and Photobiology*, 97(3), pp.527- 531.

4 [Icnirp.org](https://www.icnirp.org/en/activities/news/news- article/ff- guidelines- 2020- published.html). 2021. ICNIRP. [online] Available at: <<https://www.icnirp.org/en/activities/news/news- article/ff- guidelines- 2020- published.html>> [Accessed 19 August 2021].

5 Fukui, T., Niikura, T., Oda, T., Kumabe, Y., Ohashi, H., Sasaki, M., Igarashi, T., Kunisada, M., Yamano, N., Oe, K., Matsumoto, T., Matsushita, T., Hayashi, S., Nishigori, C. and Kuroda, R., 2020. Exploratory clinical trial on the safety and bactericidal effect of 222- nm ultraviolet C irradiation in healthy humans. *Plos One*, 15(8), p.e0235948.

6 Hickerson, R., Conneely, M., Hirata Tsutsumi, S., Wood, K., Jackson, D., Ibbotson, S. and Eadie, E., 2021. Minimal, superficial DNA damage in human skin from filtered far- ultraviolet C. *British Journal of Dermatology*, 184(6), pp.1197- 1199.

DOES IT WORK?

UV dosage (also known as fluence) is measured in units of millijoules per square centimetres. This dosage is the product of the intensity of the UV light, and the exposure time.

The exact dosage required to kill bacteria and viruses varies. Some pathogens require as little as two millijoules per square centimetre (2mj/cm²) of Far-UV or UVC to be killed or inactivated.

A wide variety of pathogens can be inactivated with less than twenty millijoules per square centimetre (20mj/cm²) of Far UV or UVC light.⁷



⁷ Childress, J., Roberts, J. and King, T., 2020. Disinfection with Far- UV (222 nm Ultraviolet light). Boeing.

VIRAL AND BACTERIAL EFFICACY:

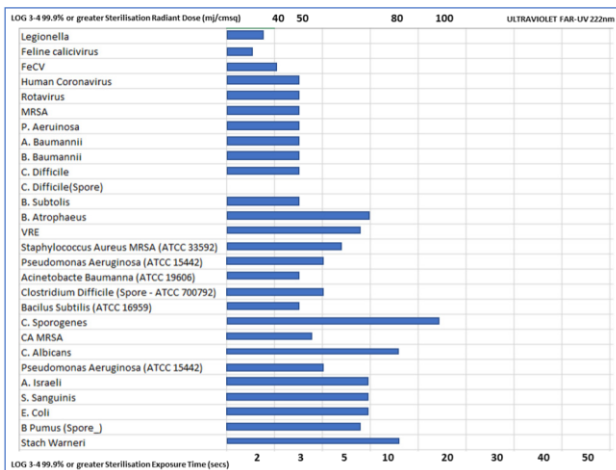
The following results for STERILRAY™ 222nm efficacy were confirmed independently by ATS Laboratories and PPC LLC (Pathogen Path Consulting LLC) of the USA:

Dr David Brenner, known as the father of Far-UV technology, demonstrated in a 2020 study with further researchers at Columbia University that low doses of 1.7 and 1.2 mj/cm² inactivated 99.9% of aerosolized coronavirus 229E and OC43 respectively.⁸ Kitigawa further demonstrated that 222nm UVC irradiation at just 3mj/cm² resulted in a

99.7% reduction of viable SARS-CoV-2 (Covid-19).⁹

When the wavelengths above and below 222nm are filtered out, scientific research has proven that 222nm technology is both safe and effective for up to 8 hours (a work day, varies for extended shifts of 12 hours) at 23 mj/cm², enough to kill 99.9% of bacteria and viruses in a room, while people are still able to occupy the space, as airborne and surface environments are decontaminated.

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⁸ Buonanno, M., Welch, D., Shuryak, I. and Brenner, D., 2020. Far- UVC light (222 nm) efficiently and safely inactivates airborne human coronaviruses. *Scientific Reports*, 10(1).

⁹ Kitagawa, H., Nomura, T., Nazmul, T., Omori, K., Shigemoto, N., Sakaguchi, T. and Ohge, H., 2021. Effectiveness of 222- nm ultraviolet light on disinfecting SARS- CoV- 2 surface contamination. *American Journal of Infection Control*, 49(3), pp299- 301.

¹⁰ <https://far-uv-vc-systems.com/scientific-facts/>

REGULATIONS WE MEET AND FOLLOW

Occupational health and safety guidelines, standards and regulations have been developed in several countries and international organizations in order to protect workers and the general public from potentially hazardous exposure to ultraviolet radiation.¹¹

The two most widely recognized and used guidelines for UVR are very similar. The International Commission on Non-Ionizing Radiation Protection (ICNIRP) and the American Conference of Governmental Industrial Hygienists (ACGIH) guidelines consider ocular (eye) and skin effects.

The ICNIRP guidelines were established in 1989, and reaffirmed in 2004^{12,13}, with the approximate exposure limit for the 222nm wavelength being 23mj/cm² for a continuous 8-hour period of exposure, as previously mentioned. This threshold limit value (TLV) was originally set by ACGIH and then adopted by the ICNIRP, hence they have the same value.

There has been discussion in 2021 around whether this value should be increased, to incorporate the recently published results on Far-UVC technology at 222nm. Regardless, our products are all within the current regulations nationally and internationally. Our range of specialised monitoring and control systems guarantee this.

¹¹ Vecchia, P., Hietanen, M., Stuck, B., van Deventer, E. and Niu, S., 2021. Protecting Workers from Ultraviolet Radiation. [online] [icnirp.org](http://www.icnirp.org/cms/upload/publications/ICNIRPUVWorkers.pdf). Available at: <<http://www.icnirp.org/cms/upload/publications/ICNIRPUVWorkers.pdf>> [Accessed 19 August 2021].

¹² [icnirp.org](https://www.icnirp.org/en/activities/news/news-article/rf-guidelines-2020-published.html). 2021. ICNIRP. [online] Available at: <<https://www.icnirp.org/en/activities/news/news-article/rf-guidelines-2020-published.html>> [Accessed 19 August 2021].

¹³ Brantner, C., Wong, A., Davis, A., Hammond, C. and Olsen, N., 2021. Safety of 222 nm Band- Pass Filtered Irradiation: A Review and Analysis of Current Data. Boeing, [online] Available at: <https://www.boeing.com/confident-travel/downloads/Boeing_Safety_of_222_nm_Band-Pass_Filtered_Irradiation.pdf> [Accessed 19 August 2021].

RISKS

There are, of course, risk elements to dealing with exposure to Far-UVC irradiation. While the harmful rays above and below 222nm are filtered out by our products, such rays can damage human skin and eyes. This is why it is vital that all our products strictly follow current, but potentially changing, international radiation guidelines and procedures.

Personal dosimeters can be small enough to fix to a person's clothing in order to measure radiation. They are simple to read, easy to use, and relatively low cost. Radiometers can be used within a confined space to also give readings of radiation throughout a day to combat the potential risks of poor UV filtering. Swab tests can also be made to give evidence of the effects of our products.

A further potential risk may be companies making false claims on the effectiveness of their UV products. It is vital to thoroughly research a company and the guidelines they abide by before purchase. It may also be necessary to wear PPE (personal protective equipment) around certain wavelengths of UV, but this is unlikely to be necessary with 222nm^{14 15} products.

¹⁴ Kaidzu, S., Sugihara, K., Sasaki, M., Nishiaki, A., Ohashi, H., Igarashi, T. and Tanito, M., 2021. Re- Evaluation of Rat Corneal Damage by Short- Wavelength UV Revealed Extremely Less Hazardous Property of Far- UV- C†. *Photochemistry and Photobiology*, [online] 97(3), pp.505- 516. Available at: <<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8251618/>> [Accessed 19 August 2021].

¹⁵ Sliney, D. and Stuck, B., 2021. A Need to Revise Human Exposure Limits for Ultraviolet UV- C Radiation †. *Photochemistry and Photobiology*, 97(3), pp.485- 492.



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