Office for Product Safety & Standards

Home use of ultraviolet radiation disinfection products

Research Report

April 2021

Executive Summary

As a Collaborating Centre of the World Health Organization (WHO), the Public Health England (PHE) Centre for Radiation, Chemical and Environmental Hazards (CRCE) provided support to WHO in March 2020 on the public message concerning the use of UV-C disinfection products. The message was essentially do not use the devices to irradiate the skin.

A range of products became available on on-line trading platforms early in the pandemic, which were promoted for reducing the risk of catching COVID-19. CRCE advised the Office for Product Safety and Standards (OPSS) and purchased 9 low-cost products for assessment. The initial results suggested two areas of concern: that the products may potentially not be effective for inactivating SARS-CoV-2 and/or they may present a risk to the eyes or the skin.

Through OPSS action, the two main on-line trading platforms blocked unsubstantiated claims of effectiveness against SARS-CoV-2/COVID-19. OPSS funded a study of products, which were assessed by CRCE. Several products were also submitted to CRCE from Trading Standards. 48 devices were assessed in total. The research assessment was undertaken by the Laser and Optical Radiation Dosimetry Group, Public Health England.

The tested devices fell into four categories: handheld wands (18), area exposure units (17), enclosures/bags (12) and one handheld vacuum cleaner. Of these, 14 incorporated some form of safety measure, such as a tilt switch, an interlock, a proximity sensor on one area exposure unit and a pressure sensor on the vacuum cleaner. Two handheld wands were supplied with protective eyewear.

For any enquiries relating to this research please use the following email address: opss.enquiries@beis.gov.uk.

Key Findings

The devices incorporating mercury lamps (24) emitting UV-C at approximately 254 nm were generally capable of inactivating viruses. However, apart from one with an effective proximity sensor, they were all capable of exposing people to levels of UV-C that may result in erythema or photokeratitis. Erythema is a reddening of the skin in response to injury and photokeratitis a painful eye condition which can develop after unprotected exposure to Ultraviolet (UV) rays and presents with symptoms of intense pain, photophobia, and a “sand in the eye” sensation.

The remaining 24 devices incorporated light emitting diodes (LEDs) of various peak emission wavelengths ranging from 277 nm (UV-C) to 460 nm (blue light). Twelve of the devices containing LEDs were found to emit wavelengths that could potentially inactivate viruses. However, the irradiance produced by the LED devices was generally a factor of ten below that emitted by the low-pressure mercury lamps. The irradiated area was also smaller.

Nine of the LED devices did not emit optical radiation capable of inactivating viruses, despite claims on the packaging and information to the user. These products had their safety assessed under the General Product Safety Regulations 2005 (GPSR)[1] or the essential safety requirements of the Electrical Equipment Safety Regulations 2016 (EESR)[2]. Corrective action was taken against any product deemed unsafe.

The effectiveness of all UV-C devices for virus inactivation is critically dependent on line-of-sight exposure conditions. The virus inactivation is also dependant on a multitude of factors including the:

- Wavelength emitted and irradiance
- Direct line of sight
- Exposure time

Most of the enclosures/bags were effective at minimising the risk of skin or eye exposure. However, items placed inside for disinfection were generally only irradiated on one or two sides, with the other surfaces shielded from the UV. The information to the user did not address this.

The OPSS Covid-19 Consumer Survey[3] conducted in April-July 2020 demonstrated that out of 3812 total respondents, 5% had recently bought and/or used UV-C devices (n=200). The data showed that out of those 200 people who had purchased, or used, a UV-C device some were reporting purchasing for use on the skin or for use on their pets[3]. The International Commission on Illumination and the World Health Organisation have warned against the use of UV disinfection lamps to disinfect hands or any other areas of the skin[4]. For the tested handheld wands it was theoretically possible for those to be used on the skin. This was also possible for those devices incorporating tilt switches if, for example, the hands were placed under the unit. The risk to the eyes was reduced for such devices, but it is reasonably foreseeable that a child could be looking up into a device being used by an adult.

---

1 General Product Safety Regulations 2005 (https://www.legislation.gov.uk/uksi/2005/1803/contents)
2 Electrical Equipment Safety Regulations 2016 (EESR) https://www.legislation.gov.uk/uksi/2016/1101/contents
3 OPSS. Covid-19 Consumer Survey. London: Office for Product Safety and Standards. (2020)
4 CIE Position Statement on the use of ultraviolet (UV) radiation to manage the risk of COVID-19 transmission (2020). http://cie.co.at/publications/cie-position-statement-use-ultraviolet-uv-radiation-manage-risk-covid-19-transmission

The full scientific results of the study have been published in the Photochemistry and Photobiology journal following peer-review (Khazova, et al., 2021).[5]

[5] Khazova, M., *et al.* "Survey of Home-Use UV Disinfection Products." Photochemistry and Photobiology (2021).

Background and methodology

Ultraviolet radiation covers the electromagnetic spectrum between visible radiation (light), with wavelengths between 400 and 700 nm, and ionising radiation (x-rays and gamma rays), with wavelengths less than about 100 nm. Ultraviolet radiation is sub-divided into:

- ultraviolet A (UV-A) from 315 to 400 nm;
- ultraviolet B (UV-B) from 280 to 315 nm;
- ultraviolet C (UV-C) from about 100 nm to 280 nm.

There is no UV-C in natural sunlight on Earth as it is blocked by the ozone layer in the atmosphere. The only way humans can be exposed to UV-C is from artificial sources[6].

Artificial ultraviolet radiation has been used to disinfect air, water and surfaces for decades. However, the primary use in the UK has been for water disinfection and in air conditioning units; consumers may be familiar with UV lamps for treatment of water in fishponds and fish tanks. In all cases, the intention is that people should not be exposed to the ultraviolet radiation by effective engineering controls.

The potential for ultraviolet radiation to inactivate viruses or kill bacteria is critically dependent on the wavelength emitted by the source[7]. UV-C is considered the most effective for disinfection. Low pressure mercury lamps, primarily emitting at 254 (253.65) nm in the UV-C region, have been used for many decades and the effectiveness at this wavelength is often used as the metric against which emission from other sources is assessed.

Theoretically, the peak effectiveness is at about 260-270 nm, the peak wavelength for RNA/DNA absorption; longer wavelengths have a reduced capability to inactivate viruses and kill bacteria. There is evidence that SARS-CoV-2 may be inactivated using UV-C, but the exact quantity of UV-C to achieve a given level of viral inactivation is still subject to investigation[8]. However, comparison with the effectiveness on similar coronaviruses suggests that a radiant exposure of about 7 J m^{-2} at 254 nm would be expected to inactivate 90% of SARS-CoV-2.[9] It is estimated that about 28 J m^{-2} at the same wavelength is needed to inactivate 99% of this virus and that 99% inactivation will require 280 J m^{-2} at 295 nm; 2,800 J m^{-2} at 305 nm; 28,000 J m^{-2} at 309 nm; and 280,000 J m^{-2} at 320 nm.[9] Above 320 nm, viral inactivation is considered unlikely.[9]

[6] World Health Organisation (2016) Ultraviolet (UV) radiation. https://www.who.int/news-room/q-a-detail/radiation-ultraviolet-(uv)

[7] Sagripanti, J.-L., & Lytle, C. D. "Predicted Inactivation of Viruses of Relevance to Biodefense by Solar Radiation." Journal of Virology (2005)

[8] SAGE-EMG. "Application of UV disinfection, visible light, local air filtration and fumigation technologies to microbial control." London: Scientific Advisory Group for Emergencies (2020).

[9] Sagripanti, J.-L., & Lytle, C. D. "Estimated Inactivation of Coronaviruses by Solar Radiation With Special Reference to COVID-19." Photochemistry and Photobiology (2020).

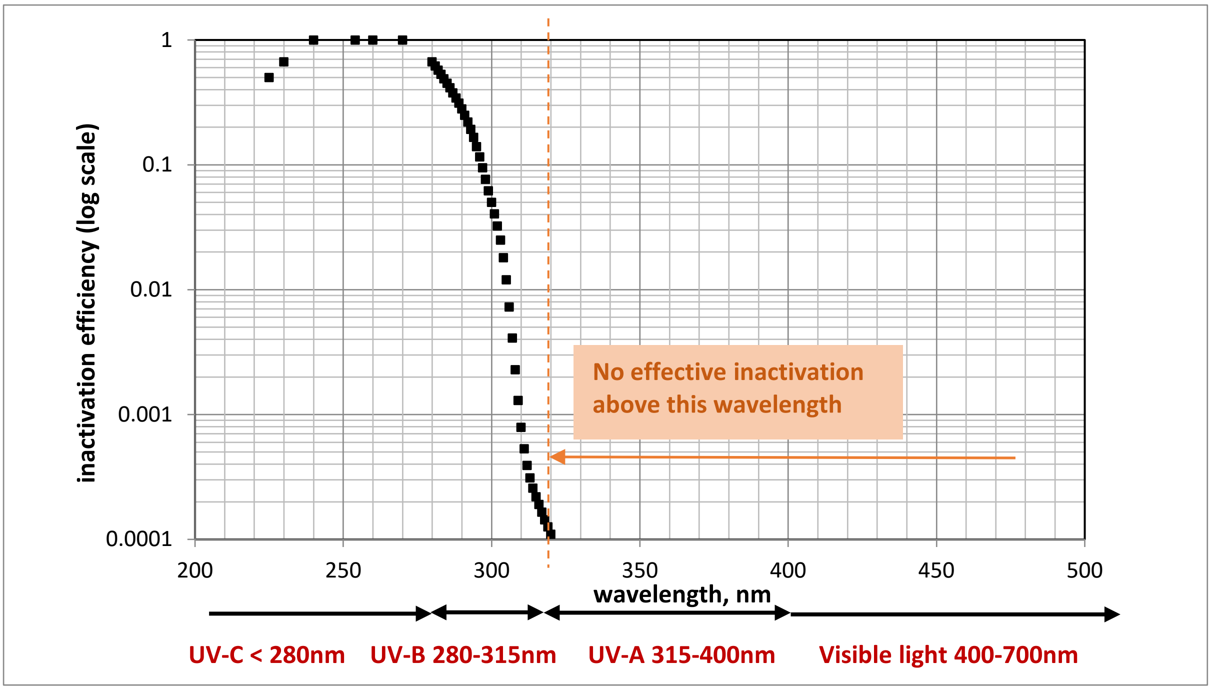

Figure 1. Estimated virus inactivation in relation to emitted wavelength range.

Viruses, such as SARS-CoV-2 may be present on surfaces, either from droplets deposited after someone has coughed, sneezed or even been speaking, or because someone has transferred the virus to the surface by touching it and virus aerosols may also be present in the air.[10] In order to consider the potential effectiveness of a product in reducing the amount of active virus, the emission characteristics are assessed. These include the spectral power distribution (spectral irradiance) of the emission and the irradiance which is spectrally weighted with inactivation efficiency function at a specified distance. It is then possible to determine the time required to achieve a given level of viral inactivation.

For wand-type devices intended to disinfect surfaces, consideration is given to the guidance provided with the product. However, it is necessary to assess the likelihood of effective viral inactivation under reasonably foreseeable use, such as the exposure distance, area of the surface exposed at that distance and exposure time.

For area-exposure devices, intended to be placed in a fixed position in an environment, the time to achieve 90% and 99% inactivation of the virus was assessed. These times assume a reasonable level of air mixing.

[10] EMG/SPI-B/TWEG. “Mitigations to reduce transmission of the new variant SARS-CoV-2 virus, 22 December 2020.” Scientific Advisory Group for Emergencies (2020).

Potential safety considerations

If people are exposed to ultraviolet radiation, energy may be absorbed in the eyes or the skin. Short-term effects include erythema (skin reddening) and photokeratitis of the eyes, a painful condition that feels like sand has been rubbed into the eyes. In the UV-B region, a potential long-term consequence of high levels of exposure is an increased risk of skin cancer. The probability of these effects depends on the amount of exposure and the emitted wavelengths. Organisations such as the International Commission on Non-Ionizing Radiation (ICNIRP) produce guidelines[11] for exposure limits to minimise the risk of harm and the weighting functions that account for the wavelength sensitivity. The exposure limits are adopted in workplace legislation but are also recommended when considering the risk to people outside of the workplace.

The exposure limit for accumulative 8-hour or longer exposures is 30 J m^{-2}, which is a weighted quantity that takes into account the wavelength sensitivity; exposure may include multiple episodes within 8h. If the source emits more than one wavelength, it is necessary to calculate the cumulative wavelength weighting.

Products emitting non-laser optical radiation should be classified in accordance with BS EN 62471: 2008 "Photobiological Safety of Lamps and Lamp Systems". This standard is harmonised under the Low Voltage Directive for products covered by that Directive. The standard specifies risk groups, from Exempt to Risk Group 3. Risk Group 3 products are likely to cause harm and are, therefore, potentially considered "unsafe" as defined by the General Product Safety Regulations and not considered to meet the essential safety requirements under EESR. In addition, some products with no potential for disinfection were deemed to be unsafe under GPSR or not meeting the essential safety requirements under EESR. BS EN 62471 does not include any requirements for information or labelling; guidance on control measures is provided in PD IEC/TR 62471-2:2009.

Low-pressure mercury lamps have additional associated hazards, such as usually having a fragile glass envelope, which could be broken if inappropriately handled. Apart from the risk of cuts from the broken glass, a small amount of mercury will be released into the environment.

UV-C has the potential to generate ozone, with increased probability for wavelengths shorter than 200 nm. Mercury lamps may emit UV at a number of specific wavelengths; if emissions below 200 nm are not filtered out, ozone may be produced. Ozone is a very strong oxidant that may cause irritation when breathed in and to the eyes; at higher concentrations it may be toxic or interact with materials to produce other chemical by-products indoors[12]

[11] ICNIRP Guidelines on Limits of Exposure to Ultraviolet Radiation of Wavelengths Between 180 nm and 400 nm (Incoherent Optical Radiation). Health Physics 87(2):171-186; 2004

[12] Nuvolone, D., *et al*. "The effects of ozone on human health." Environmental Science and Pollution Research (2017)

References

BS EN 62471:2008. Photobiological safety of lamps and lamp systems

Khazova, M., Johnstone, L., Naldzhiev, D., O'Hagan, J. (2021). Survey of Home-Use UV Disinfection Products. Photochemistry and Photobiology. https://doi.org/10.1111/php.13423

EMG/SPI-B/TWEG. (2020). Mitigations to reduce transmission of the new variant SARS-CoV-2 virus, 22 December 2020. Scientific Advisory Group for Emergencies. Retrieved from https://www.gov.uk/government/publications/emgspi-btweg-mitigations-to-reduce-transmission-of-the-new-variant-sars-cov-2-virus-22-december-2020

Nuvolone, D., Petri, D., & Voller, F. (2017). The effects of ozone on human health. Environmental Science and Pollution Research volume, 25, 8074–8088.

OPSS. (2020). Covid-19 Consumer Survey. London: Office for Product Safety and Standards.

SAGE-EMG. (2020). Application of UV disinfection, visible light, local air filtration and fumigation technologies to microbial control. London: Scientific Advisory Group for Emergencies (SAGE).

Sagripanti, J.-L., & Lytle, C. D. (2005). Predicted Inactivation of Viruses of Relevance to Biodefense by Solar Radiation. Journal of Virology, 14244-14252. doi:DOI: 10.1128/JVI.79.22.14244-14252.2005

Sagripanti, J.-L., & Lytle, C. D. (2020). Estimated Inactivation of Coronaviruses by Solar Radiation With Special Reference to COVID-19. Photochemistry and Photobiology, 96(4), 731-737. doi:https://doi.org/10.1111/php.13293

Contact us if you have any enquiries about this publication, including requests for alternative formats, at: OPSS.enquiries@beis.gov.uk

Office for Product Safety and Standards

Department for Business, Energy and Industrial Strategy
4th Floor, Cannon House, 18 The Priory Queensway, Birmingham B4 6BS
https://www.gov.uk/government/organisations/office-for-product-safety-and-standards