GLOBAL LIGHTING ASSOCIATION

Position Statement on Germicidal UV-C Irradiation

UV-C SAFETY GUIDELINES

May 2020

FOREWORD

About the Global Lighting Association

The Global Lighting Association (GLA) is the voice of the lighting industry on a global basis. GLA shares information on political, scientific, business, social and environmental issues of relevance to the lighting industry and advocates the position of the global lighting industry to relevant stakeholders in the international sphere. See www.globallightingassociation.org.

UV-C and urgent need for safety guidelines

UV-C[1] irradiation is a proven germicidal methodology for inactivating bacteria and viruses in water, air and solid surfaces. For effective disinfection purposes, the UV-C energy of UV-C devices is much higher than normal sunlight. These high UV-C energies can be a hazard to exposed humans and materials if proper safety measures are not observed.

In this context, and in the midst of a global COVID-19 epidemic, GLA is concerned at the proliferation of UV-C disinfecting devices – particularly being sold on the internet – with dubious safety features and inadequate safety instructions.

There is an urgent need for comprehensive technical safety standards for UV-C devices. Standards are expected to be developed by the International Electrotechnical Commission (IEC), Underwriters Laboratories (UL) and other standards development organisations (SDOs), but will take many months before they are published. Pending development and publication of such standards, the Global Lighting Association has published this document as an intermediate measure to draw attention to safety issues associated with UV-C products and to provide guidance on their safe use.

[1] UV-C forms part of the ultraviolet (UV) spectrum and is defined within ISO standard ISO-21348 as having wavelengths between 100 - 280 nm. In practice, 100 nm – 200 nm wavelengths are strongly absorbed by atmospheric oxygen which means they can only be used effectively under vacuum conditions. (This is also the reason the scope of the IEC standard *Photobiological safety of lamps and lamp systems* starts at 200 nm). This document changed the lower boundary from 200 nm to 180 nm to include low-pressure mercury lamps.

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1. INTRODUCTION

UV-C devices are considered safe if they meet the electrical, thermal, mechanical, human exposure to electromagnetic fields (EMF) and photobiological safety requirements provided in IEC and UL standards. Regional safety codes or policies may reference these standards and other regional safety requirements. An overview of applicable IEC and UL safety standards is given in Appendix A.

Additionally, special attention should be given to UV-C **irradiance** hazards [1] which can damage the human eye and cause severe sunburn-like reaction to the human skin. UV-C **irradiance** can damage materials. It can also produce ozone (O_3), a known human toxin. Ozone can be produced in air due to exposure to optical radiation at wavelengths below 240 nm.

The information in this document represents current UV-C safety knowledge. Pending publication of comprehensive safety standards by SDOs, this document provides safeguards to avoid human exposure to **irradiance** hazards (section 3) and to excessive ozone concentrations (section 4). The associated information requirements and compliance criteria are given in section 5 and 6 respectively. Definitions of **bold-marked** terms are given in section 7.

The Global Lighting Association strongly recommends applying these guidelines during safety assessments of UV-C devices in conjunction with applicable IEC and/or UL standards and/or other regional safety requirements.

2. SCOPE OF THIS GUIDANCE DOCUMENT

The safety advice in this document applies to UV-C sources and UV-C products which emit in the wavelength range of 180[2] nm to 280[3] nm.

Not within the scope are:

- devices having their own product safety standard, such as IEC 60335-2-109 applicable to UV-C water disinfection equipment and IEC60335-2-65 applicable to UV-C air disinfection equipment
- application environments of UV-C devices
- products combining UV-C **irradiance** with chemicals and additives
- products that do not emit UV-C radiation such as UV-A, UV-B and near-UV devices
- requirements for performance and functional characteristics
- requirements for preventing material degradation and material damage

[2] The lower wavelength boundary of the UV-C wavelength range has been adjusted from 200 nm to 180 nm to include 185 nm low-pressure mercury lamps. The product safety requirements for this wavelength extension are derived from ICNIRP 2004 Guidelines [1].

[3] There are also broadband UV-C devices with UV emission above 280 nm. These broadband UV-C devices have additional product safety requirements described in IEC 62471.

3. UV-C RADIATION SAFETY REQUIREMENTS

Section 3.1 summarises UV-C safety requirements identified in the photobiological safety standard IEC 62471 [3]. It also alters the lower wavelength boundary from 200 nm to 180 nm to extend safety considerations to common 185 nm sources as outlined in the scope of this document. Section 3.2 supplements these requirements with quantification of the effective UV-C **irradiance** distribution. Section 3.3 describes the safeguards which should be taken to avoid human exposure to **irradiance** hazards.

3.1 Summary of UV-C safety requirements of photobiological safety standard IEC 62471

[Source: IEC 62471 modified to lower 180 nm wavelength boundary and limited to upper 280 nm wavelength boundary]

Note: The product safety requirements for the wavelength extension are derived from ICNIRP 2004 Guidelines [1].

3.1.1 Effective UV-C irradiance

To determine the effective **irradiance** of broadband UV-C devices, the device **irradiance** should be weighted against the peak of the spectral effectiveness curve (270 nm) according to Equation 1.

$$E_{eff} = \sum_{180\ nm}^{280\ nm} E_\lambda \cdot S(\lambda) \cdot \Delta(\lambda) \qquad [Equation\ 1]$$

For monochromatic UV-C devices Equation 1 can be simplified to Equation 2.

$$E_{eff} = E_\lambda \cdot S(\lambda) \qquad [Equation\ 2]$$

where:

E_{eff} = effective **irradiance** at a distance d_1 from the UV-C device in µW/cm² or W/m² and weighted against a 270 nm source
E_λ = spectral device **irradiance** in µW/cm²/nm or W/m²/nm measured at a distance d_1 from the UV-C device
$S(\lambda)$ = relative spectral effectiveness as given in Table 1
$\Delta\lambda$ = bandwidth in nanometres of the calculation or measurement intervals

Table 1 – Spectral weighting S(λ)

UV-range	λ (nm)	S (λ)
UV-C	180	0.012
	185*	0.015
	200	0.03
	220	0.12
	222	0.13
	240	0.30
	254*	0.50
	260	0.65
	270	1.00
	280	0.88

Note 1: Values marked * are mercury lines
Note 2: Wavelengths chosen are representative. Other values should be obtained by logarithmic interpolation at intermediate wavelengths.
Note 3: CIE 239:2020 TR Goniospectroradiometry of Optical Radiation Sources gives guidance on spectral distribution measurements for 200 nm-2500 nm. Effective UV-C spectral **irradiance** distribution acquisition needs spectroradiometers or detectors sensitive in the range of interest: 180 nm-280 nm. Below 200 nm, there are difficulties in measuring **irradiance** distributions in typical air conditions. A nitrogen environment may be required due to ozone blocking of the UV.
Note 4: Broadband UV-C devices that emit in the 280 nm to 400 nm range should be evaluated according to IEC 62471 as such devices have additional product safety requirements.

3.1.2 Effective irradiance at a distance d_2

The effective **irradiance** from a UV-C device can be determined at any distance d_2 by the inverse square law as given in Equation 3.

$$E_{eff@d2} = \left(\frac{d_1}{d_2}\right)^2 \cdot E_{eff} \qquad [Equation\ 3]$$

where:

E_{eff} = effective **irradiance** at a distance d_1 from the UV-C device in µW/cm² or W/m² and weighted against a 270 nm source

$E_{eff@d2}$ = effective **irradiance** at a distance d_2 from the UV-C device in µW/cm² or W/m² and weighted against a 270 nm source

For devices unable to be modelled by the inverse square law (such as collimated sources), the effective irradiance should be measured at all relevant distances.

3.1.3 Effective irradiance at a distance d_2 = 200 mm

The effective **irradiance** from UV-C devices should be determined in the direction where the highest **irradiance** occurs and at a fixed distance d_2 of 200 mm.

Note: The distance d_2 of 200 mm derives from IEC 62471 [1] and should be used for all UV-C devices to make them comparable and to categorize them in the correct UV-C risk group

3.1.4 UV-C risk groups

The UV-C risk group of UV-C devices should be determined by $E_{eff@d2\,=\,200mm}$ according to section 3.1.3, the exposure time (t) per 8 hours' time interval and the flow-chart of Figure 1.

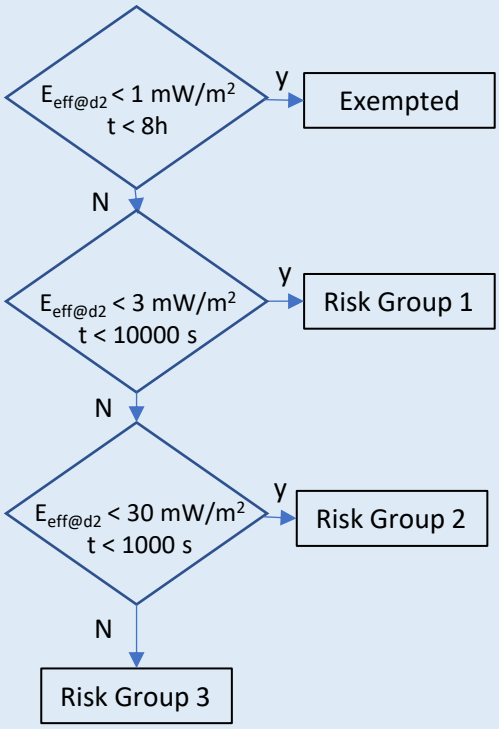

Figure 1: UV-C Risk Groups (UV-C RGs)

3.2 Effective UV-C irradiance distribution

To provide adequate installation instructions (see section 5) for **Partially Open Enclosures**, the effective UV-C **irradiance** of UV-C devices should be determined according to Equation 3, at all relevant directions and at a distance d_2 which the device is intended to have during far-field or near-field operation.

3.3 UV-C irradiance safeguards

UV-C devices belonging to the exempted UV-C Risk Group (UV-C RG) require no safeguard.

Devices accessible to **Ordinary Persons** and which have a UV-C RG higher than or equal to 1 (UV-C RG ≥ 1) require at least:

I. an **Instructional Safeguard** AND
II. a **Time Safeguard** which should limit the exposure times per UV-C RG as given in Table 2, OR an **Equipment Safeguard** OR a **Containment Safeguard** which should reduce the effective **irradiation** to below 1mW/m^2.

Table 2 – Maximum exposure time per UV-C RG for an 8 hours' time interval

UV-C Risk Group (UV-C RG)	Maximum exposure time, t in seconds
1	10000
2	1000
3	< 30 J/m^2/ $E_{eff@d2}$

Devices which are only accessible to **Skilled Persons** and which have a UV-C RG higher than or equal to 1 (UV-C RG ≥ 1) require at least an **Instructional Safeguard** AND a **Personal Safeguard**.

The **bold-marked** terms are defined in section 7.

4. OZONE SAFETY REQUIREMENTS

This section includes ozone safety requirements to protect humans against long-term toxic effects from high ozone concentrations generated by UV-C devices with emission wavelengths below 240 nm.

4.1 Long-term exposure limits for ozone

The limits are derived from section 7.3 in IEC 62368-1 [4] and are for long-term ozone exposures limited to 0.1 ppm per volume (≈ 200 µg/m^3) calculated as an eight hours' time-weighted average concentration. Alternative ozone exposure levels are provided in Table 3.

Table 3 – Alternative ozone exposure levels[4]

Country/ organisation	Level [µg/m³]	Source
WHO	100	World Health Organisation ambient (outdoor) air pollution https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health
EU	120	Directive 2008/50/EC, annex 7
US (EPA)	140	2015 National Ambient Air Quality Standards (NAAQS) for Ozone https://www.epa.gov/ground-level-ozone-pollution/2015-national-ambient-air-quality-standards-naaqs-ozone
China	160	TOAR: China is Hot Spot of Ground-Level Ozone Pollution 29 August 2018 https://esrl.noaa.gov/csl/news/2018/244_0829.html

4.2 Ozone safeguard requirements

UV-C devices which exceed the long-term ozone exposure limits require ozone instructional safeguards. See section 5.

5. INFORMATION REQUIREMENTS

Unless exempted in section 4 and section 5, the following product information requirements apply to UV-C devices.

5.1 Warning symbols

a) A UV-C warning symbol 

according IEC 61549-310-1. Other regional required or accepted warning symbols may be utilized.

b) An ozone warning symbol[5] such as 

should be applied. Other regional required or accepted warning symbols may be utilized.

5.2 Warning labels

a) A UV-C warning label with the following elements:

1: The UV-C warning symbol 

according to IEC 61549-310-1
2: UV-C risk group marking
3, 4 and 5: Text recommendations for these warning label elements are provided in Table 4 according to the appropriate UV-C risk group for the UV-C source or UV-C product.

[4] California Code of Regulations Title 17 [5] limits the ozone concentration to 0.05 ppm per volume calculated over 24 hours.

[5] The yellow background of the ozone warning symbol is not required. The IEC reference for the ozone warning symbol is not yet defined.

Table 4 - Instructional safeguards for ultraviolet hazard 180 nm to 280 nm

Element	Exempt Group	UV-C Risk Group 1	UV-C Risk Group 2	UV-C Risk Group 3
3	Not required	**NOTICE UV-C** emitted from this product	**CAUTION UV-C** emitted from this product	**WARNING UV-C** emitted from this product
4	Not required	Minimize exposure to eyes or skin. Use appropriate shielding.	Eye or skin irritation may result from exposure. Use appropriate shielding.	Avoid eye and skin exposure to unshielded product.
5	Not Required	Follow the installation instruction and user manual		

The elements 1, 3, 4 and 5 should be black on a yellow background, as illustrated in Figure 2.

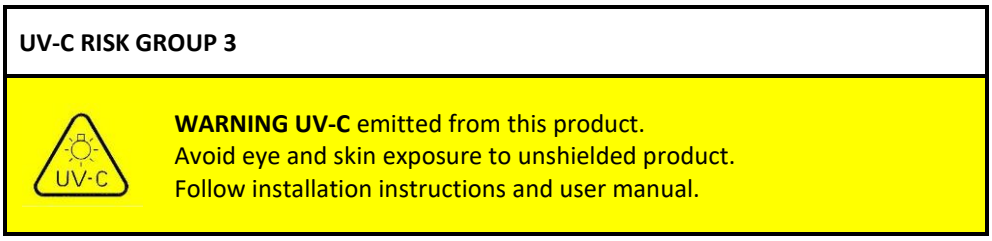

Figure 2 - Example of UV-C warning label

b) Ozone warning label

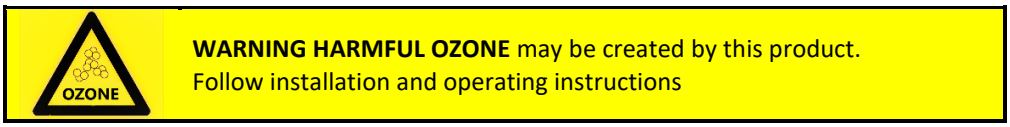

Figure 3 - Example of an ozone warning label

Environments in which a high ozone concentration is expected should be marked with an additional safety label that summarises the emergency overview, the safeguards, first aid procedures, fire procedures and spill procedures. An example of such a warning label is given in Appendix B.

If the size or design of the UV-C device makes marking impractical, the marking should be included in the packaging and with appropriate web-based links. Other regional required or accepted colour schemes may be utilized.

5.3 Installation instructions and user manual

The following information should be included in the installation instructions and user manual:

- Warning labels in section 5.2
- UV-C wavelength or wavelength range (for broadband sources)
- Effective device irradiance at a distance d2 = 200 mm as defined in section 3.1
- Detailed description of the **Time**, **Equipment**, **Containment** and/or **Personal Safeguards** that are needed to avoid possible hazardous exposure to UV-C radiation and/or ozone concentrations
- In case of an **Equipment Safeguard** with a **Partially Open Enclosure**, the effective UV-C irradiance distribution as defined in section 3.2

- Adequate instructions for proper assembly, installation, maintenance and safe use, to avoid possible hazardous exposure to UV-C radiation and/or ozone concentrations
- Advice on safe operating procedures and warnings concerning reasonably foreseeable misuse, malfunctions and hazardous failure modes. Where servicing and maintenance procedures are detailed, they should wherever possible include explicit instructions on safe procedures to be followed.

5.4 Instructional training

Containment Safeguards[6] should be provided with instructional training (e.g. instructional manual or video) which includes all relevant elements of the installation instructions and user manual as defined in section 5.3.

6. COMPLIANCE

Compliance is determined by evaluation of the installation instructions and user manual, by inspection and by measurements[7].

7. TERMS AND DEFINITIONS[8]

Closed Enclosure
Enclosures which completely enclose the hazardous UV-C irradiance. A Closed Enclosure which can be opened by an ordinary person without tools and which would expose this person to a UV-C risk group should be equipped with an automatic shut-off switch.

Containment Safeguard
Cabinets or **Controlled Access Locations**, not being a physical part of the equipment, which block physical access to the UV-C device while it is operating or prevent the device from operating when it is physically accessible.

Controlled Access Location
An area where an engineering and/or administrative control measure is established to prevent access during UV-C operation.

Equipment Safeguard
Closed Enclosure, **Partially Open Enclosure** and/or **Presence Detection System** that are a physical part of the equipment.

Instructional Safeguard
Details on the Instructional Safeguard are given in section 5.

[6] It is the responsibility of the containment owner to address hazardous exposure risks and to ensure that people entering the containment area while the UV-C system is operating are aware of the risks and that appropriate controls and safeguards are in place.

[7] For guidance on measuring techniques, see the relevant part of the IEC 62471 series. For guidance on measuring ozone emission and concentration from light sources and products see UL 867 Standard for Safety for Electrostatic Air Cleaners, UL 867, Section 37 Ozone Test. [6]

[8] Definitions are derived from [4] – see Section 8 REFERENCES.

Irradiance (at a point on a surface)
Quotient of the radiant flux dϕ incident on an element of a surface containing the point, by the area dA of that element, i.e.,

$$E = d\phi/dA \qquad \text{Unit: } W/m^2$$

Ordinary Person
A person not being a **Skilled Person.**

Partially Open Enclosure
Enclosure which partially encloses hazardous UV-C **irradiance**. Partially Open Enclosures should have a defined installation position and defined mounting properties based on the effective UV-C **irradiance** distribution as defined in section 3.2. Properly installed Partially Open Enclosures protect occupants of a space during their normal activity while irradiating unoccupied portions of a space. An example application is upper-room air disinfection.

Personal Safeguard
Personal protective equipment that is worn on the body and that reduces exposure to the UV-C device. Examples are shields, goggles, gloves, aprons, dose-meters, face masks and breathing apparatus. The UV-C personal safeguard normally complies with section 7.4. of IEC 62368-1 [3].

Presence Detection System
A system of sensors and controls which detects the presence of people. A single motion detection sensor is not a presence detection system. A risk assessment should be performed on the system of sensors and controls to determine if it qualifies as an **Equipment Safeguard**.

Skilled person
A person with relevant education or experience to enable him or her to identify hazards and take appropriate actions to reduce risk of injury to themselves and others.

Time Safeguard
A timer that switches off the UV-C power to stay below the human exposure energy of 30 J/m^2 within an 8-hours' time interval.

8. REFERENCES

[1] ICNIRP Guidelines "On limits of exposure to Ultraviolet radiation of wavelengths between 180 nm and 400 nm (incoherent optical radiation)" published in: HEALTH PHYSICS 87(2):171-186; 2004

[2] Product Chemical Properties CB6851738

[3] IEC 62471:2006 "Photobiological safety of lamps and lamp systems"

[4] IEC 62368-1:2018 "Audio/video, information and communication technology equipment – Part 1: Safety requirements"

[5] California Code of Regulations Title 17. "Public Health" - Division 3. "Air Resources" - Chapter 1. "Air Resources Board" - Subchapter 8.7. "Indoor Air Cleaning Devices" - Article 1. "Indoor Air Cleaning Devices"

[6] UL 867 - "Safety for Electrostatic Air Cleaners, UL 867, Section 37 Ozone Test"

APPENDIX A

IEC and UL standards for lighting equipment addressing electrical, thermal, mechanical, human exposure to electromagnetic fields and photobiological safety requirements

Standard	Description
IEC 60335-2-27	Household and similar electrical appliances – Safety – Part 2-27: Particular requirements for appliances for skin exposure to optical radiation
IEC 60335-2-65	Household and similar electrical appliances - Safety - Part 2-65: Particular requirements for air-cleaning appliances
IEC 60432-3	Incandescent lamps – Safety specifications – Part 3: Tungsten halogen lamps (non-vehicle)
IEC 60598-1	Luminaires – Part 1: General requirements and tests
IEC 61167	Metal halide lamps - Performance specification
IEC 62031	LED modules for general lighting – Safety specifications
IEC 62035	Discharge lamps (excluding fluorescent lamps) – Safety specifications
IEC 62471	Photobiological safety of lamps and lamp systems
IEC/TR 62471-2	Photobiological safety of lamps and lamp systems - Part 2: Guidance on manufacturing requirements relating to non-laser optical radiation safety
IEC 62493	Assessment of lighting equipment related to human exposure to electromagnetic fields
IEC 62776	Double-capped LED lamps designed to retrofit linear fluorescent lamps – Safety specifications
IEC 62838	LEDsi lamps for general lighting services with supply voltages not exceeding 50 V a.c. r.m.s. or 120 V ripple free d.c. – Safety specifications
UL 499	Electric Heating Appliances
UL 935	Fluorescent Lamp Ballast
UL 1598	Luminaires
UL 1993	Self-Ballasted Lamps and Lamp Adapters
UL 8750	LED Driver, LED Array and LED Package

APPENDIX B

Example of warning label for environments and products in which a high ozone concentration is expected