All about Safety: UV-C Hazards and Risks

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One hundred years of increasingly effective germicidal UV light irradiance has helped mitigate infectious transmission within buildings. Our last paper, "**The Ins & Outs of UV-C Germicidal Irradiation**" examined how UV-C breaks down the RNA of viruses like Covid-19 in a range of applications including HVAC systems and can treat upper room air. Until the 1990's however, the hazards were largely ignored. The safety data has accumulated to warrant its own paper. UV-C devices have proliferated - especially since the pandemic – to clean everything from hospital and motel rooms to phones and PPE. UV-C can be a miracle agent of disinfection - with careful design and caution.

Users may not realize the danger until after exposure has caused damage four to 24 hours afterwards. Chronic effects are long-lasting and cumulative and may not appear for years including skin cancer and ocular cataracts.[1] In addition, new health challenges related to ozone damage from far UV-C sources require careful design and regulation.

The FDA highlighted the risks in their Feb. 27, 2020 Safety communication focused on CPAP medical devices.[2] Accidental or lengthy exposure to UV light while it is cleaning can put a user at risk of eye injury, skin burns or an increased risk of skin cancer – while being unable to penetrate and disinfect all areas of hoses, masks and connectors. At a larger scale, upper air UV-C requires design with safety interlocks, an understanding of surface reflectivity, and may require a thermodynamic analysis of air movement in complex spaces to ensure effectiveness.

Since our case study, described in **our last UV-C paper,** we learned that titanium coated surfaces are not recommended for occupied spaces. We now know that ***reflected*** UV-C is still hazardous to skin and eyes. Surfaces should be painted with non-UV-reflecting material. Although the long-term health risks may be negligible compared to

[1] "Safety Tips for Using UV Lamps" revised January 2017. https://www2.lbl.gov/ehs/safety/nir/assets/docs/uv/UV%20lamps%20safety%20tips.pdf

[2] https://www.fda.gov/medical-devices/safety-communications/potential-risks-associated-use-ozone-and-ultraviolet-uv-light-products-cleaning-cpap-machines-and

ordinary sun exposure, short term damage to skin and eyes is a liability to avoid. The following sections summarize key recommendations to minimize risks and avoid hazards.

Safety Guidelines:

<u>UV-C Risk Groups</u>

- UV-C Risk Group (RG)[3]
  UV-C Risk Group should be determined by $E_{eff@d2,}$ the exposure time (t) per 8 hours' time interval and the flow-chart on the right.

  $E_{eff@d2}$ = effective irradiance at a distance d_2 from the UVC device in µw/cm² or W/m² and weighted against a 270nm source
  d_2 = fixed distance of 200mm.[4]

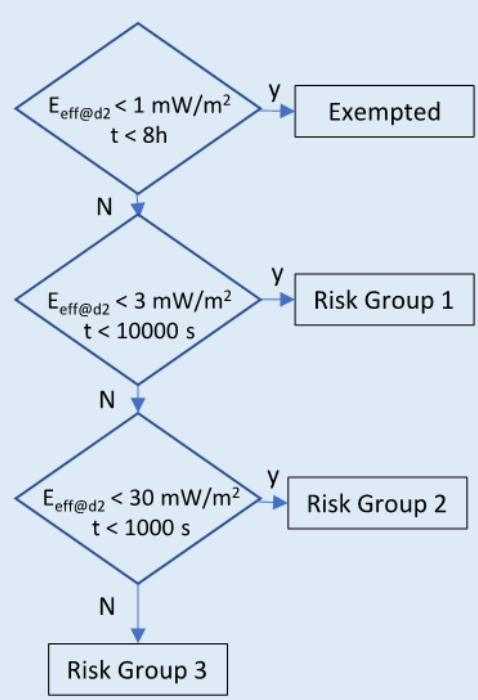


Figure 1: UV-C Risk Groups (UV-C RGs)

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/m²/ $E_{eff@d2}$

- UV-C RG = exempt, no safeguards required.
- UV-C RG ⩾ 1 accessible to Ordinary Persons[5] requires:
  - An Instructional Safeguard AND
  - A timer which limits the exposure times as given in Table 2 above, OR
  - An Equipment Safeguard, OR
  - A Containment Safeguard which should reduce the effective irradiation to below 1mW/m².

[3] Position Statement on Germicidal UV-C Irradiation, UV-C Safety Guidelines, Global Lighting Association, May 2020

[4] This number derives from IEC 62471 [1] and should be used for all UV-C devices to make them comparable to categorize them in the correct UV-C risk group.

[5] A person not being a Skilled Person.

- UV-C RG ⩾ 1 accessible to Skilled Persons[6] requires:
    - An Instructional Safeguard AND
    - PPE

Controls Design Considerations

Here are four options for controlling human exposure to UV-C, in order of complexity. Engage a lighting controls consultant to coordinate the sequence of operations for occupancy detection and a mechanical controls consultant for programming.

Location: Limit access to trained staff by locating control switch in a separate room or a low traffic area, to keep it away from public.

Interlock: UV-C systems may include built-in interlock devices that prevent operation when safety may be compromised.

Occupancy detection: Provide two sources of occupancy detection. CO2 sensors indicate spaces have recently been occupied and vacancy sensors indicate people are no longer present. This way energy is not wasted treating spaces that are not being used and people will not be exposed to UV light.

Programming: Connecting data on occupancy detection and UV-C lighting on-off states to a building's Energy Management Information System (EMIS) enables automatic fault detection and alarms.

Hazard Warnings:
Provide the following signage.

- UV-C warning symbol according to IEC 61549-310-1
- Warning sign that eyes and the skin must be protected – "UV HAZARD – PROTECT EYES AND SKIN".
- Provide labels and indicator switches that illuminate when UV-C device is ON.
- For upper room UVGI lamps, place warning signs near the lamps.
- For HVAC UV-C systems, place signs on AHU access panels.
- Label activation switches and consider lockable switch guards to prevent access from unauthorized persons.
- Ozone warning symbol, if applicable.
- Instructional safeguards [7]

[6] A personal with relevant education or experience to enable him/her to identify and take appropriate actions to reduce risk of injury to themselves and others.
[7] Position Statement on Germicidal UV-C Irradiation, UV-C Safety Guidelines, Global Lighting Association, May 2020.

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		

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 Instruction Safeguard table above.

Example of UV-C warning label:

UV-C RISK GROUP 3

UV-C

WARNING UV-C emitted from this product.
Avoid eye and skin exposure to unshielded product.
Follow installation instructions and user manual.

Mercury Content

Most UV-C sources are mercury-based, until LEDs lamps are redesigned to peak at UV-C wavelengths. The World Health Organization considers mercury one of the top ten chemicals of major public health concern affecting nervous, digestive, and immune systems as well lungs and kidneys.[8] To reduce human exposure to mercury vapor and salts, follow mercury handling recommendations. Recycling lamps, as described in the graphic below, captures the mercury allowing reuse and safe processing.

[8] https://www.who.int/news-room/fact-sheets/detail/mercury-and-health

- Remember to treat broken or used UV-C lamps as hazardous waste to minimize the cumulative effect of this health hazard. Consult an industrial hygienist on proper handling to avoid mercury contamination.
- Plan to upgrade to LED UV-C lamps when available.

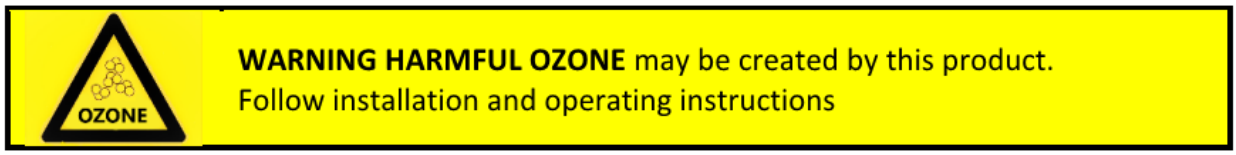
Ozone

Ozone (O_3), or "activated oxygen", is an unstable form of oxygen gas that can kill harmful bacteria. When you search for "Ozone and UV-C" the results conflict. Many UV-C system manufacturers indicate ozone is not produced above 200nm. EPA standards, however, indicate long-term exposure to O_3 is an issue below emission wavelength of 240nm, which includes the supposedly safer "Far UV-C" spectrum.

Traditionally, lamps with a shortwave UV-blocking coating are sold as "ozone-free." Even these lamps can produce enough ozone to cause discomfort. [9] As with dilution of the Covid-19 virus, adequate ventilation with high outside air ratios should be calculated before any UV-C system is used.

Product marketing may extol the additional disinfecting properties of ozone, but when it effectively destroys harmful bacteria, its concentration is above levels considered safe for humans. [10]

The figure below is an example of Ozone warning label.



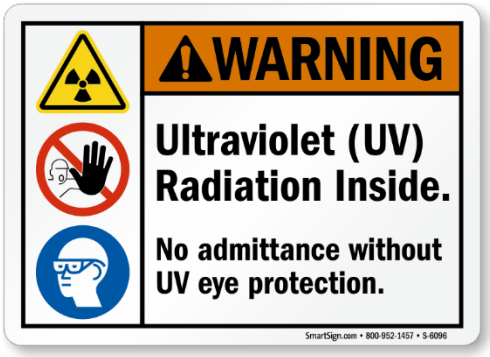
- Emission wavelength below 240 nm: long-term ozone exposure limit – 0.1 ppm (approx. 200 ug/m^3), EPA standards
- UV-C devices that exceed limits above require ozone warning label.

Maintenance

Risk of exposure during maintenance requires an equal amount of care as during use of UV-C systems. Frequency depends on scheduled use and predicted lamp life. 10,000-hour lamps are typically changed yearly in HVAC systems. Well-placed hazard warning signs indicating the presence of potential

[9] https://www2.lbl.gov/ehs/safety/nir/assets/docs/uv/UV%20lamps%20safety%20tips.pdf
10 https://www.fda.gov/medical-devices/safety-communications/potential-risks-associated-use-ozone-and-ultraviolet-uv-light-products-cleaning-cpap-machines-and

UV radiation hazards should restrict access and specify PPE. Special safety glasses with appropriate UV filter markings for the UV range. Protective wear / clothing to cover exposed skin – including hands and face.



Additional procedures include:

- Lamp must be OFF and cool prior to cleaning
- Lamp/Bulb replacement should proceed according to manufacturer's instruction.

Training should include:

- Use of appropriate PPE
- Safe handling of UV-C device
- First aid response
- Health and safety education
- Complete understanding of manufacture's instruction and user manual.

Standards

- 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"

Conclusion

Incorporating a UV-C germicidal irradiation strategy to mitigate the transmission of Covid-19, along with masks, distance, and testing, is still sound logic. As long-range LED UV-C systems are developed, a few of the risks associated with the use and maintenance of UV-C systems will dissipate. Planning how to safely use UV-C systems to protect all occupants can mitigate the associated risks and liabilities. Identify risk groups and design appropriate control systems. Dig into the mercury issue of current UV-C systems and be aware of potential ozone issues with future Far UV-C products. Maintenance tasks have the highest risk and will always require careful training. Finally, signage is key to help occupants understand the risks of UV-C exposure. Think twice before implementing UV-C systems where people who are visually impaired, children, animals, and those who can't read may occupy spaces without assistance.

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