Considerations for UVC Efficacy Test Standard of UV Devices in Healthcare Settings

UV for Whole Room Surface Disinfection

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presented by

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Current Status of Standards or Efficacy Claims for Whole Room UV Disinfection Devices

• Currently, no industry standards for characterizing efficacy of whole room UVC disinfection devices

• EPA regulated UV devices as pesticidal device, nut unlike pesticidal devices, they do not require product registration. Only requirement is of the facility to be EPA registered. Manufacturer is expected to have proof of whatever claims are being made for their device.

• Example marketing claims
  – … Destroys (.or kills) bacteria in xxx minutes
  – … disinfects whole room in xxx minutes
  – … reduce infection rates by xxx %
  – … deactivates endospores in less than 5 minute
  – …xxx % reduction of endospores in xxx minutes
  – …achieves minimum xxx log reduction in xxx minutes at xx feet distance
Variations of Portable UV Devices for Room Disinfection

- Fixed – Ceiling Mounted Devices available
- Various Object (phones, tablets, keypads, pens) disinfection also being introduced
Variations of Portable UV Devices for Room Disinfection

• Different form factors and features such as user interface, safety, software, data reporting

• Different UV wavelengths employed:
  – UVC (254 nm) - pulsed xenon (200-315nm)
  – Far UV 222 nm - Visible 405 nm (reactive oxygen species)
  – UV LEDs 254 nm, 270+ nm

Source: Adapted from Jagger (1967)
Variations of Portable UV Devices for Room Disinfection

• Variation in treatment protocols: total room treatment time varies from 10 mins to 50 mins (except continuous 405 nm)
  – Total device output as a fn of # lamps, height, intensity, configuration, reflectors etc.
  – Device location / proximity to target surfaces
  – Single placement versus multiple placements
  – Automated cycle times based on room size mapping; reflected dose measurements, measured dose on surfaces
  – Clinical lab studies- variation in study set-up (no standard)
    • Strain of microorganism, carrier type & size, prep of inoculum, type of soiling, inoculation of carrier, distance/orientation of carrier w.r.t device etc. *(now addressed by new ASTM E 3135 standard)*
  – Inconsistent dose assumptions used by different manufacturers
How Much UV-C Do I Need?
UVC Efficacy

- UVC Dose to achieve a specific log reduction varies from one micro-organism to another

UVC Dose Values for 99% Disinfection (2 Log Reduction)

- **MRSA**
  - 7,106 μW-sec/cm²

- **Clostridium difficile**
  - 38,500 μW-sec/cm²

- **Acinetobacter Baumannii**
  - 6,600 μW-sec/cm²

- **VRE**
  - 12,600 μW-sec/cm²

- **Influenza A**
  - 4,558 μW-sec/cm²

- **Aspergillus Niger**
  - 330,000 μW-sec/cm²
Understanding UVC Dose vs Efficacy

• Level of disinfection is measured in terms of % disinfection or log reduction
  
  Log 1 (90%)  Log 2 (99%)  Log 3 (99.9%)  Log 4 (99.99%).....

• Log reduction achieved on a target micro-organism is a function of applied UVC dose

• **Total Applied Dosage** = UVC Intensity at target x Time

  • Example: Clostridium Difficile (C-Diff)
  
  • 99% Disinfection (2 Log Reduction)
  • Dose required for 99% disinfection: 60,00 \( \mu \text{w cm}^2\)-sec
  • Assume Device intensity on surface: 100\( \mu \text{w/cm}^2\)
  • Total Time required : 60,000/100 = 600 secs (10 mins)!

  • 99.99% Disinfection (4 Log Reduction)
  • Theoretical Dose required for 99.99% disinfection: 120,000 \( \mu \text{w secs/cm}^2\)
  • Total Time required : 120,000/100 = 1200 secs (20 mins)! **IS THAT TRUE?**
Log Reduction as a function of UV Dose

Nerandzic et al. BMC Infectious Diseases 2010, 10:197

Multistage Microbial Response

Figure 2.8. Shapes of UV Dose-Response Curves

Source: Adapted from Claggett et al. (1965)
### UV Rate Constants

#### Factors affecting UV rate constants

- Microbial species
  - Vegetative bacteria
  - Bacterial spore
  - Virus
  - Fungal cells & yeast
  - Fungal spores
- UV wavelength
- UV intensity
- Relative humidity
- Media type
  - Water
  - Air Surface

#### Airborne Pathogen Table

<table>
<thead>
<tr>
<th>AIRBORNE PATHOGEN</th>
<th>GROUP</th>
<th>SHAPE</th>
<th>DIA (microns)</th>
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</thead>
<tbody>
<tr>
<td>Rhinovirus</td>
<td>VIRUS</td>
<td>icosahedral</td>
<td>0.023</td>
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<tr>
<td>Orthomyxovirus - Influenza</td>
<td>VIRUS</td>
<td>helical</td>
<td>0.10</td>
</tr>
<tr>
<td>Coronavirus</td>
<td>VIRUS</td>
<td>helical</td>
<td>0.11</td>
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<tr>
<td>Pseudomonas aeruginosa</td>
<td>BACTERIA</td>
<td>rods</td>
<td>0.57</td>
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<tr>
<td>Staphylococcus aureus</td>
<td>BACTERIA</td>
<td>spherical</td>
<td>0.90</td>
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<tr>
<td>Bacillus anthracis</td>
<td>BACTERIA</td>
<td>spores</td>
<td>1.13</td>
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<tr>
<td>Aspergillus niger</td>
<td>FUNGI</td>
<td>spores</td>
<td>3.50</td>
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<tr>
<td>Candida albicans</td>
<td>FUNGI</td>
<td>spores</td>
<td>5.00</td>
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<tr>
<td>Stachybotris chartarum</td>
<td>FUNGI</td>
<td>spores</td>
<td>5.65</td>
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</table>
# UV Rate Constants and Dose

<table>
<thead>
<tr>
<th>Microbe</th>
<th>Type</th>
<th>Water</th>
<th>Surface</th>
<th>Air-Lo RH</th>
<th>Air –High RH</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>$K \ (m^2/J)$</td>
<td>$D_{90} \ (J/m^2)$</td>
<td>$K \ (m^2/J)$</td>
<td>$D_{90} \ (J/m^2)$</td>
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<tr>
<td>Bacteria</td>
<td>Veg</td>
<td>0.08463</td>
<td>27</td>
<td>0.14045</td>
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<tr>
<td>Viruses</td>
<td>All</td>
<td>0.05798</td>
<td>40</td>
<td>0.03156</td>
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<tr>
<td>Bacterial spores</td>
<td>Spores</td>
<td>0.01439</td>
<td>160</td>
<td>0.01823</td>
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<tr>
<td>Fungal cells/yeast</td>
<td>Veg</td>
<td>0.01008</td>
<td>229</td>
<td>0.00700</td>
<td>329</td>
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<tr>
<td>Fungal spores</td>
<td>Spores</td>
<td>0.00916</td>
<td>251</td>
<td>0.00789</td>
<td>292</td>
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