Germicidal Ultraviolet Light (Radiation) for Reducing Disease Transmission

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Germicidal UV

253.7nm UV-C LAMPS = GERMICIDAL EFFICIENCY WITHOUT OZONE PRODUCTION

LOW-PRESSURE MERCURY LAMP

GERMICIDAL EFFECTIVENESS CURVE

UVC LED WITH PEAK OUTPUT AT 265 NM

Transmission [%] vs Wavelength [nm]

Mercury vapor lamps

UVC LEDs
Germicidal UV damages DNA/RNA

Dimers form between adjacent thymine nucleotides inactivates cells

Microbial response to germicidal UV (cm²/mJ)
...a low value means you need a lot of UV...

Inactivation rates in Air

- fungal spores
- B.sub spores
- M.para
- M.tb
- S.aureus
- MHV coronavirus
- Measles**
- Influenza A

In water

Kowalski, W., 2010; Walker and Ko 2007
Relative Humidity Effect

Dose for 90% inactivation

- **Fungal spores**: High RH vs. Low RH
- **Fungal - veg**: High RH vs. Low RH
- **Bacterial spores**: High RH vs. Low RH
- **Viruses - all**: High RH vs. Low RH
- **Bacteria - veg**: High RH vs. Low RH

Kowalski, W. 2010
Rooms in which HVAC retrofits are difficult to do but additional air changes are needed to reduce risk of infections (e.g. hospital ERs, treatment and isolation rooms).

Rooms in which infectious aerosol may be generated (e.g. hospital treatment and isolation rooms) and additional control is needed.

Crowded environments where unsuspected infectious persons may be present (e.g. jails, homeless shelters, hospital waiting rooms).

Upper-Room Air Disinfection

Lighting Research Center
Rensselaer Polytechnic Institute
Air Disinfection in Day Schools*

W. F. WELLS

Associate Professor in Research in Air-borne Infection, Laboratories for the Study of Air-borne Infection,† Department of Preventive Medicine and Public Health, University of Pennsylvania School of Medicine, Philadelphia, Pa.

The first sentence of this paper reads: “The prevalence of respiratory infection during the season of indoor congregation suggests a natural relationship between ventilation and communicable disease.”
UVC in NY schools modified the spread of measles/chicken pox (Perkins et al. 1947)

Guinea pigs receiving hospital ward air irradiated with UVC did not contract TB (Riley et al. 1962)

The History of Ultraviolet Germicidal Irradiation for Air Disinfection (Reed 2010)
Fig. 2. Spatial distribution of ultraviolet irradiance measured using actinometry in the upper-room zone with 100% UVGI (216 W, all UV lamps operating).

87 m³ room, upper zone 42 µW/cm²

Xu, P. et al. 2003; Xu, P., et al. 2005
We found that among different engineering control measures, UVGI singly is the optimal strategy combined with effective isolation and vaccination interventions for containing influenza, measles, and chickenpox.

Liao et al. 2008

Xu, P. et al. 2003; Xu, P., et al. 2005
Addition of germicidal UV lights can significantly increase air changes without HVAC modifications

**Fig. 7.** The effect of air cleaning strategies on TB concentration in the distribution room (DR).

*Emmerich et al. 2013*
CDC/NIOSH guidelines 2008

• Uniform UVC radiation in upper zone
• 30-50 µw/cm² average
• 1.87 W/m² of lamps for floor area or 6 W/m³ of lamps for upper zone volume
• Humidity < 60% RH
• Mixing preferred
Safety of Upper-Room gUV

• Tuberculosis Ultraviolet Shelter Study: a double-blind, placebo-controlled field trial of upper-room UVGI at 14 homeless shelters in six U.S. cities from 1997-2004

• No statistically significant difference in the number of reports of symptoms between the active and placebo periods

• Maintenance important!
UV-C surface/air cleaning technology

Anderson et al. 2017

1st randomized control trial with UV device: “Patients admitted to rooms previously occupied by patients harbouring a multidrug-resistant organism or C. difficile were 10–30% less likely to acquire the same organism if the room was terminally disinfected using an enhanced strategy. The largest risk reduction occurred when a UV-C device was added to the standard disinfectant strategy.”

<table>
<thead>
<tr>
<th>Meticillin-resistant Staphylococcus aureus</th>
<th>Reference group</th>
<th>UV group</th>
<th>Bleach group</th>
<th>Bleach and UV group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exposed patients</td>
<td>3300</td>
<td>1872</td>
<td>3631</td>
<td>2425</td>
</tr>
<tr>
<td>Incident cases (%)</td>
<td>73 (2.2%)</td>
<td>28 (1.5%)</td>
<td>74 (2.0%)</td>
<td>63 (2.6%)</td>
</tr>
<tr>
<td>Exposure days</td>
<td>14525</td>
<td>7934</td>
<td>15343</td>
<td>10681</td>
</tr>
<tr>
<td>Rate (per 10 000 exposure-days)</td>
<td>50.3</td>
<td>35.3</td>
<td>48.2</td>
<td>59.0</td>
</tr>
<tr>
<td>Risk reduction (95% CI)</td>
<td>Reference</td>
<td>15.0 (-0.6 to 30.6)</td>
<td>2.1 (-13.8 to 17.8)</td>
<td>-8.7 (-18.0 to 0.5)</td>
</tr>
<tr>
<td>RR (95% CI); p value</td>
<td>Reference</td>
<td>0.67 (0.48 to 0.94); 0.019</td>
<td>0.89 (0.72 to 1.09); 0.260</td>
<td>1.09 (0.85 to 1.39); 0.503</td>
</tr>
</tbody>
</table>
UV In-Duct Air Disinfection

No reduction in culturable concentrations at this duct velocity

Max velocity 2.6 m/s

Fig. 9. Inactivation efficiency for devices installed at mixed and supply air locations in New York.

Lee and Bahnfleth 2013; Kujundzic et al. 2007
Conclusions

- Long history of upper-room germicidal UV for air disinfection, used against infectious diseases that have airborne transmission.
- Highly effective with appropriate design and use, and can add additional air changes per hour.
- Appropriate installation and maintenance is safe.
- Surface and in-duct applications are effective and useful with appropriate design and use.


Nardell et al. (2008) Public Health Reports, 123:52-60


Xu et al. (2003). Efficacy of ultraviolet germicidal irradiation of upper-room air in inactivating bacterial spores and Mycobacteria in full-scale studies, Atmos Environ 37:405-419.