


Germicidal Ultraviolet Light (Radiation) for Reducing Disease Transmission

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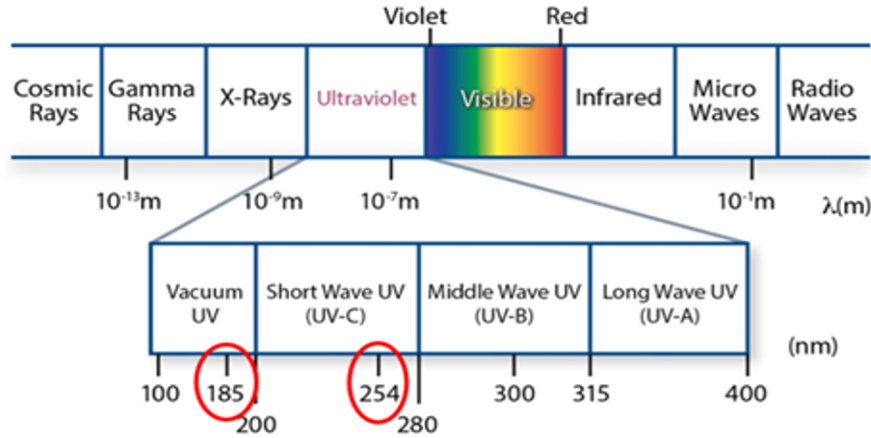
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Shellym80304.com



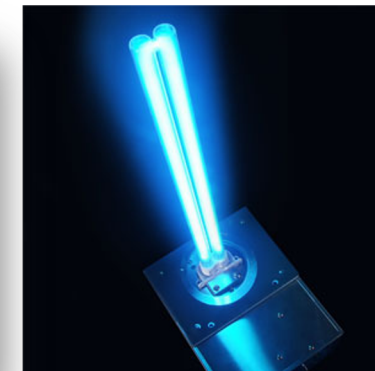
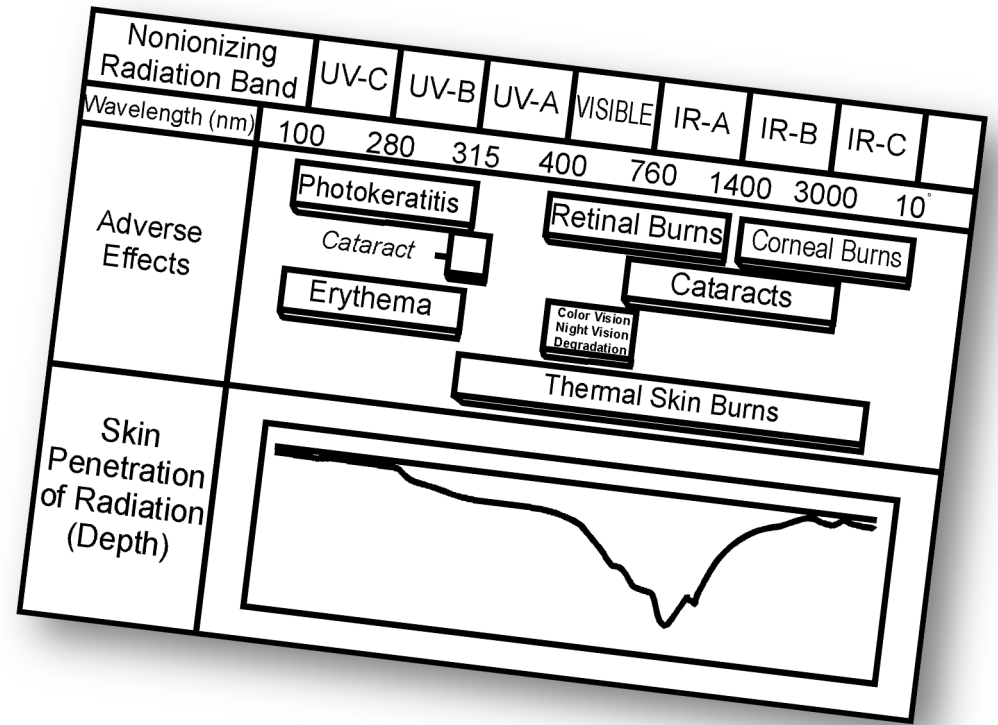
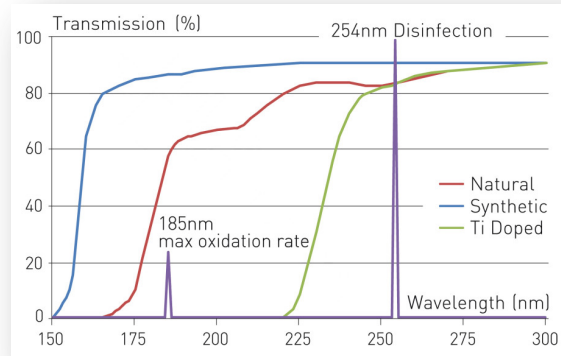
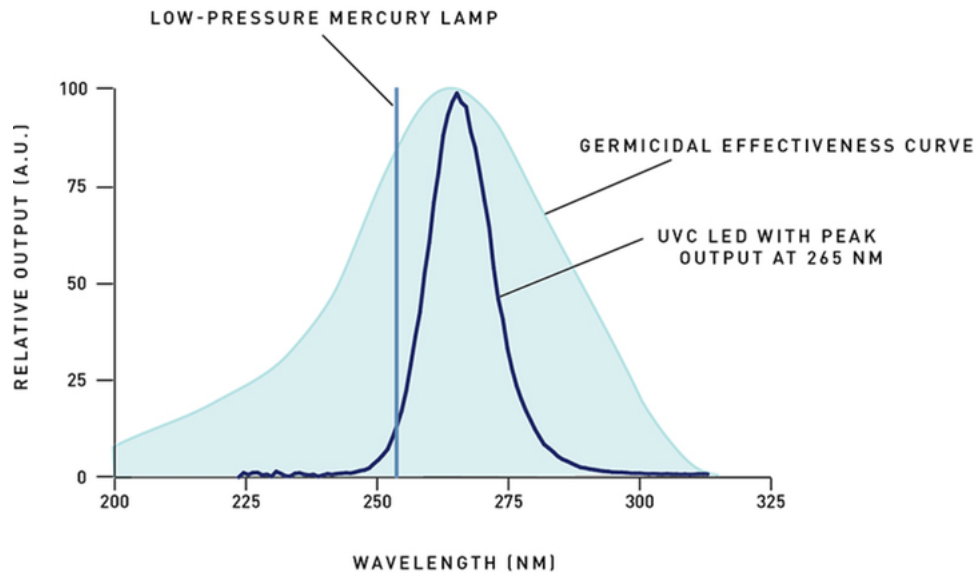
Engineering & Applied Science

UNIVERSITY OF COLORADO **BOULDER**

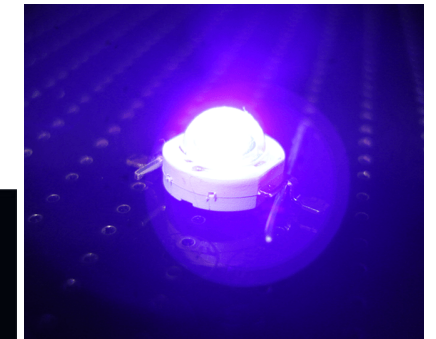
Germicidal UV



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

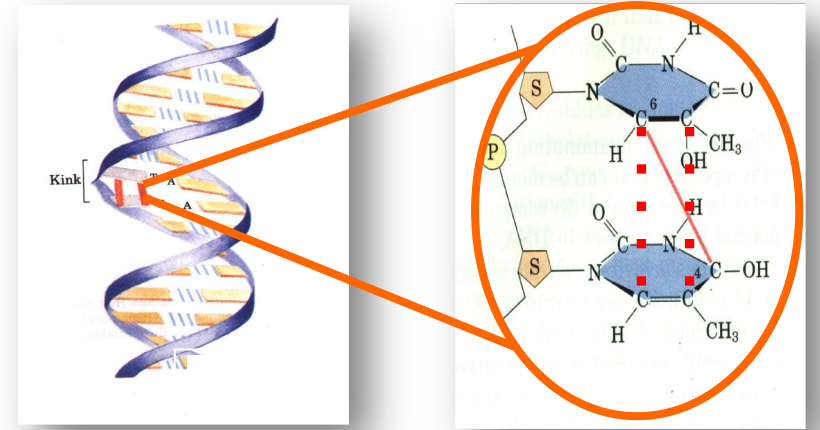


Mercury vapor lamps



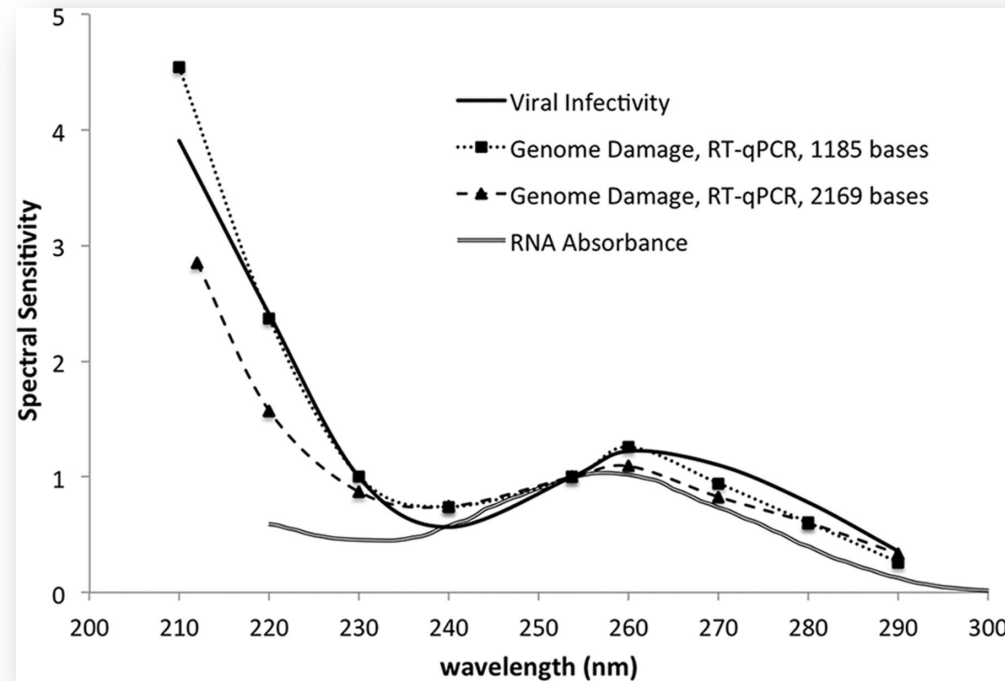
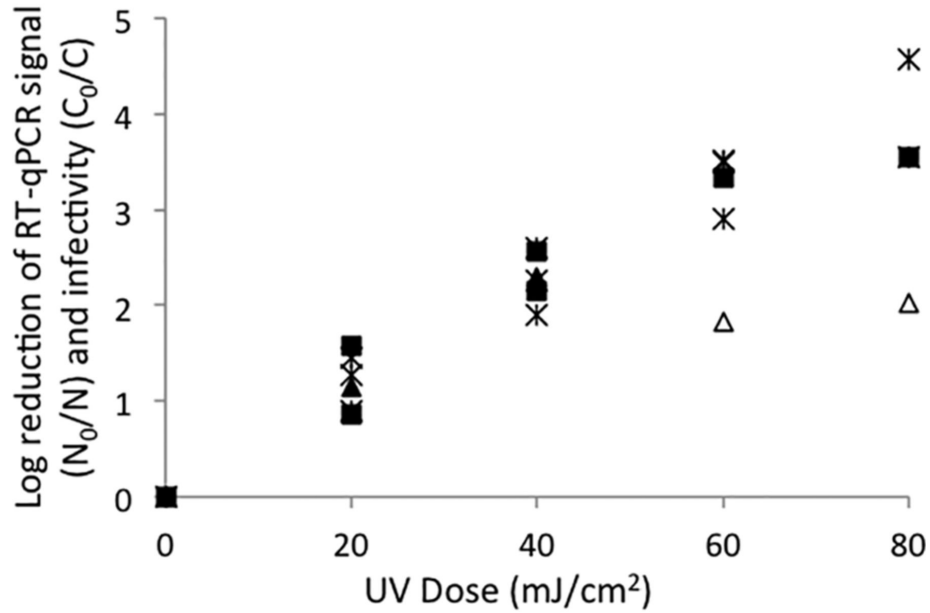
UVC LEDs

Germicidal UV damages DNA/RNA



dimers form between adjacent thymine nucleotides inactivates cells

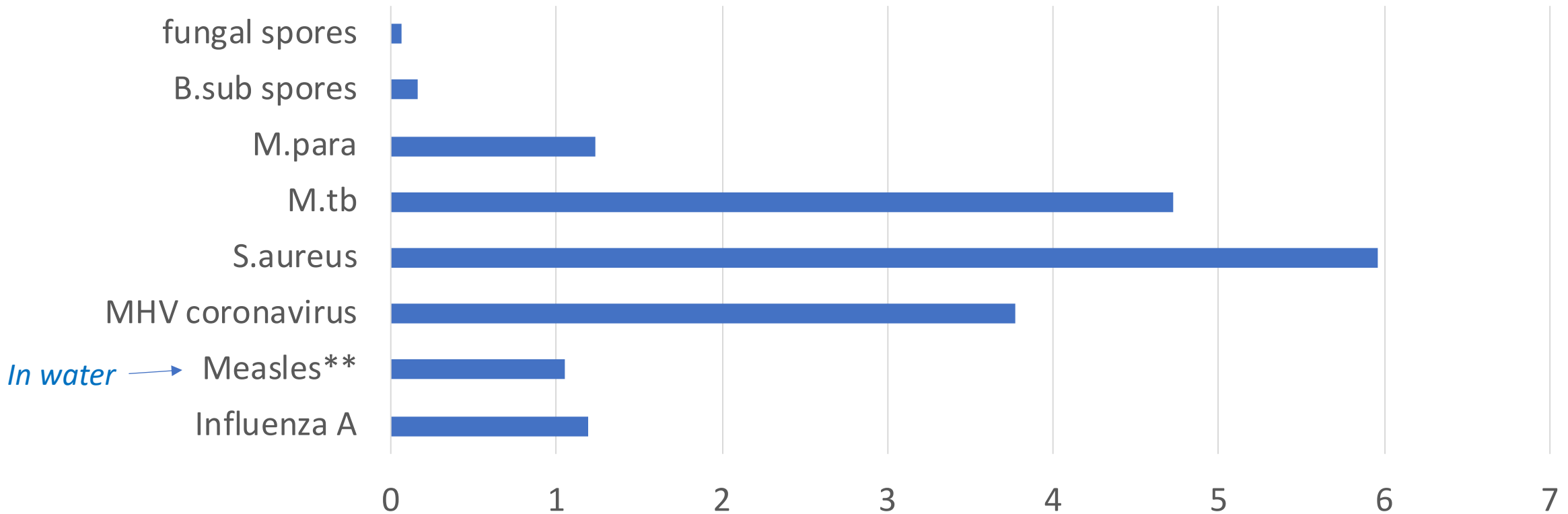
253.7 nm



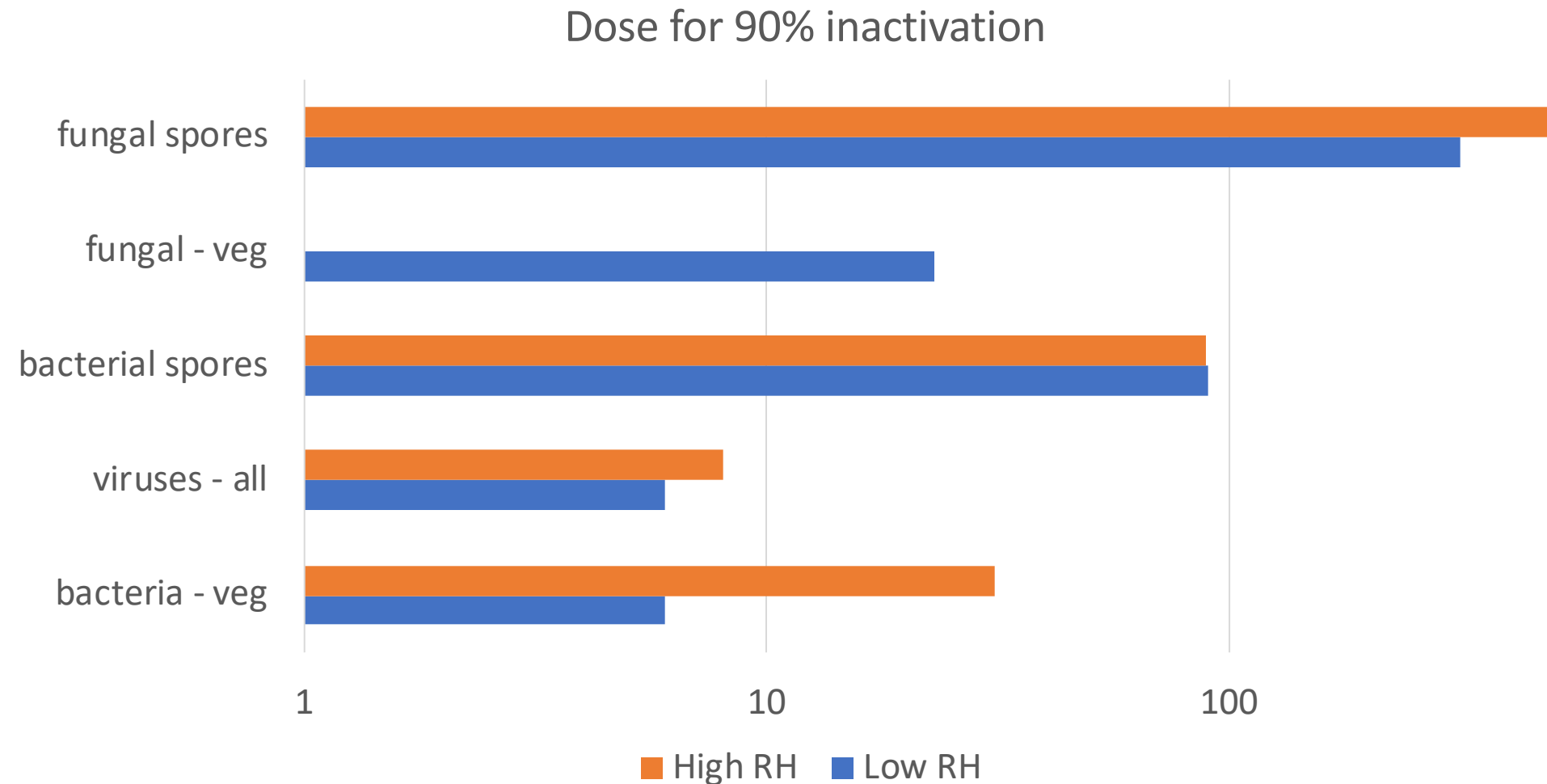
Microbial response to germicidal UV (cm^2/mJ)

...a low value means you need a lot of UV...

Inactivation rates in Air



Relative Humidity Effect



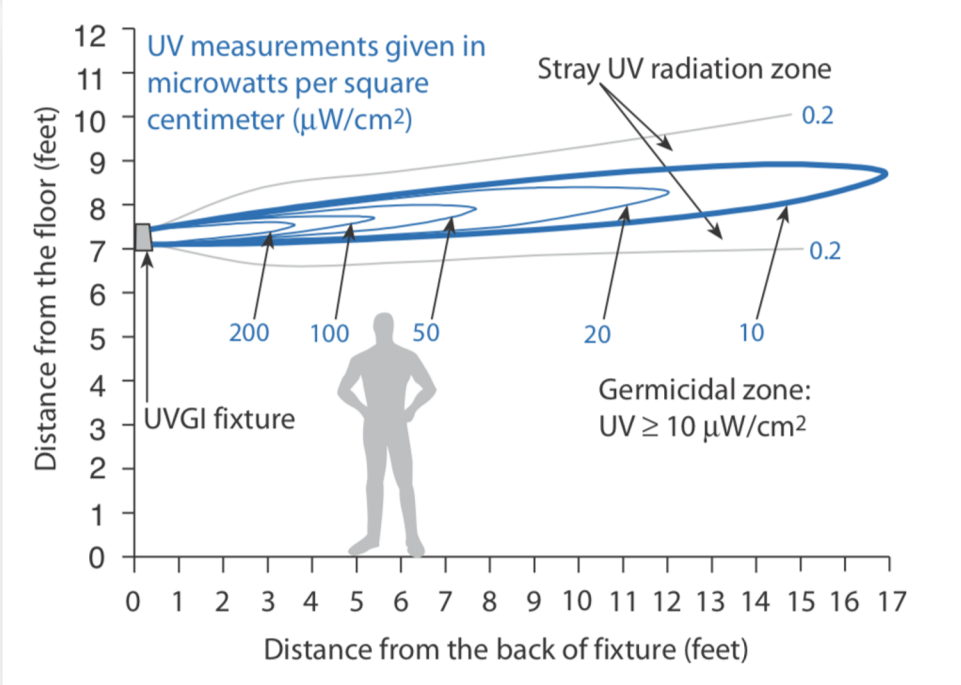


Rooms in which HVAC retrofits are difficult to do but additional air changes are needed to reduce risk of infections (e.g. hospital ERs, treatment and isolation rooms)

Upper-Room Air Disinfection



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



*Lighting Research Center
Rensselaer Polytechnic Institute*

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



Dec., 1943

Air Disinfection in Day Schools*

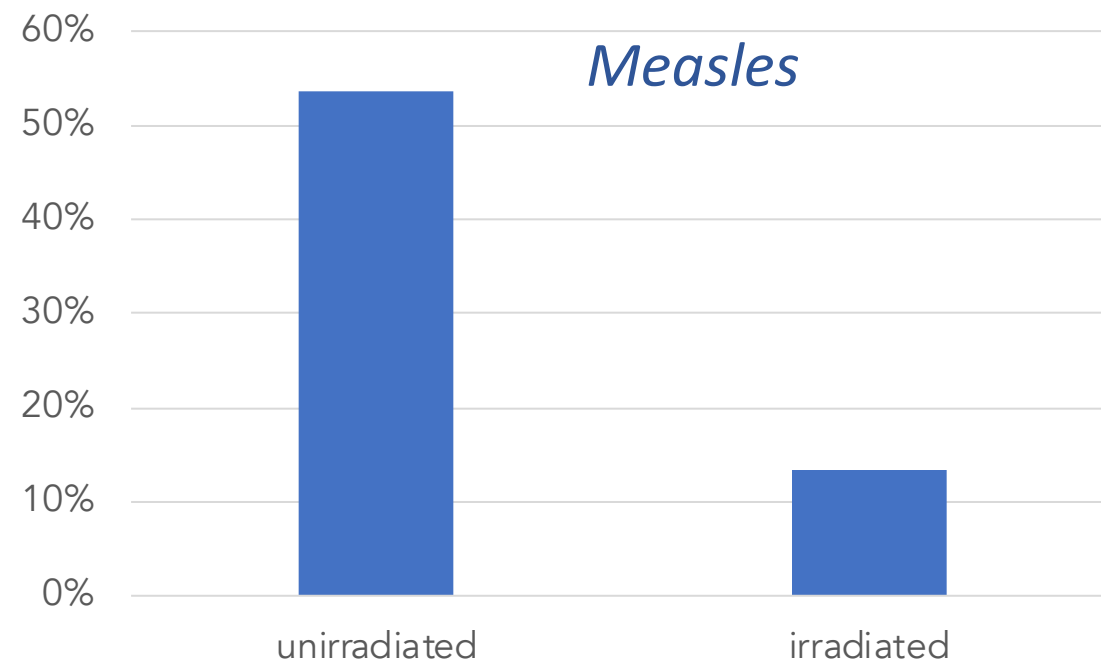
W. F. WELLS

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.



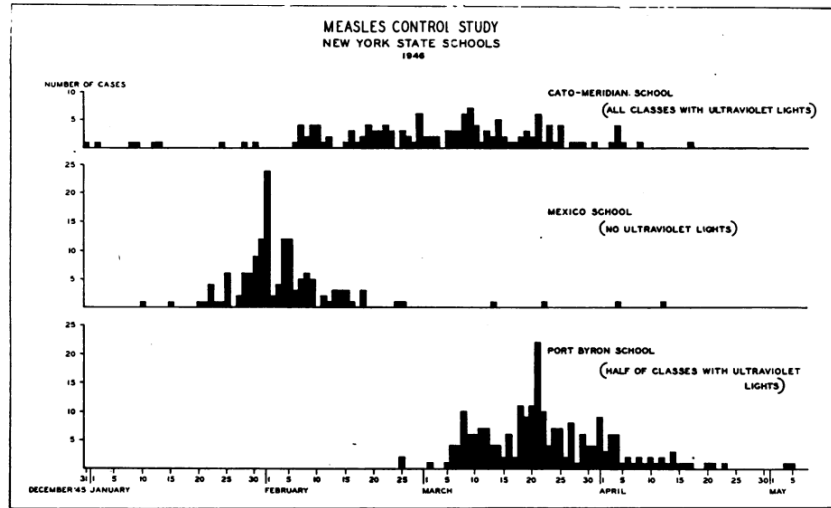
*The first sentence of this paper reads:
"The prevalence of respiratory infection during the season of indoor congregation suggests a natural relationship between ventilation and communicable disease."*

Susceptibles infected



UVC in NY schools modified the spread of measles/chicken pox

(Perkins et al. 1947)

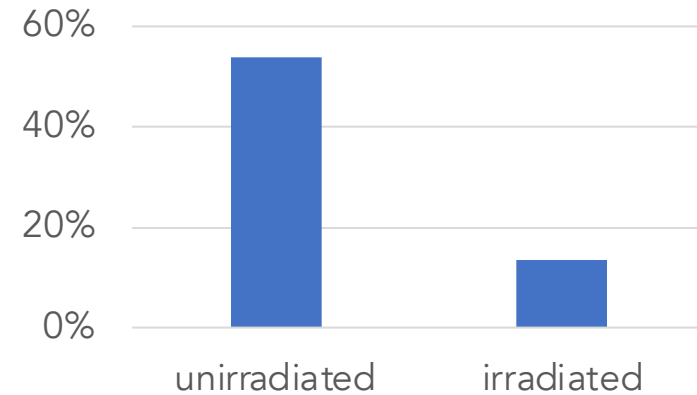


Air Disinfection in Day Schools*

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.

Susceptibles infected



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)

CDC NIOSH Upper Room Air Studies

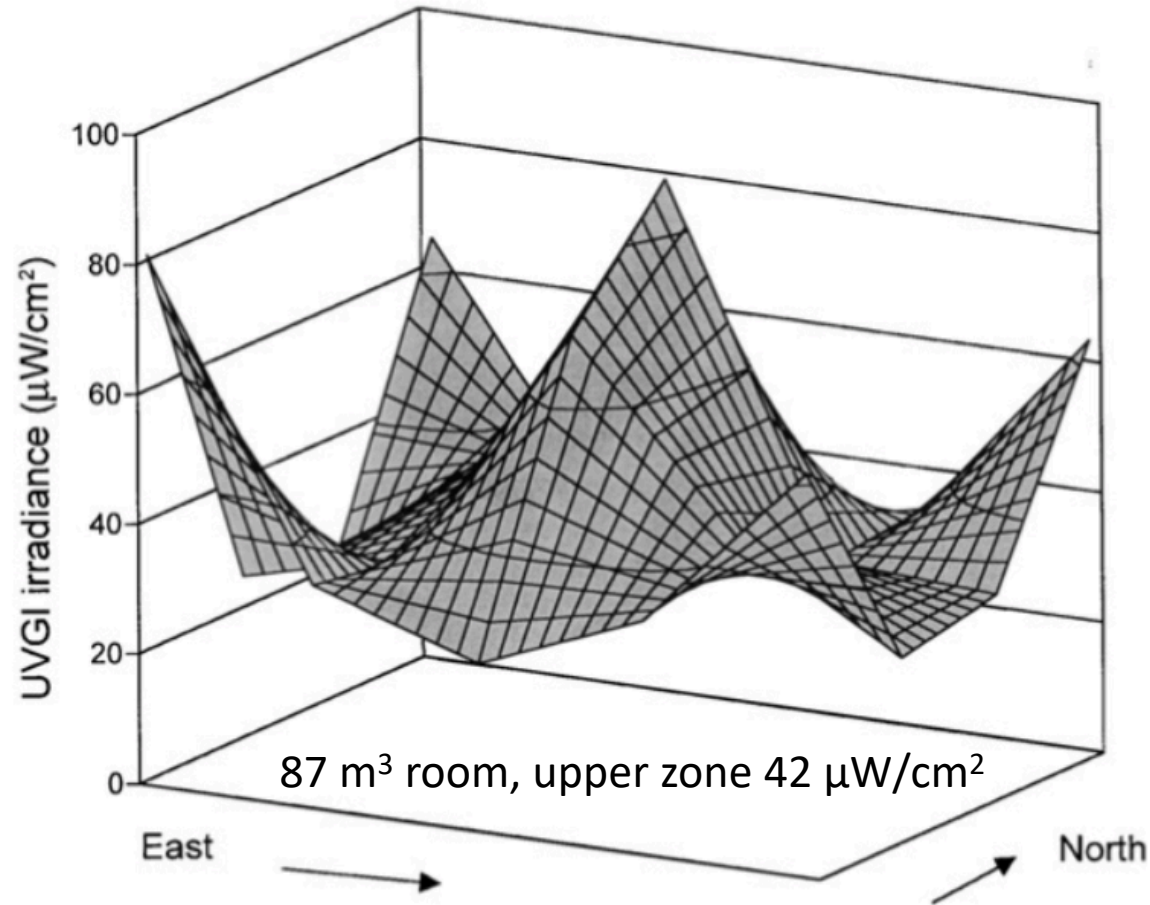


Fig. 2. Spatial distribution of ultraviolet irradiance measured using actinometry in the upper-room zone with 100% UVGI (216 W, all UV lamps operating).



CDC NIOSH Upper Room Air Studies

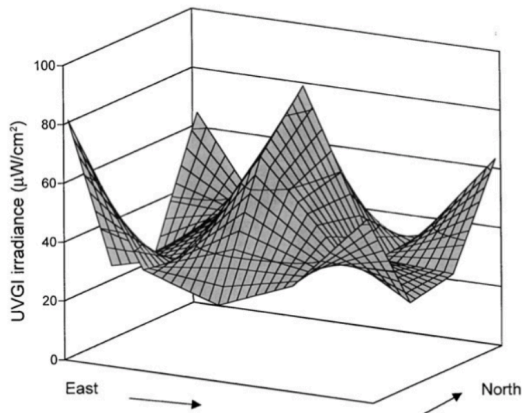
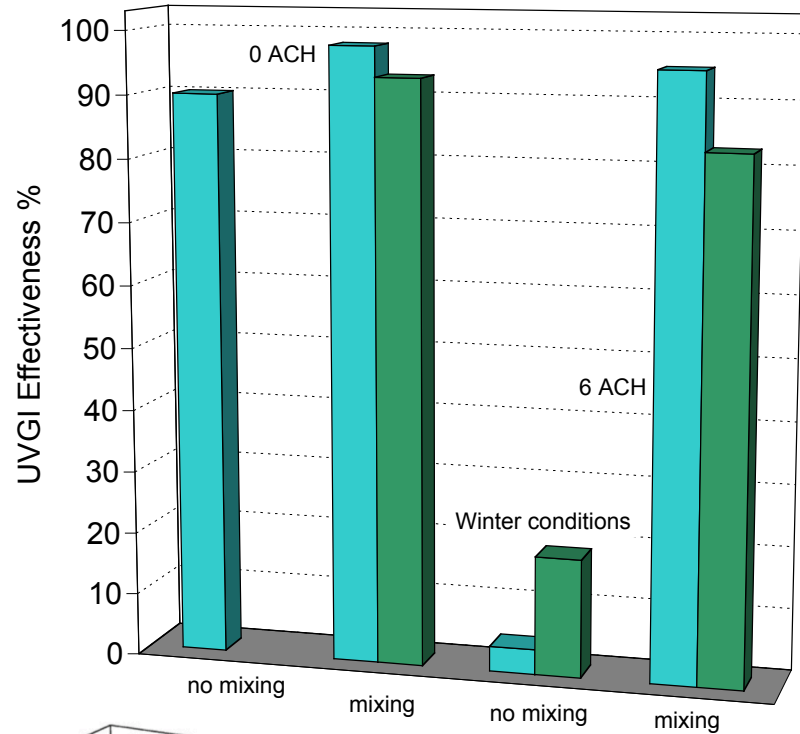


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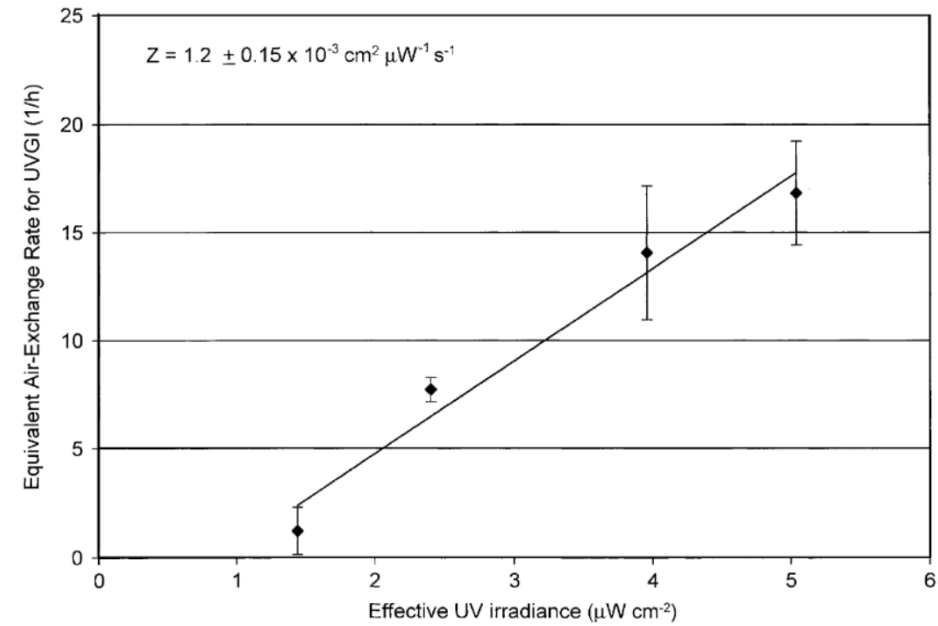


Fig. 7. UVGI inactivation rate as a function of effective UVGI spherical irradiance for *M. parafortuitum*. Effective UVGI spherical irradiance is the irradiance measured by actinometry in the upper-room zone only normalized to the fraction of room volume irradiated by UV (0.3/2.5 m).

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

Addition of germicidal UV lights can significantly increase air changes without HVAC modifications

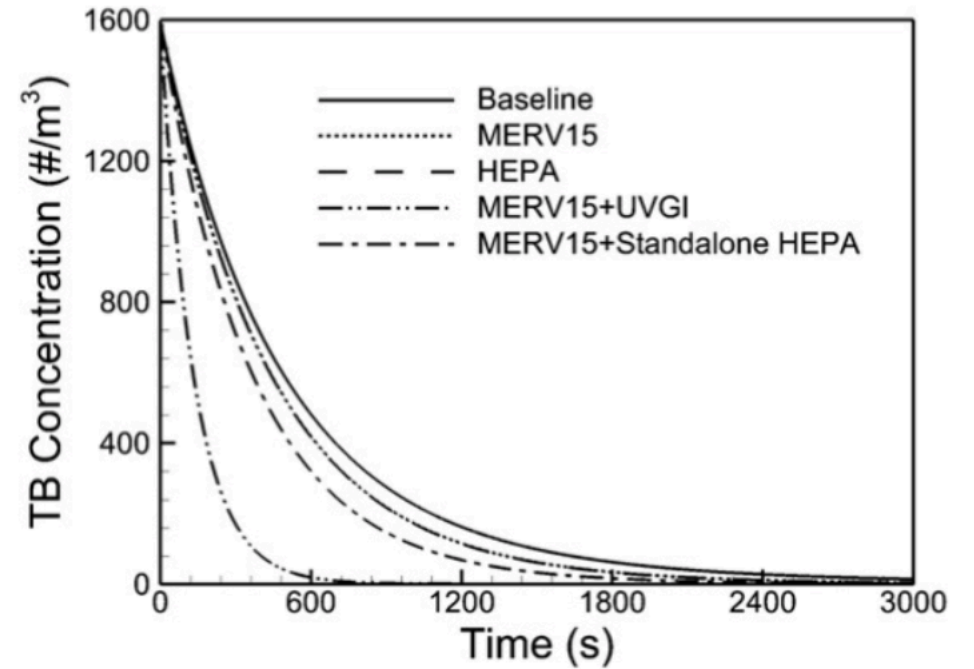
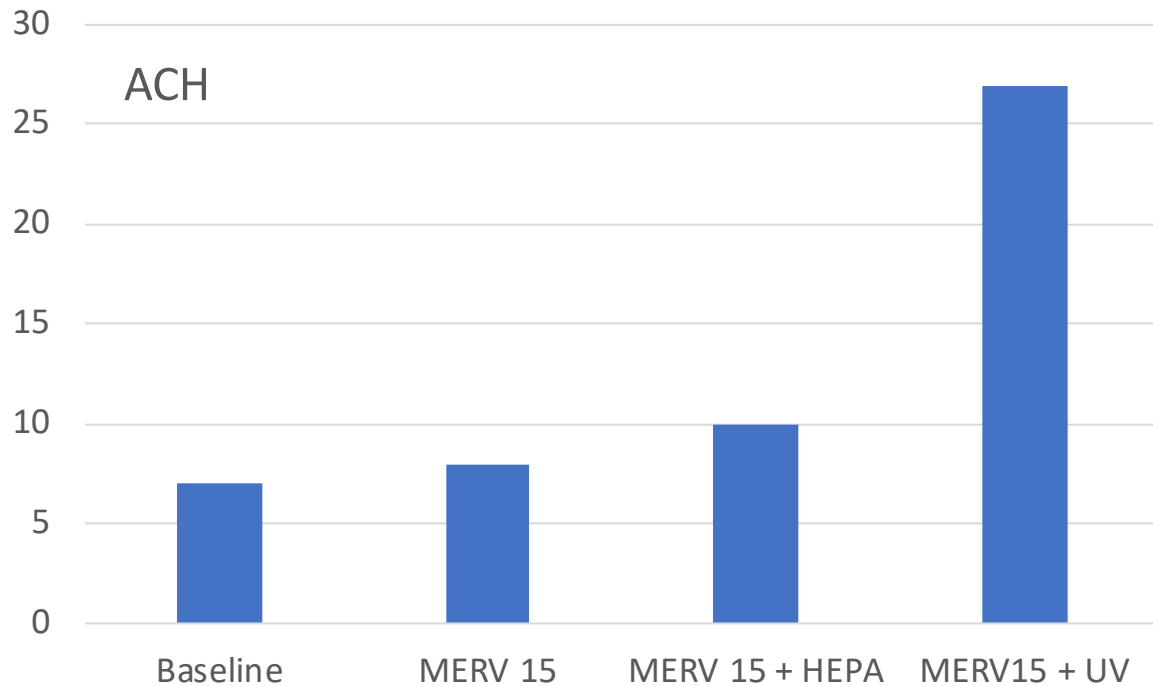
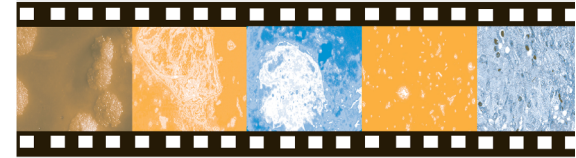


Fig. 7. The effect of air cleaning strategies on TB concentration in the distribution room (DR).

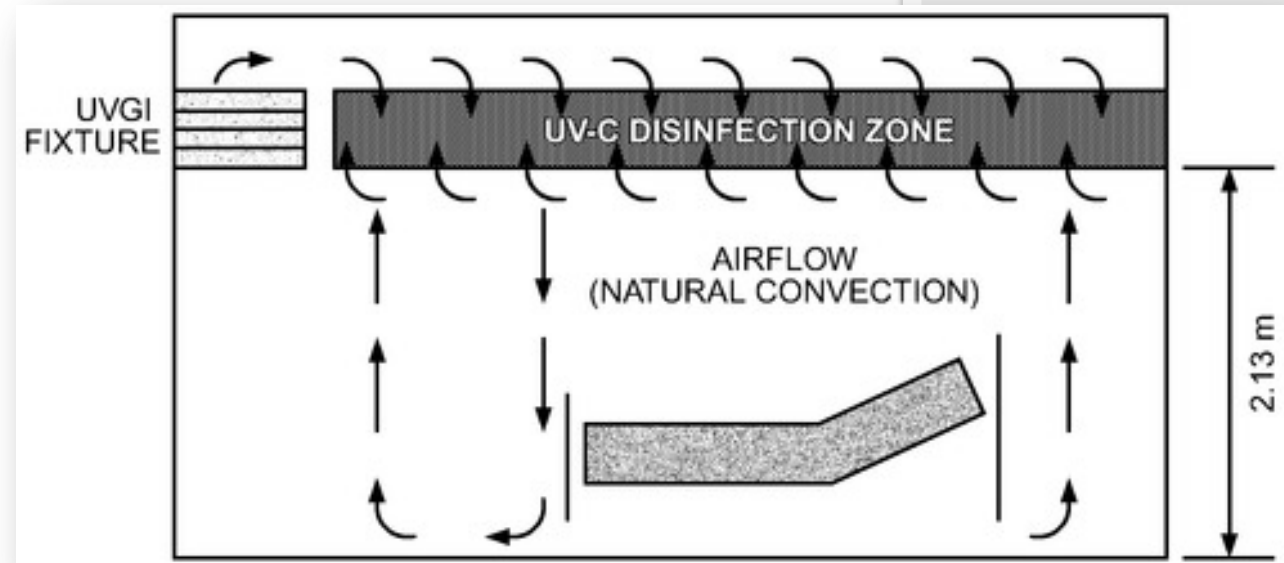
CDC/NIOSH guidelines 2008

- Uniform UVC radiation in upper zone
- 30-50 $\mu\text{w}/\text{cm}^2$ average
- 1.87 W/m^2 of lamps for floor area or 6 W/m^3 of lamps for upper zone volume
- Humidity < 60% RH
- Mixing preferred

*Environmental Control for Tuberculosis:
Basic Upper-Room Ultraviolet
Germicidal Irradiation Guidelines
for Healthcare Settings*



Department of Health and Human Services
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health



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!



Tuberculosis Ultraviolet Shelter Study New York City shelter in a church basement. Note the ultraviolet germicidal irradiation fixtures located on the upper wall, directly below the vents. Photo: ©Randall Perry Photography.

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."



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

UV In-Duct Air Disinfection

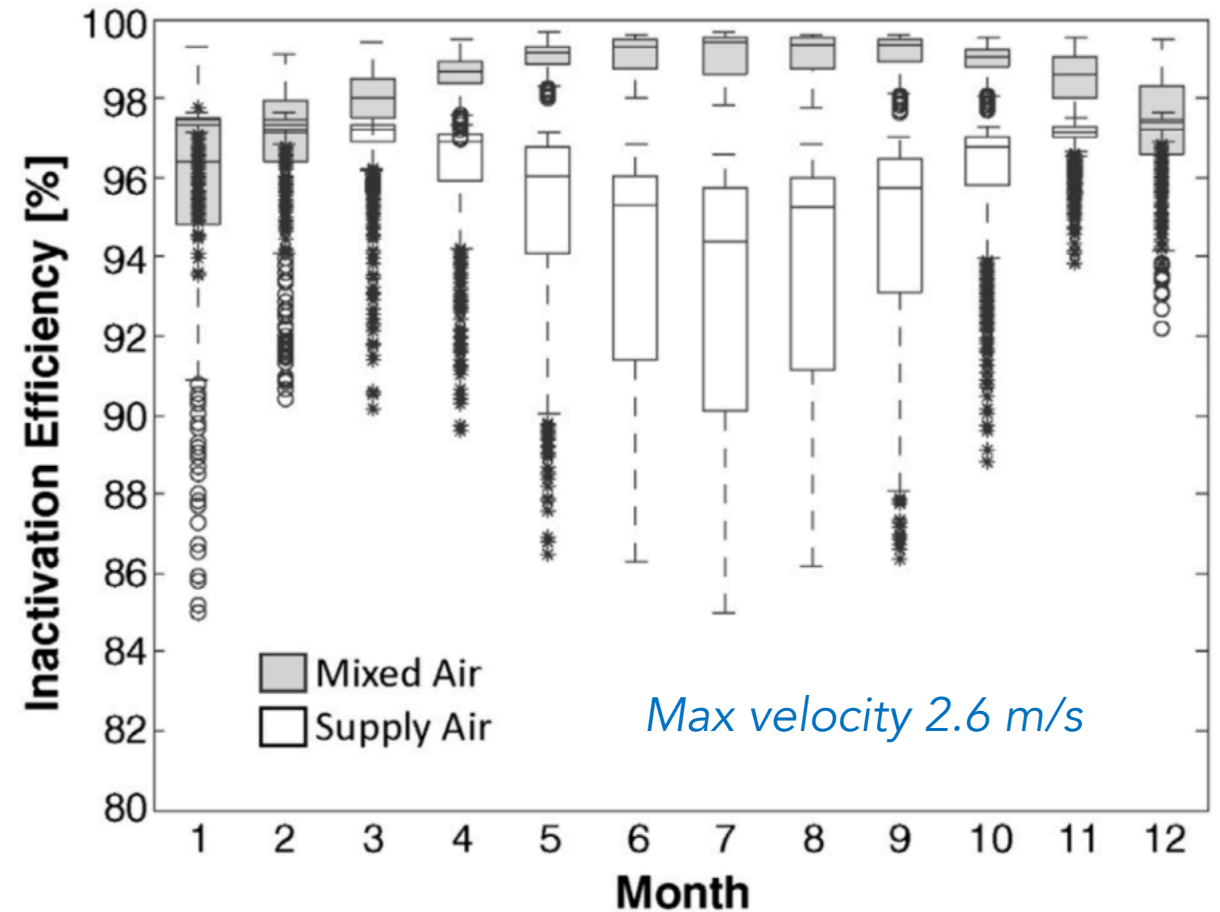
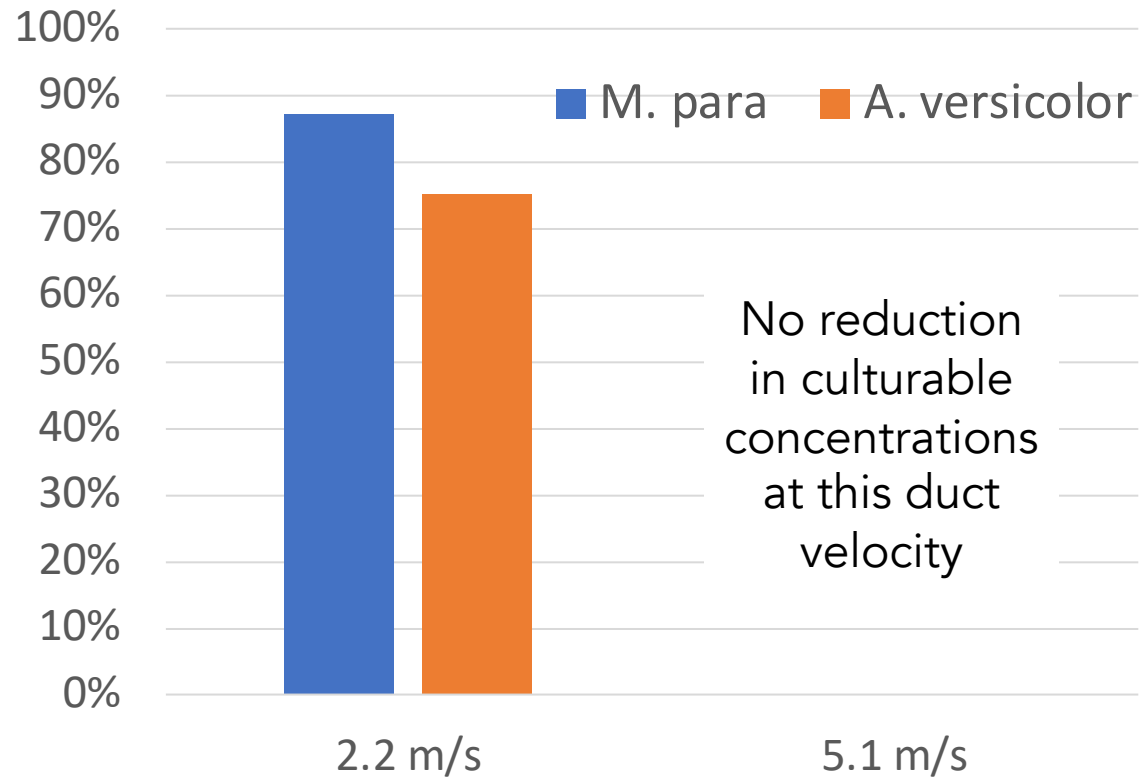


Fig. 9. Inactivation efficiency for devices installed at mixed and supply air locations in New York.

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

Anderson et al. (2017). Enhanced terminal room disinfection and acquisition and infection caused by multidrug-resistant organisms and *Clostridium difficile* (the Benefits of Enhanced Terminal Room Disinfection study): a cluster-randomised, multicentre, crossover study. *The Lancet*, 389(10071), pp.805-814.

Beck, et al. (2016). Comparison of UV-induced inactivation and RNA damage in MS2 phage across the germicidal UV spectrum. *Appl. Environ. Microbiol.*, 82(5), pp.1468-1474.

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Emmerich et al. (2013). Multizone modeling of strategies to reduce the spread of airborne infectious agents in healthcare facilities. *Building and Environment*, 60, pp.105-115.

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Perkins et al. (1947). Effect of ultra-violet irradiation of classrooms on spread of measles in large rural central schools, *AJPH* 73:529-537.

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