Considerations for Indoor Air Protection with Far-UVC

James Montavon[1,*], Richard Williamson[1], Peter Masschelin[2], Neal N. Oza[2], Sam Reynolds[3], Jacob L. Swett[1,4]

[1]Blueprint Biosecurity, Washington, DC, USA [2]Booz Allen Hamilton, Mclean, VA, USA[†], [3]Amodo Design, Sheffield, UK, [4]Biodesign Institute, Arizona State University, Tempe, AZ, USA

***Corresponding author: james.montavon@blueprintbiosecurity.org**

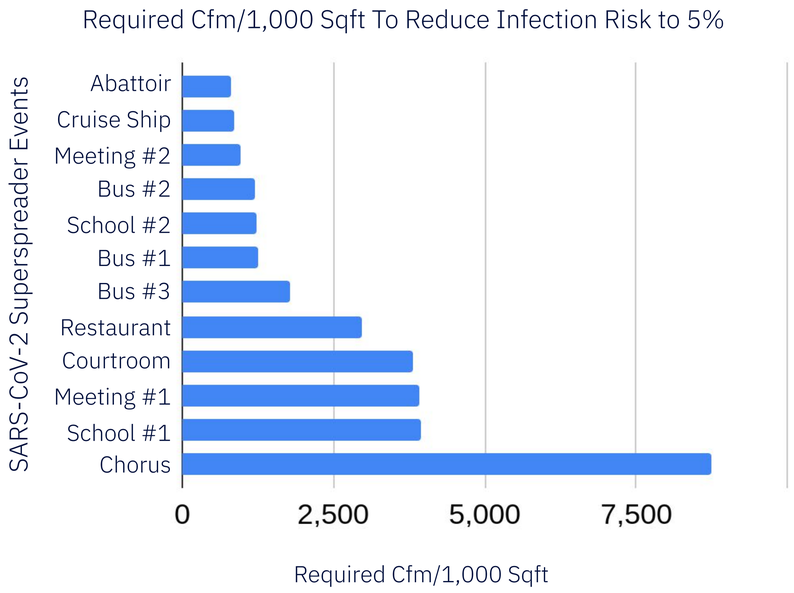
Protecting indoor air from infectious aerosols is challenging

ASHRAE 241 *Control of Infectious Aerosols* standard requires substantial interventions in some spaces.

ASHRAE 241 specifies an equivalent clean airflow per person for infection risk mitigation, or ECAi, which is multiplied by occupancy to give a total air cleaning requirement:[1]

	Occupant Density	Minimum Ventilation Requirements		**Min ACH (3.5m ceiling)**	Total ECA_i	**Additional eACH (3.5m ceiling)**
	ASHRAE 62.1				**ASHRAE 241**	
	Persons / 100m²	*L / s / person*	*L / s / m²*	**hr⁻¹**	*L / s / person*	**hr⁻¹**
Office	5	2.5	0.03	**0.4**	15	**0.3**
Elementary School Classroom	25	5	0.06	**1.9**	20	**3.2**
Gym (Aerobics room)	40	10	0.03	**4.4**	40	**12.0**
Restaurant Dining Space	70	3.8	0.09	**3.7**	30	**17.9**
Lecture Hall	150	2.5	0.03	**6.2**	25	**32.4**

SARS-CoV-2 superspreader events demonstrate the challenge:*

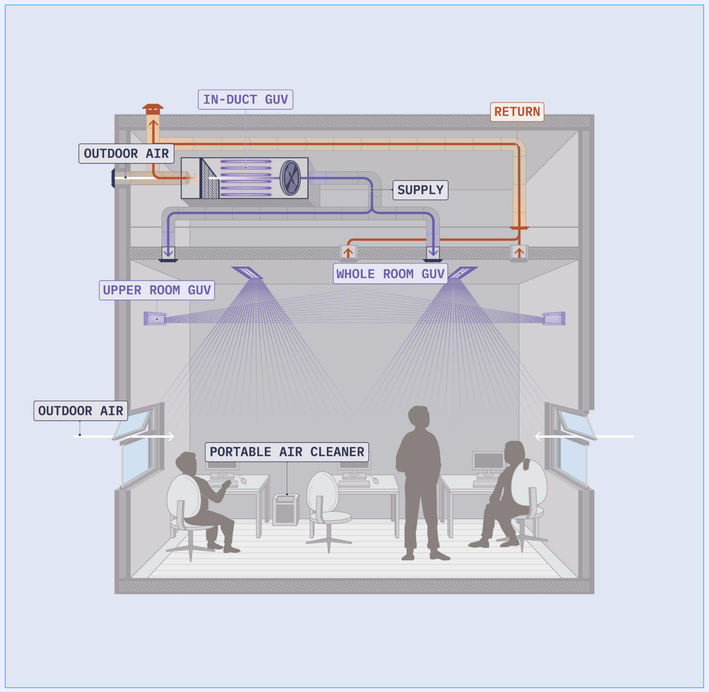


800-8,800 cfm of equivalent clean airflow per 1,000 sqft is required to reduce infection probability to 5%. This translates to 2.5-53 equivalent air changes per hour (eACH). **Ventilation and filtration alone cannot achieve the equivalent clean airflow needed to protect some spaces.**

Far-UVC can act as a supplement to ventilation and filtration

Germicidal UVC disinfection has been used for decades in high infection risk spaces. Shorter wavelength far-UVC is showing promise for wider application.

Far-UVC is ultraviolet light between 200-235 nm. Safe thresholds for human skin and eye exposure are an order of magnitude higher than conventional germicidal UVC (peak wavelength at 254 nm)[2] because far-UVC is highly absorbed by proteins[3] and cannot penetrate beyond the outer protective layer of dead skin.



Within these exposure limits, far-UVC can be used in occupied spaces to inactivate viruses and kill bacteria, and help prevent airborne transmission.

How well far-UVC works depends on the dose and the susceptibility of the pathogen to far-UVC, known as the inactivation constant 'k':[4]

$$eACH \approx k \times I \times 3.6 \qquad CADR \approx k \times P \times L \times 0.212$$

k = inactivation constant (cm^2/mJ)	I = UV fluence rate ($\mu W/cm^2$)	P = UV power output (mW)	L = avg. photon pathlength (m)

NB: These equations assume a uniform dose distribution

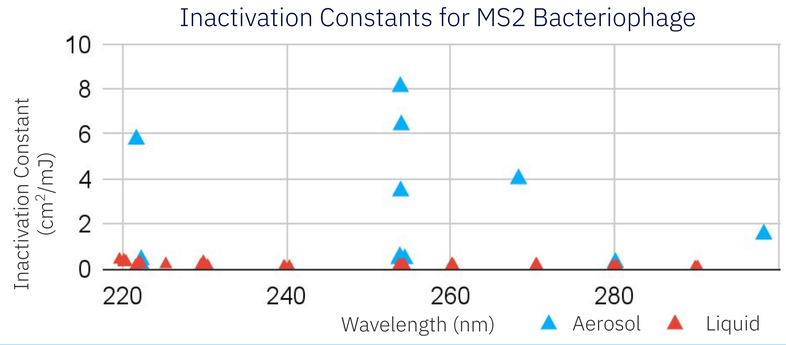
A high *k* means you can use a small amount of far-UVC to achieve large amounts of *eACH*. As *k* decreases, the amount of far-UVC needed to achieve the same disinfection increases.

Clarifying dose requirements is essential for effective deployment. How much far-UVC is needed to protect spaces from infectious aerosols is linked to all the opportunities and challenges with the technology.

What do we still need to know to get the most out of far-UVC?

We need to understand why inactivation varies so much in different experiments.

Recent studies suggest high inactivation constants (k = 12-20) for human coronaviruses and Influenza A virus.[5] However, inactivation constant estimates vary widely for aerosolized pathogens across studies, much more than estimates for liquid inactivation. For example, here are the estimated inactivation constants for MS2 bacteriophage across UVC wavelengths:*



It is difficult to ensure that chamber study conditions fully represent real-world environments. The factors below likely account for some of the variation in *k*, but we might still be overlooking other key influences:

- Environmental conditions (e.g., RH, temperature, pH, airflow, dose distribution)
- Experimental conditions (e.g., media, particle size, chamber size, aerosolization method, measurement method)

The impact of human respiratory aerosols on pathogen susceptibility to far-UVC is a critical knowledge gap.

- The protein absorption that makes far-UVC safer than other forms of UV will also reduce penetration into human respiratory aerosols. We do not currently know how significant this effect is.
- The difficulties of synthesizing representative human respiratory aerosols in the lab makes obtaining pathogen inactivation data from actual human respiratory aerosols an urgent priority.

SUMMARY

Far-UVC holds promise as a transformative technology for suppressing the spread of airborne disease.

Understanding its real-world effectiveness requires consistent reporting practices, standardized methods, and validation using human aerosols.

Blueprint Biosecurity

[†]This research was prepared by the authors in their personal capacity. The views and opinions expressed in this article are those of the author and do not necessarily reflect the official policy, opinion, or position of their employer.

[1]Bahnfleth, W., & Sherman, M. (2023). *Infectious Aerosol Control: A First Look at ASHRAE Standard 241.* ASHRAE Journal, 65(8) | [2]Görlitz et al.(2023) *Assessing the safety of new germicidal far-UVC technologies.* Photochem Photobiol, 100 | [3]Hill, S. C., Doughty, D. C., & Mackowski, D. W. (2024). *Inactivation of virions in host particles in air using 222- and 254-nm UV: Dependence of shielding on particle size and UV wavelength.* Aerosol Science and Technology, 58(5) | [4]Kowalski, et al. (2000) *Mathematical modeling of ultraviolet germicidal irradiation for air disinfection.* Quant. Microbiol, 2 (3) | [5]Welch et al. (2022) *Inactivation rates for airborne human coronavirus by low doses of 222 nm far-UVC radiation.* Sci Rep, 14 (4) and Buonnano et al. (2024) *Far-UVC light (222 nm) efficiently and safely inactivates airborne human coronaviruses.* Sci Rep, 10 | *citations are available upon request

Visit our website