Filtration and Air Cleaning for Airborne Pathogens

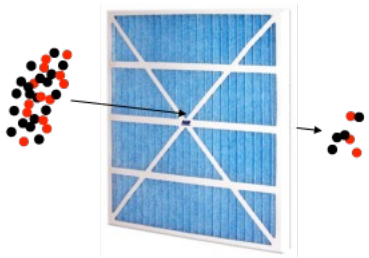
Brent Stephens, PhD

Professor and Department Chair

Arthur W. Hill Endowed Chair in Sustainability

Department of Civil, Architectural, and Environmental Engineering

Illinois Institute of Technology, Chicago, IL



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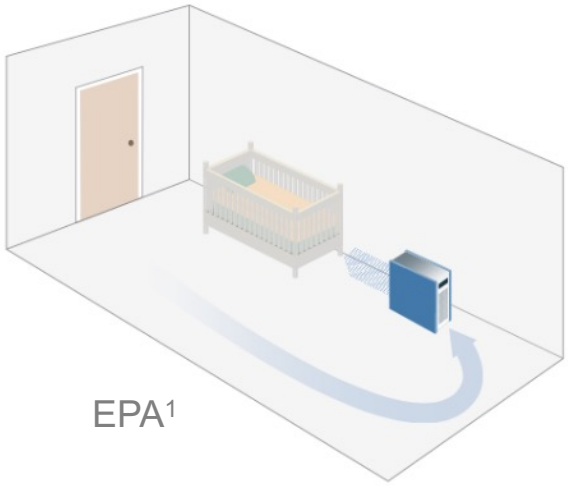
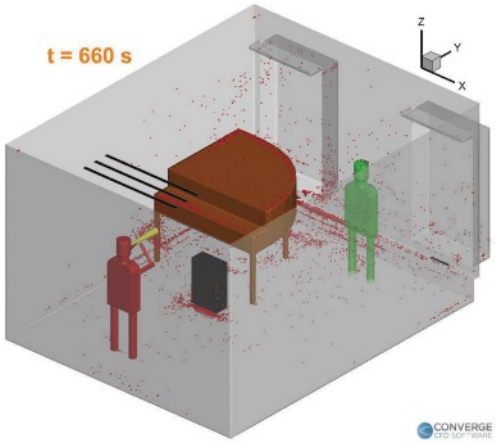
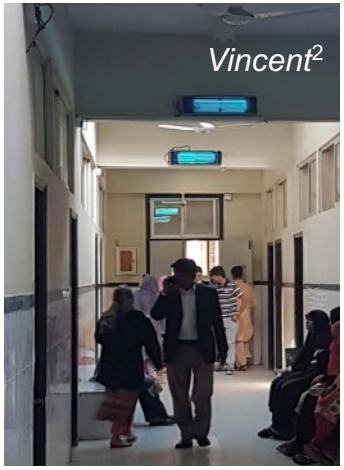
Two main types of air cleaners

Portable/stand-alone/in-room air cleaners

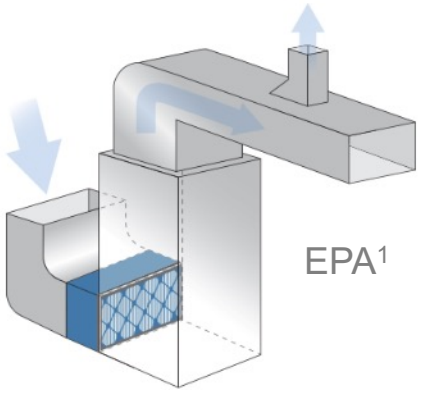


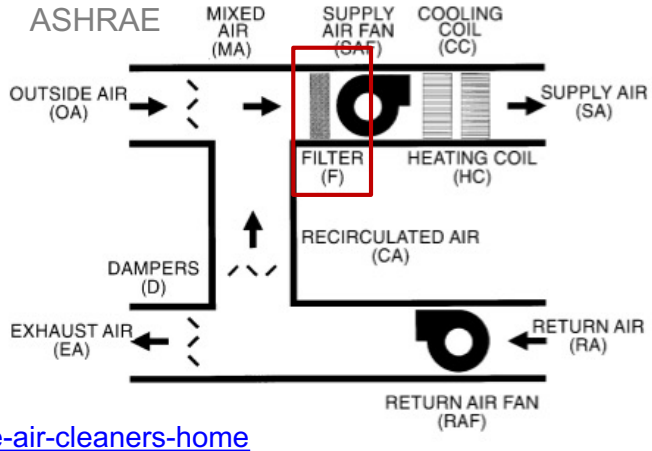


Narayanan and Yang **2021**
Phys. Fluids 33, 033307



In-duct air cleaners (HVAC)





[1] https://www.epa.gov/indoor-air-quality-iaq/guide-air-cleaners-home
[2] Vincent, 2020, Upper-room UVGI Air Disinfection, National Academies of Sciences

Many types of air cleaning technologies

"Subtractive" technologies

Mechanism of action: Removing or inactivating targeted contaminants (e.g., pathogens) from indoor air when they come in contact with the technology

Key parameters:

- Single-pass removal efficiency
- Airflow rate
- Airflow rate vs. space volume
- Runtime
- Potential for byproduct formation (e.g., O_3 w/ ESP)

Examples: filters, electrostatic precipitators (ESPs), ultraviolet germicidal irradiation (UVGI)

"Additive" technologies

Mechanism of action: adding constituents (e.g. ions or reactive compounds) to the air to remove particles, inactivate microorganisms

Key parameters:

- Type and amount of additives
- Potential toxicity of additives
- Potential for byproduct formation (particles/gases) and toxicity of byproducts

Examples: ionizers, ozone, plasma, hydrogen peroxide, hydroxyl, reactive oxygen species

Some air cleaners use a combination of technologies

Filtration/air cleaning: Recommended to reduce risk

Filtration (+ some air cleaning technologies) can **remove** particles in air
- Some air cleaning technologies can **inactivate** pathogens in air

CDC Ventilation in Buildings

- Improve central air filtration (more = better)
- Use portable HEPA fan/filtration systems
- Supplement with UVGI when ventilation/filtration options are limited

https://www.cdc.gov/coronavirus/2019-ncov/community/ventilation.html

ASHRAE EPIDEMIC TASK FORCE

Ventilation, filtration, air cleaning
- Minimum outdoor air (OA) flow rates
- Use MERV 13 or better filters
- Only use air cleaners for which evidence of effectiveness and safety is clear

https://www.ashrae.org/technical-resources/resources

How do you know if a technology is effective and safe?

1. Seek performance data

Ideal	Potentially Useful	Worst
Standard test methods and metrics Independent tests and/or peer-reviewed literature	Non-standardized test methods and metrics Manufacturer-provided tests and literature	No performance data of any kind

Standard test methods and metrics:

Efficacy:

In-duct filters/air cleaners:

Single-pass removal efficiency (%):
MERV, ePM, HEPA, FPR, MPR (filters)
ASHRAE Standard 185.1 (UV)

Portable/stand-alone air cleaners:

Clean Air Delivery Rate (CADR, ft^3/min):
CADR (for particles) from AHAM AC-1
m-CADR (for microbes) from AHAM AC-5

Safety:

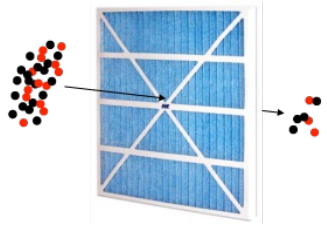
Ozone (O_3) emissions:
UL 867 – low O_3
UL 2998 – (near) zero O_3

Byproduct formation: none (yet)

How do you know if a technology is effective and safe?

2. Interpret performance data

For standardized tests and metrics, it's fairly straightforward:



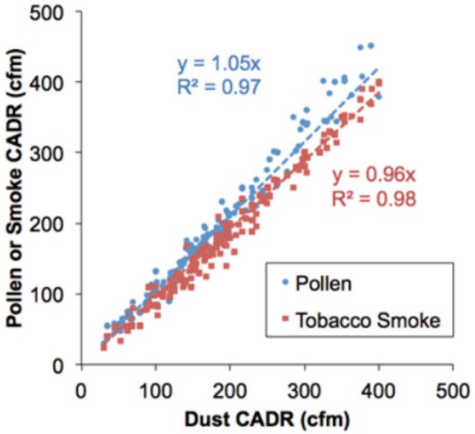
Single-pass efficiency tests (%):

- MERV, ePM, HEPA, FPR, MPR (filters)
- ASHRAE Standard 185.1 (UV)
  - Higher rating (e.g. MERV) → higher removal
  - Need to know **flow rate** through the filter/air cleaner to determine impact

CADR = Flow x Efficiency

Clean Air Delivery Rate (CADR) tests (ft^3/min):

- CADR (for particles) from AHAM AC-1
- m-CADR (for microbes) from AHAM AC-5



50 to 500 CFM CADR typical range*

*Check units!
e.g. ft^3/min vs. m^3/h vs. L/day

Higher CADR → greater removal

Corsi-Rosenthal DIY Cube

Up to 800 ft^3/min!

~10 cents per CFM CADR

Compare to ~80 cents for typical HEPA

smartairfilters.com

https://www.epa.gov/indoor-air-quality-iaq/air-cleaners-and-air-filters-home

Dal Porto et al. **2022** *AS&T* 56:564-572

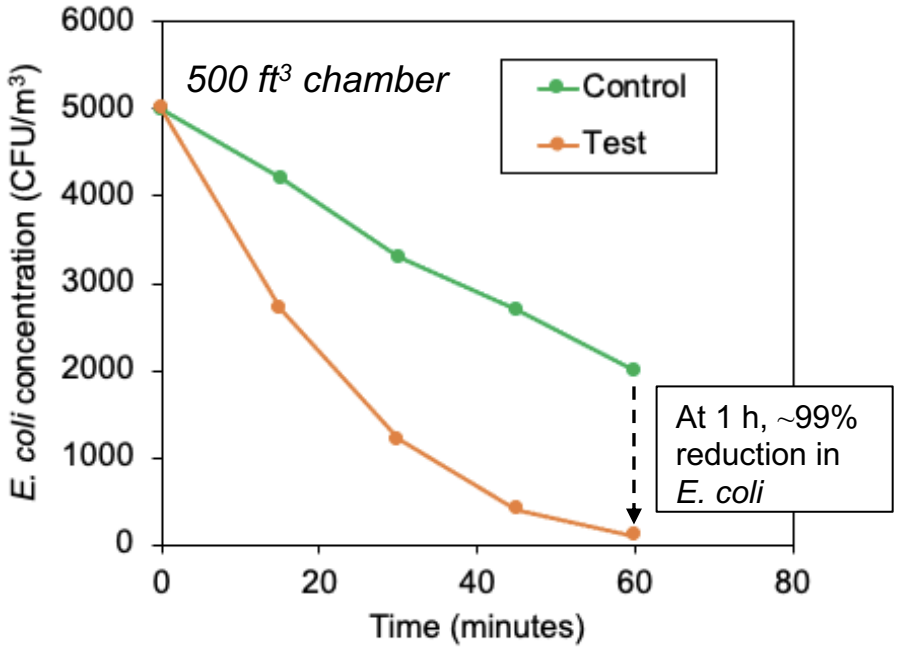
How do you know if a technology is effective and safe?

2. Interpret performance data

For non-standardized tests and metrics, some interpretation is required

Air Cleaner Technology A reduces viable pathogens by **99% in 60 minutes** in a test chamber

Hypothetical microbial inactivation test results



Stephens et al. **April 2022** *ASHRAE Journal*

How do you know if a technology is effective and safe?

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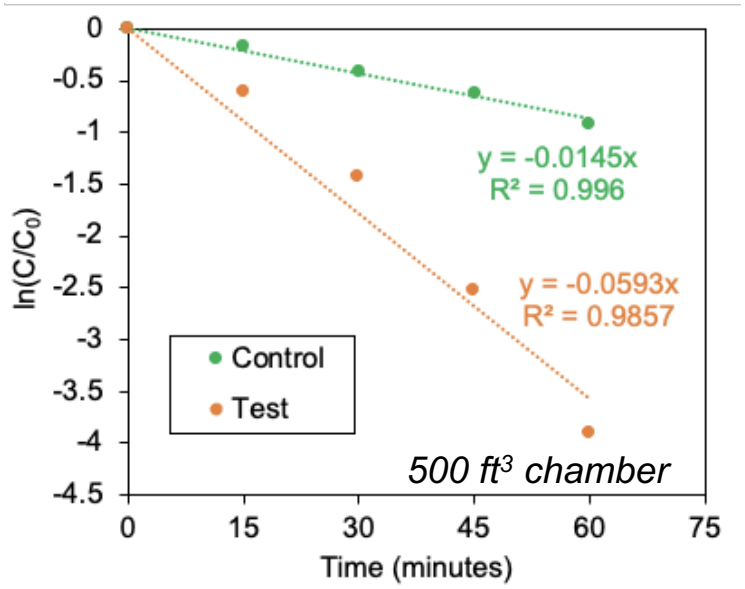
99% in 60 minutes in a test chamber

Fit data to a 1st-order decay model



Determine CADR from loss rates

$$CADR = V_{test}\left(L_{ac\ on} - L_{ac\ off}\right)$$

$$CADR = 500\ ft^3 \times \left(0.0593 - 0.0145\frac{1}{min}\right)$$

$$CADR = 22.4\ \frac{ft^3}{min} \approx \mathbf{22\ CFM}$$

A 250 CFM CADR air cleaner would reduce concentrations more than 99.999999% in 1 hour

ACE-IT AIR CLEANER EFFICACY INVESTIGATION TOOL

https://www.pdx.edu/healthy-buildings/ace-it

Stephens et al. **April 2022** *ASHRAE Journal*

How do you know if a technology is effective and safe?

2. Interpret performance data

For non-standardized tests and metrics, some interpretation is required

Some questions to ask:

- How do chamber test results translate to standard metrics and real-life conditions?
  - What was the chamber size?
  - What were natural decay rates without operating the air cleaner?

- For additive air cleaning technologies:
  - Were real-world additive constituent levels used?
  - Were chemical or particle byproducts measured?

- For air cleaners with multiple technologies:
  - Which technologies were active?
  - How much did each technology contribute to removal/inactivation?

Acknowledgements and Resources

- Collaborators: Elliott Gall, Delphine Farmer, Mohammad Heidarinejad
  - Stephens et al. “Interpretating Air Cleaner Performance Data,” *ASHRAE Journal* April 2022
  - Stephens and Gall 2021, “Navigating the Landscape of Air Cleaning Technologies for COVID-19,” EPA Indoor Air Quality Science Webinar: https://content.govdelivery.com/accounts/USEPAIAQ/bulletins/2eb0653

- Other helpful resources:

AHAM VERIFIDE Independently Tested. Consumer Trusted.

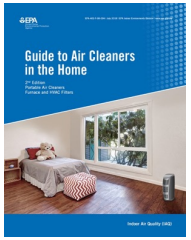
https://www.ahamdir.com/room-air-cleaners/

ASHRAE

ASHRAE Position Document on Filtration and Air Cleaning

https://www.ashrae.org/about/position-documents

EPA United States Environmental Protection Agency



Air Cleaners, HVAC Filters, and Coronavirus (COVID-19)

https://www.epa.gov/coronavirus/air-cleaners-hvac-filters-and-coronavirus-covid-19

https://www.epa.gov/indoor-air-quality-iaq/air-cleaners-and-air-filters-home

THE CENTER FOR GREEN SCHOOLS

School IAQ Fact Sheet

https://www.usgbc.org/resources/school-iaq-fact-sheets-entire-series