

Germs And Flying: **Developing Ventilation System Criteria**



Douglas Stuart Walkinshaw
ECHO Air Inc **www.indoorair.ca**

SAE *International*™

PAPER # 2011-01-2690

**This presentation develops ventilation system criteria
for 7 different settings which:**

Limit the risk of bioeffluent aerosol inhalation in the presence of a person ill with the flu in these settings to that in an office setting. (Walkinshaw, 2010, 2011).

8 settings analysed

Wide body aircraft	Office: Reference setting
Narrow body aircraft	Covered stadium
Grade 9+ classroom	Theater/auditorium
Grade 3-8 classroom	Subway car

Some background events

1988	Lengthwise cabin air movement found due to boundary turbulence of row-wise diffuser flows. Horstman, Chao
2001	Bioeffluent dose increases with occupancy density (space per person). Walkinshaw.
2006	Human virus & bacteria measured in cabin air. La Duc, Venkat.
2007	New ASHRAE aircraft ventilation standard of 7.5 cfm/p outdoor air + 7.5 cfm/p recirc air with HEPA filter. Does not consider contaminant dose or individual V_e . ASHRAE 161.
2007	ECS Venturi filtration by diffusers designed to reduce infectious aerosol exposures. Walkinshaw, Horstman, Lin, Johnson.
2007	Influenza transmission risk for guinea pigs increases with decreasing RH. Lowen.
2008	Influenza virus measured in normally exhaled breath of ill persons. Fabian

Virus concentration calculation

$$C = [N/(V * V_e)][1 - \exp(-V * V_e * t/v)] \dots \dots \dots (1)$$

C = bioeffluent aerosol concentration at time t in a uniformly mixed setting, virus/L

N = bioeffluent generation/person, virus/s/ill person

t = duration of infectious aerosol generation, s

v = spatial volume/person, L/p

V = infection-free ventilation rate (HVAC outside air + filtered recirculation air + envelope infiltration air) per person, L/s/p

V_e = efficiency of supplying this combined ventilation air to each occupant's breathing zone. $V_e = 1$ in a uniformly mixed system.

Inhalation calculation

$$D = \int ICdt \dots \dots \dots (2)$$

D = virus inhaled or dose, virus

I = inhalation rate, L/s

C = bioeffluent aerosol concentration at time t, virus/L

t = duration of exposure, s

Filtration depends on:

- a) the flow rate through the filter, and
- b) the filter efficiency in removing the particle size of concern at that flow rate face velocity.

e.g. 0.3 micron filtration is ~ 2 times greater in an office with Merv 13 filters than in an aircraft with HEPA filters.

That's because, while a MERV 13 filter at office building face velocities removes only 30% of 0.3 micron particles passing through it, the flow through it per occupant is 7 times higher.

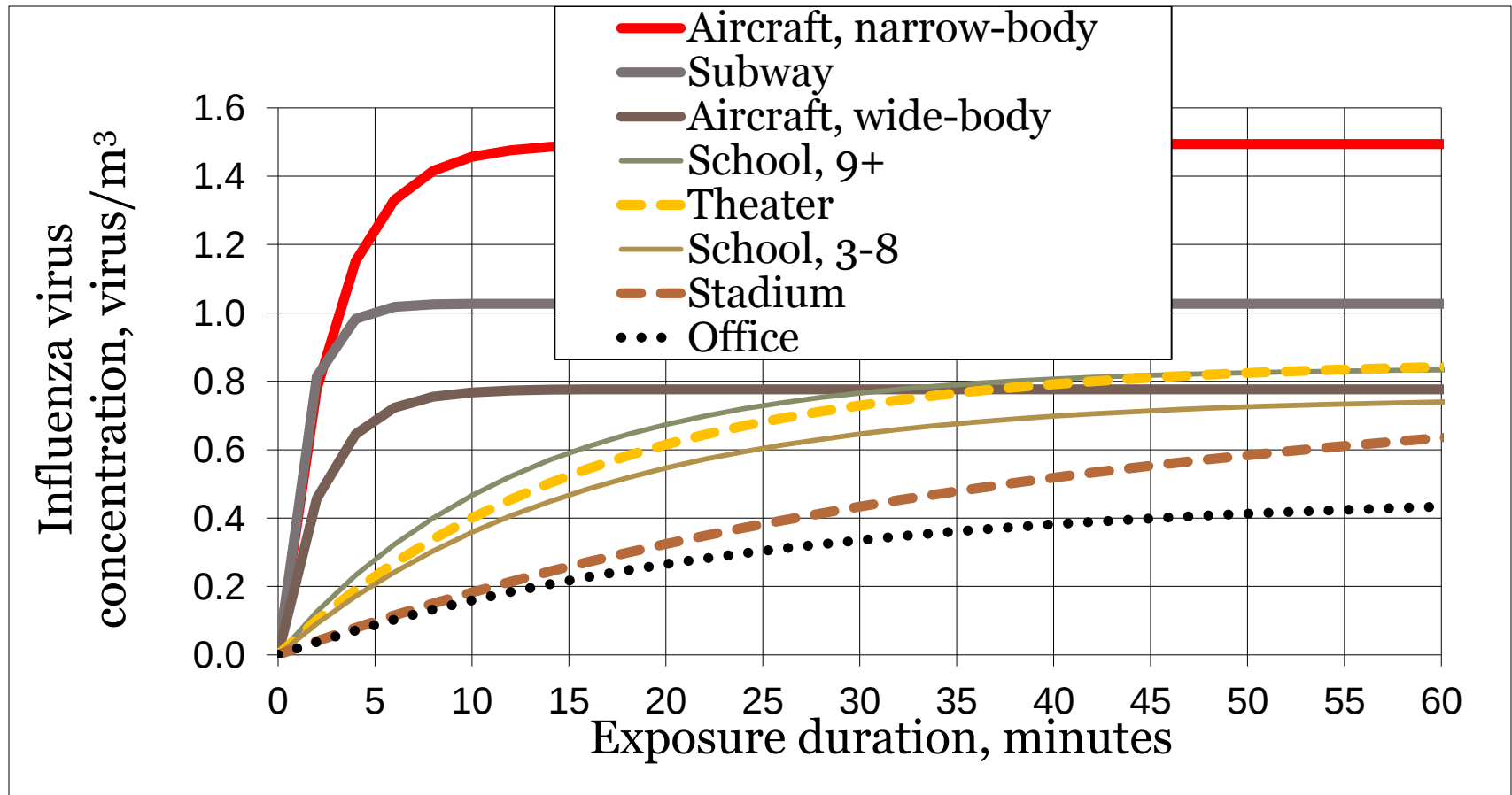
Germ and flying: developing ventilation system criteria

Input data for the 8 settings

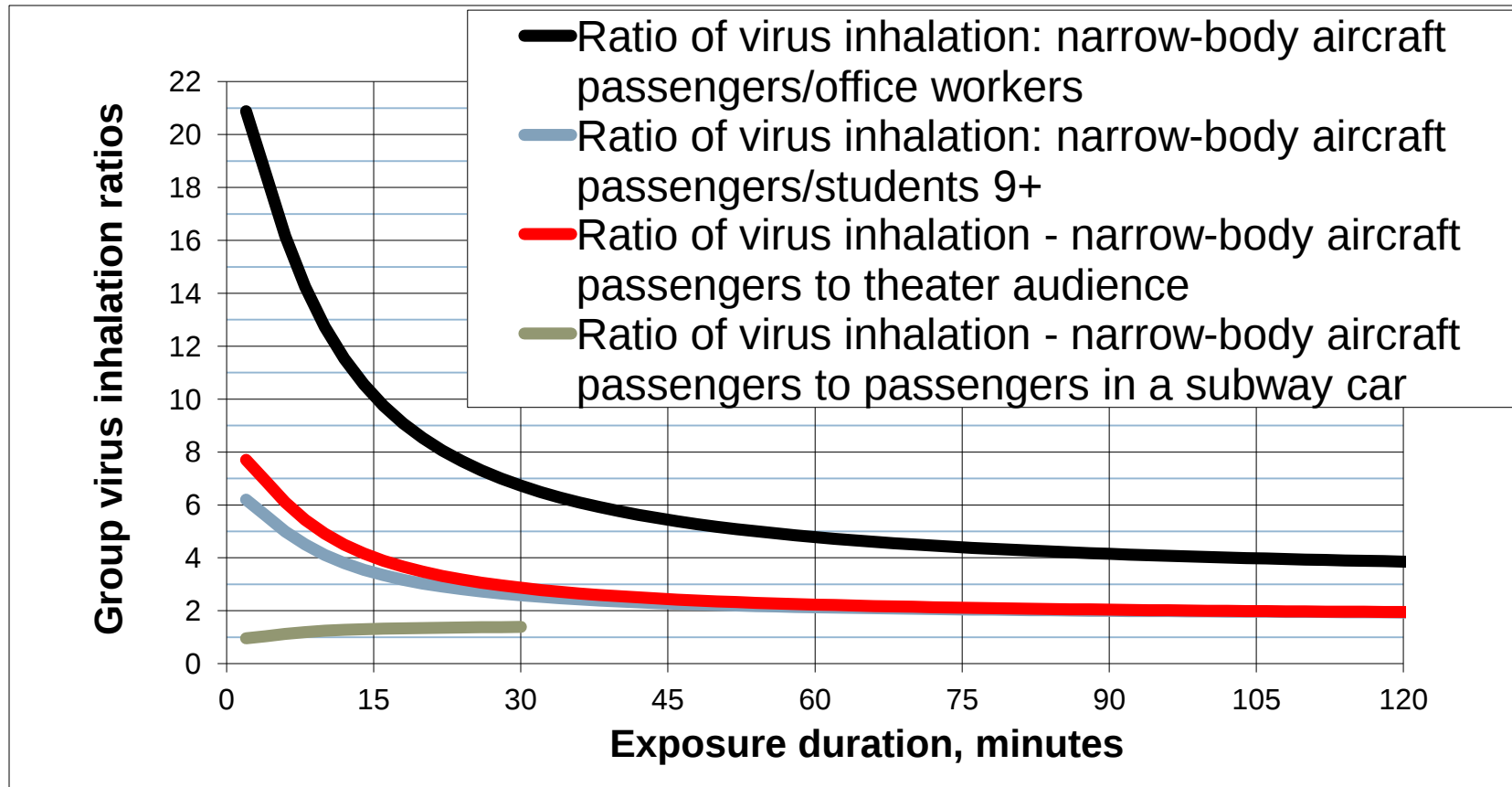
	Sub-way car	Aircraft, narrow-body	Aircraft, wide-body	Class-room 9+	Theater	Class-room 3-8	Stadium spectator area	Office
Virus/min aerosolized	11	11	11	11	11	11	11	11
Inhalation rate, L/s/p	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Spatial vol/p, m ³	0.7	1.0	1.6	8.1	10.2	11.3	26.6	28.3
Design (longest) exposure time, hrs	0.5	6	14	6	4	6	4	8
Pathogen filtration, %	0	100	100	30	30	30	0	30
Filter circulation rate, L/s/person	0	5.2	6.1	13.7	23.6	13.7	0.0	37.8
Ve	0.65	0.65	1	1	1	1	0.9	1
V*Ve, L/s/p	8.9	6.1	11.8	10.9	10.6	12.1	11.3	23.1

Germ and flying: developing ventilation system criteria

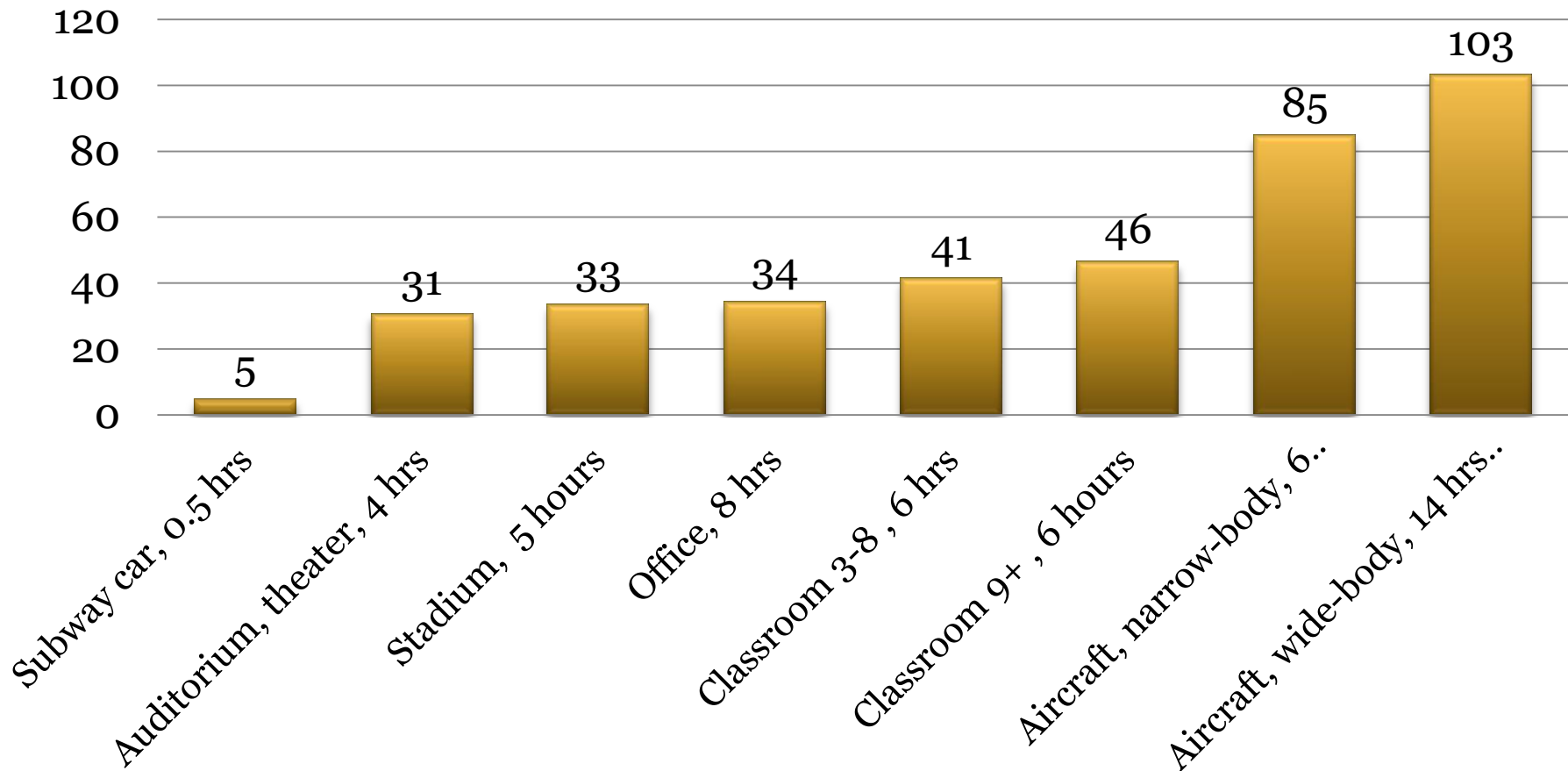
Setting virus aerosol concentrations vs time, 1 ill person, 20 exposed persons



Ratio of exposed group virus dose – narrow body cabin vs 4 other settings



Exposed group virus inhalation for 1 ill person & setting design (longest) exposure durations



Leveling the group virus inhalation dose to that in an office for each setting design (longest) exposure time

Changes to the ventilation + filtration rate control required
e.g. [pathogen filtration/dilution rates/person], [ventilation effectiveness]:

Wide body aircraft

Increase rate 3 times

Office: Reference setting

Narrow body aircraft

Increase rate 2.5 times

Covered stadium spectator

No change

Grade 9+ classroom

Increase rate 1.4 times

Theater/Auditorium

Decrease rate 1.1 times

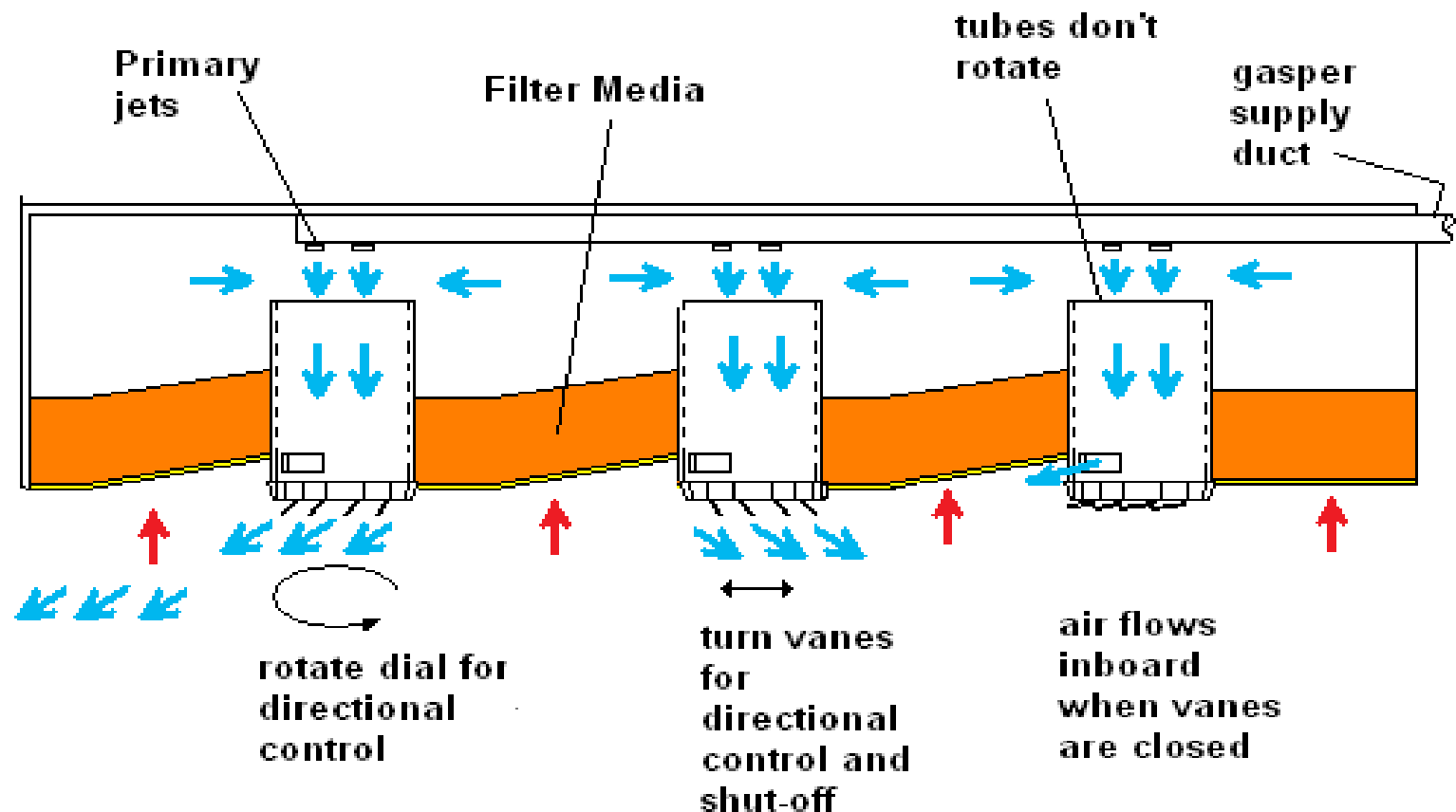
Grade 3-8 classroom

Increase rate 1.2 times

Subway car

Decrease rate 6.8 times

Increasing filtration rate and V_e in aircraft: Venturi filtration added to gaspers



Conclusion

Relative airborne pathogen risks of infection vary widely for the 8 settings based on their current V , V_e and filtration practice with overseas and national flights the highest risk, followed by classrooms. Subway cars pose the lowest risk. New ventilation approaches are required if the risks are to be reduced in aircraft.



Germ and flying: developing ventilation system criteria
Closing note on Air Changes per Hour (ACH)

Spatial outside air change per hour (ACH), rather than ventilation rate V per occupant, often is referenced in health care studies and designs as the ventilation parameter of importance.

However, ACH is a misleading ventilation indicator of occupant-generated bioeffluent concentrations and exposures, since its value is independent of the number of occupants present.

ACH vs V/person

Location	Subway	Aircraft narrow body	Aircraft wide-body	Class-room 9+	Theater	Class-room 3-8	Covered stadium spectator area	Office
ACH	72.7	15.3	12.8	3.0	1.2	2.5	1.7	1.5
V*Ve, L/s/p	8.9	6.1	11.8	10.9	10.6	12.1	11.3	23.1

If bioeffluent airborne concentrations were dependent upon ACH, then they would be significantly lower in aircraft passenger cabins (some 8 to 10 times) and in subway cars (some 48 times) than in offices for the same source strength, **WHICH THEY ARE NOT**, and the **ventilation standards set by ASHRAE** to control occupant bioeffluent have been using the wrong parameter **V/p** for the last several decades **WHICH THEY HAVE NOT**.

Closing note on HEPA Filtration

Perhaps because HEPA filters are used in hospital operating rooms, some persons believe that a HEPA filter will eventually remove all airborne 0.3 micron and larger particles and pathogens in the air of the space being recirculated, whereas in fact it only removes these from the air passing through this filter. **This filter, or any other for that matter, can never remove all the 0.3 micron particles in a uniformly mixed space if they are being produced there.**

The number of 0.3 micron particles in the air of the space will be lower, the higher the recirculation rate through the HEPA filter. But it will never be zero. There will come a point when the number of particles being generated in the space equals the number of particles being removed from it. That will be the equilibrium or maximum concentration in the space.

Germ and flying: developing ventilation system criteria

The public and HVAC concerns with infectious aerosols in aircraft represent an industry opportunity for competitive advantage.

