Disease Resilient and Energy-Efficient Centralized Air-Conditioning Systems
Webinar 1 – Disease Resilience and Indoor Air Quality
Coordinated by Asian Development Bank TA 6563

Indoor Air Quality, Health and Control Technologies – Active and Passive

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What is indoor air *quality*?

"Indoor Air Quality (IAQ) refers to the air quality within and around buildings and structures, especially as it relates to the health and comfort of building occupants." (US EPA)

Definition of "quality" is elusive

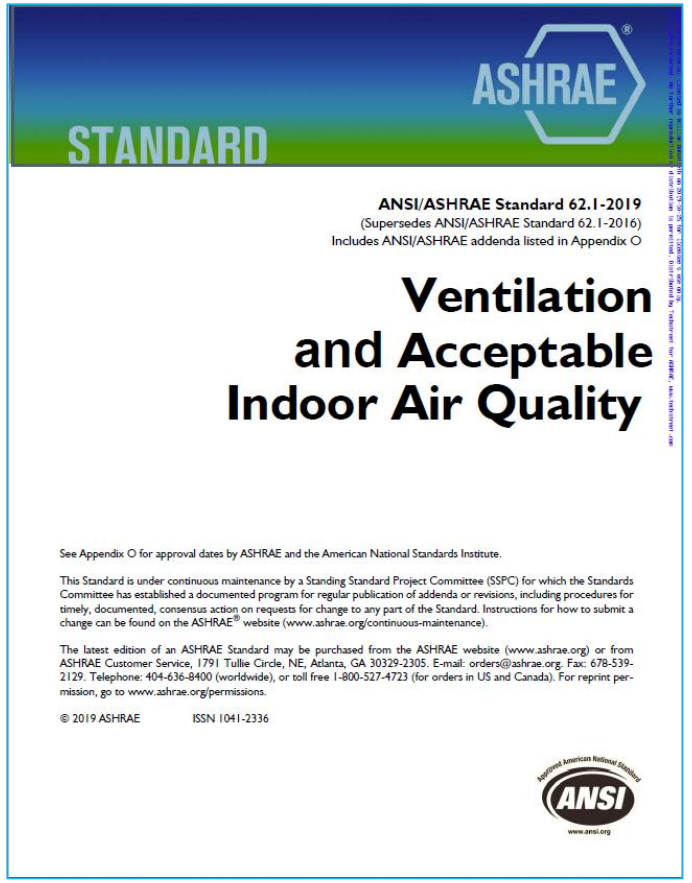
- Related to levels of air contaminants and consequences of exposures
- "Good" IAQ ~ limitation of consequences to acceptable levels

To date, no consensus definition of ideal IAQ

Working definition in most standards: Safe and Satisfactory

acceptable indoor air quality (IAQ):
air in which there are no known contaminants at harmful concentrations, as determined by cognizant authorities, and with which a substantial majority (80% or more) of the people exposed do not express dissatisfaction.

Usually achieved prescriptively


STANDARD

ASHRAE

ANSI/ASHRAE Standard 62.1-2019
(Supersedes ANSI/ASHRAE Standard 62.1-2016)
Includes ANSI/ASHRAE addenda listed in Appendix O

Ventilation and Acceptable Indoor Air Quality

See Appendix O for approval dates by ASHRAE and the American National Standards Institute.

This Standard is under continuous maintenance by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the Standard. Instructions for how to submit a change can be found on the ASHRAE® website (www.ashrae.org/continuous-maintenance).

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Approved American National Standard
ANSI
www.ansi.org

What is health?

Multiple definitions, movement away from focus on disease to overall wellbeing

Absence of disease or impairment (medical definition)

A state that allows the individual to adequately cope with all demands of daily life (subjective, exclusive)

A state of balance that an individual has established within himself and between himself and his social and physical environment. (Best? Disease does not necessarily displace health)

~Sartorius, N., 2006. The meanings of health and its promotion. *Croatian medical journal*, *47*(4), p.662.

WHO health-based air quality criteria

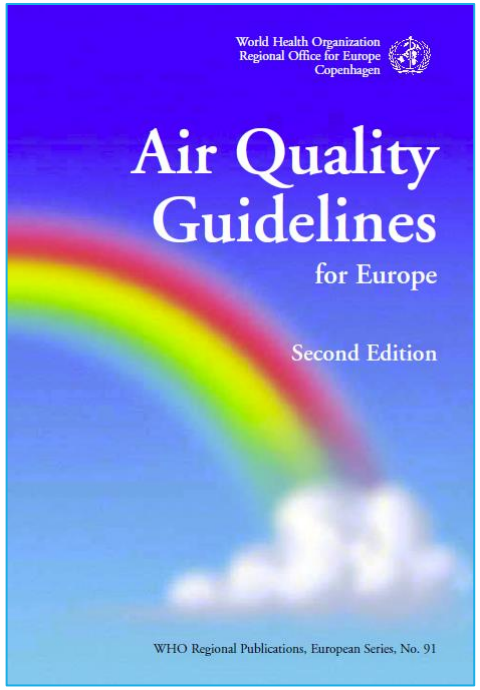
"Clean air is considered to be a basic requirement for human health and wellbeing."

Major indoor and outdoor pollutants

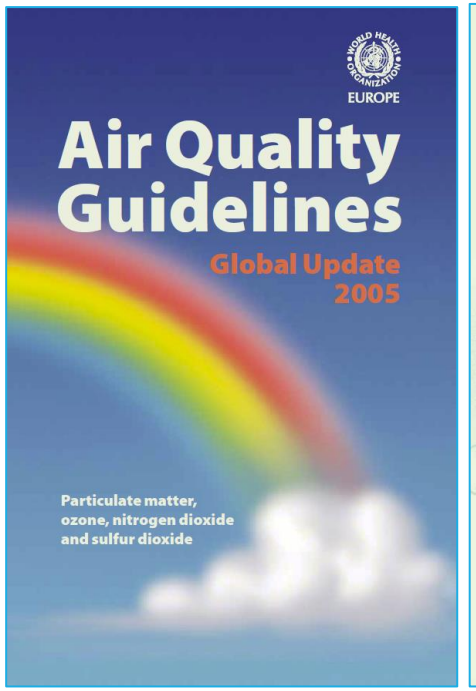
Health-based recommendations based on available research

Still only a small subset of indoor pollutants

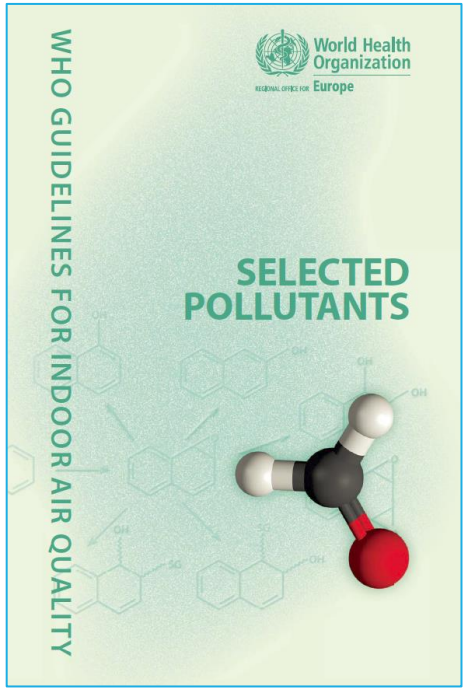
Do not address airborne infectious disease



2000



2005



2010

Proposed ASHRAE criteria: Indoor Air Quality Procedure

Compound or PM2.5	Cognizant Authority	Design Limit
Acetaldehyde	Cal EPA CREL (June 2016)	140 ug/m^3
Acetone	AgBB LCI	1,200 ug/m^3
Benzene	Cal EPA CREL (June 2016)	3 ug/m^3
Dichloromethane	Cal EPA CREL (June 2016)	400 ug/m^3
Formaldehyde	Cal EPA 8-hour REL (2004)	33 ug/m^3
Naphthalene	Cal EPA CREL (June 2016)	9 ug/m^3
Phenol	AgBB LCI	10 ug/m^3
Tetrachloroethylene	Cal EPA CREL (June 2016)	35 ug/m^3
Toluene	Cal EPA CREL (June 2016)	300 ug/m^3
1,1,1-trichloroethane	Cal EPA CREL (June 2016)	1000 ug/m^3
Xylene, total	AgBB LCI	500 ug/m^3
Carbon monoxide	USEPA NAAQS	9 ppm
PM2.5	USEPA NAAQS (annual mean)	12 ug/m^3
Ozone	USEPA NAAQS	70 ppb
Ammonia	Cal EPA CREL (June 2016)	200 ug/m^3

Beyond health?

Decades of research document attainable benefits if IAQ is improved

- Productivity
- Cognitive function
- Student learning
- Sleep quality
- Consequences of infectious diseas

Monetizeable benefits that should drive policy change

Mainly overlooked externalities and focus is on energy and environment

Must recognize that IAQ, health are part of sustainability goals

Engineering controls

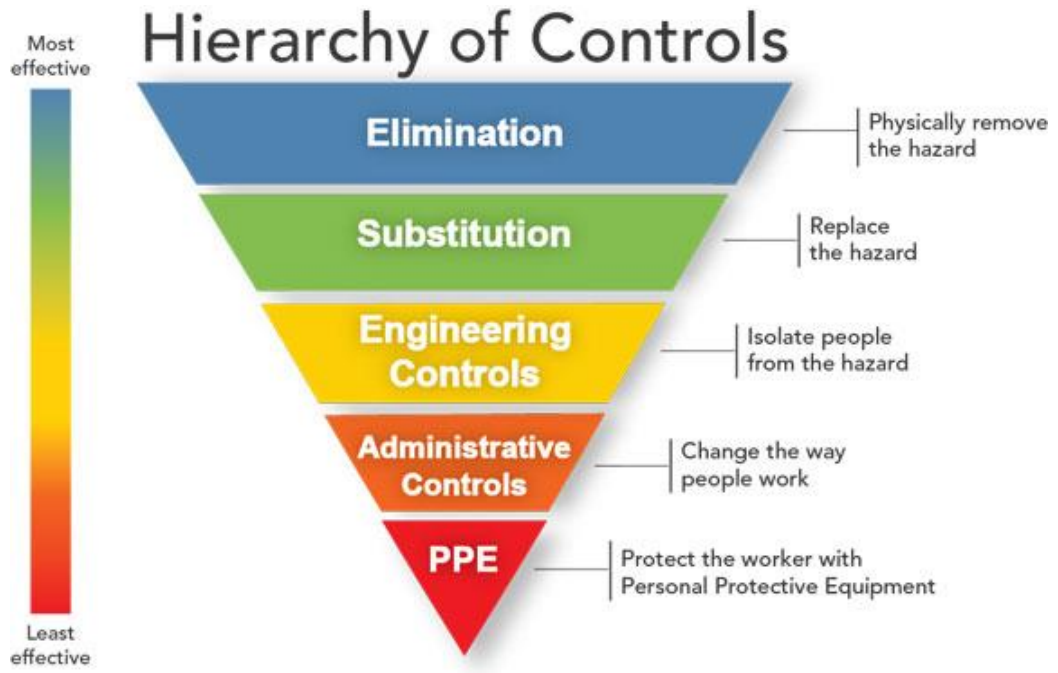
Reduce exposure

- Remove contaminants
- Direct away from people

Contaminant types

- Particles/aerosols
- Gases
- Microorganisms

Many control technologies – some general, some specific



https://www.cdc.gov/niosh/topics/hierarchy/default.html

Ventilation

Dilute or displace contaminated air

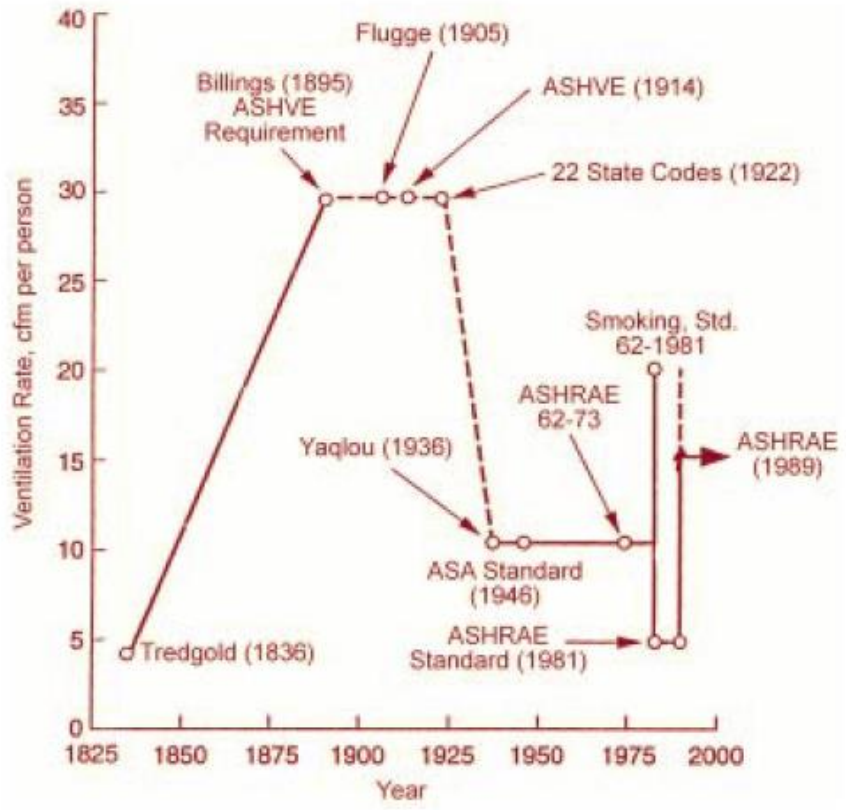
Mechanical or natural (or hybrid)

Required for all occupied buildings

Can remove all types of contaminants

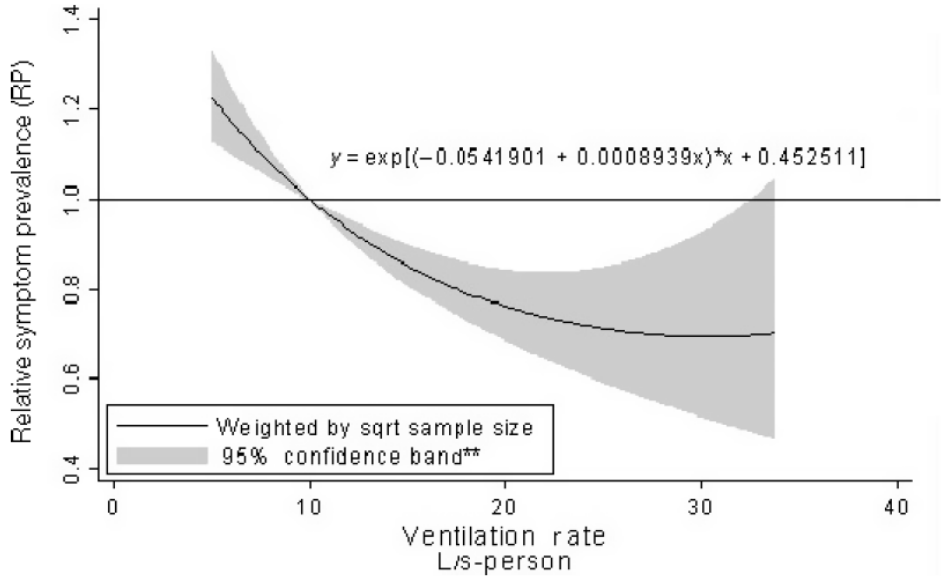
Rates depend on definition of acceptability

If conditioning is needed, can be energy intensive

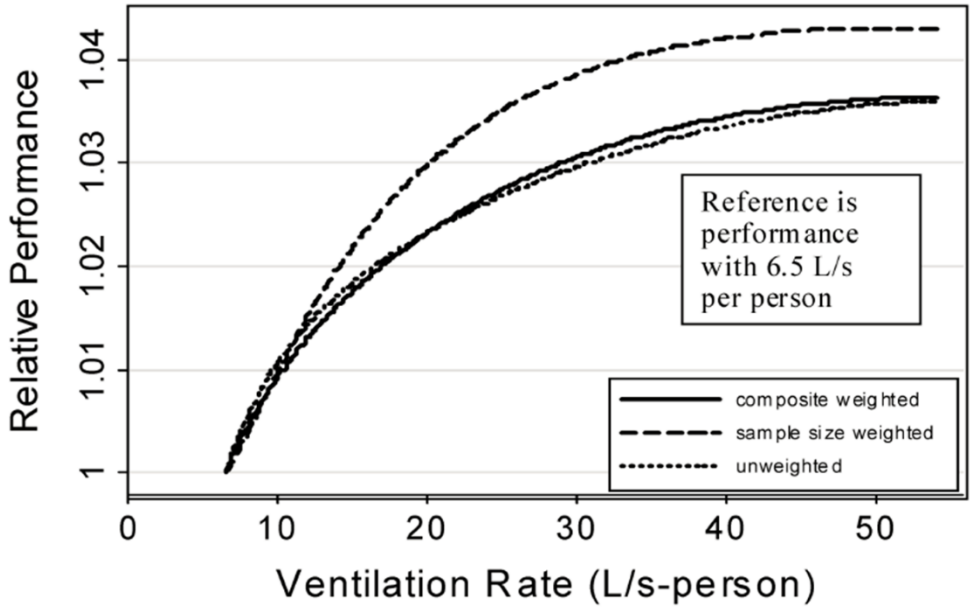


Janssen, J.E., 1999. The history of ventilation and temperature control: The first century of air conditioning. *ASHRAE Journal*, *41*(10), p.48.

Increased rates have demonstrated benefits



W. Fisk, A Mirer, M. Mendell. 2009. Quantitative relationship of sick building syndrome symptoms with ventilation rates. Indoor Air



Seppänen, O. and W. Fisk. 2006. Some Quantitative Relations between Indoor Environmental Quality and Work Performance or Health. HVAC&R Research.

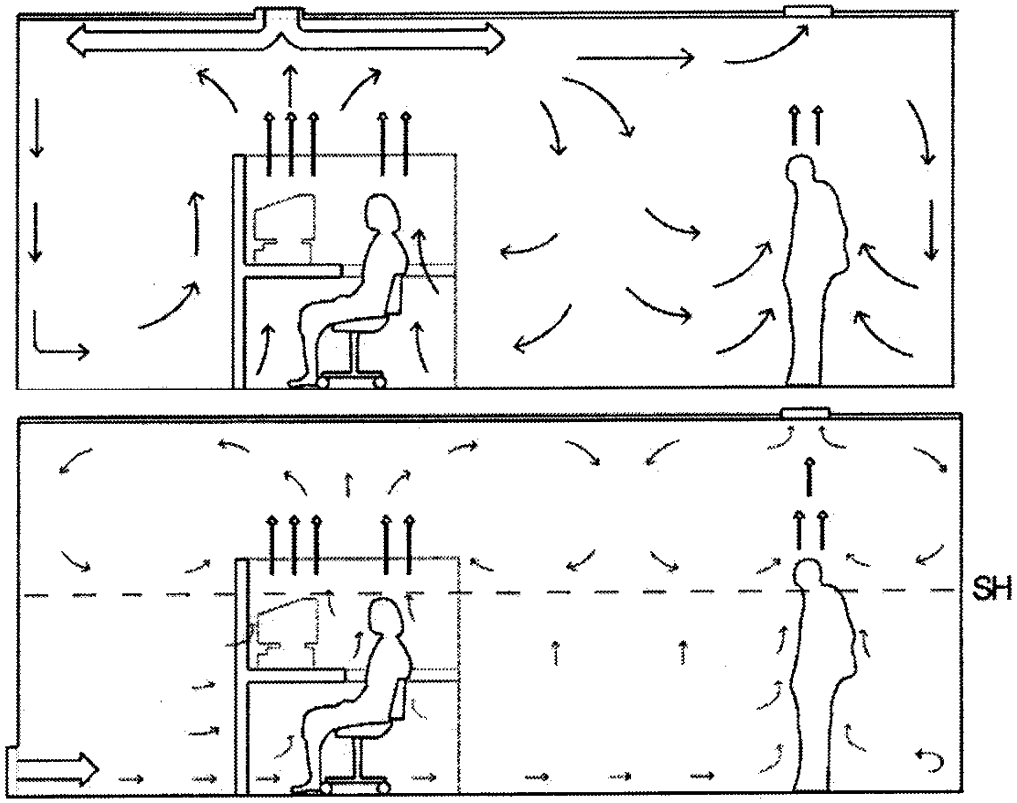
Air distribution

Alternatives to overhead mixing ventilation

- Underfloor air distribution
- Displacement ventilation
- Personalized ventilation

Increase ventilation effectiveness

Lower ventilation requirement for same IAQ



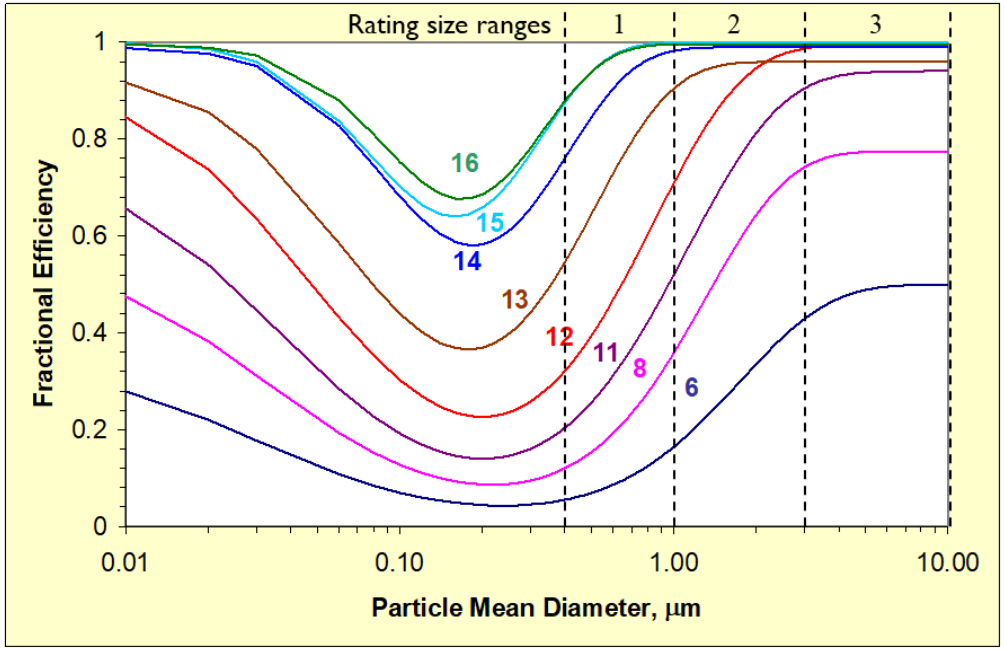
Source: Chen and Glicksman. 2003. System Performance Evaluation and Design Guidelines for Displacement Ventilation. ASHRAE.

Mechanical filtration

Predominant means of removing particles from air

Most buildings have moderate levels of filtration

To protect health, higher than standard efficiency is needed



Kowalski, W.J. and Bahnfleth, W.P., 2002. MERV filter models for aerobiological applications. Air Media, Summer, 1.

Filter efficiency is important

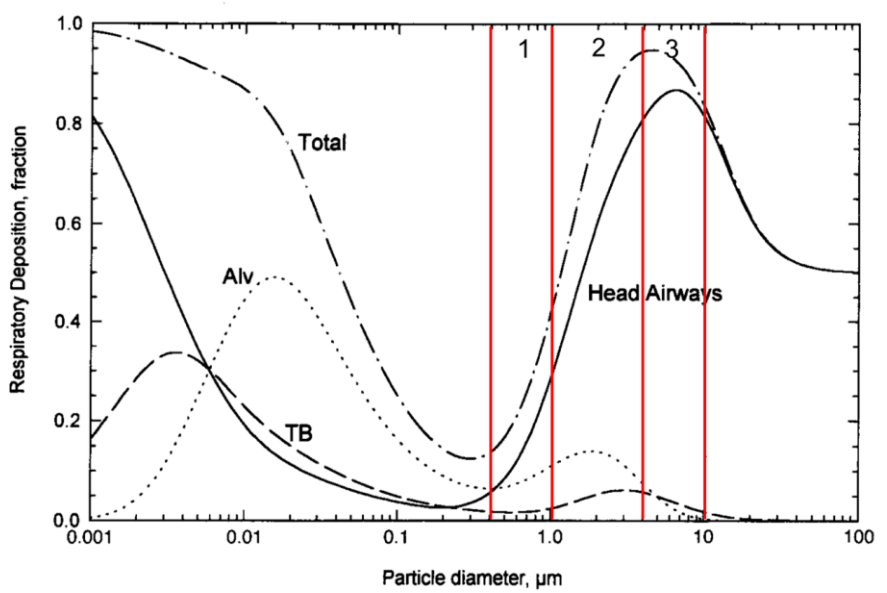
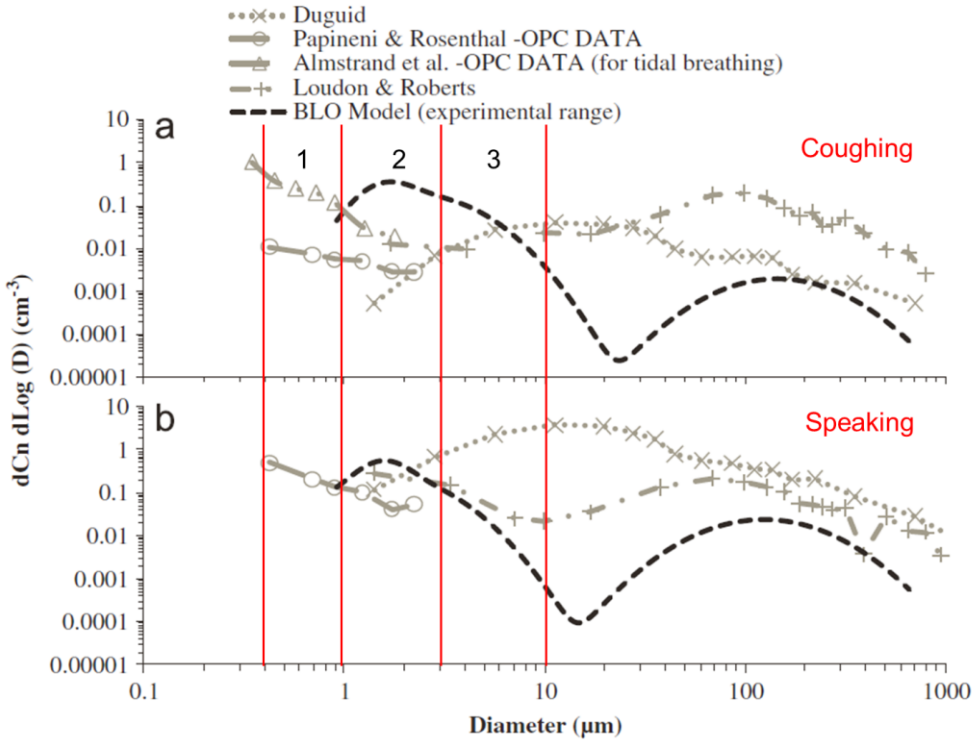


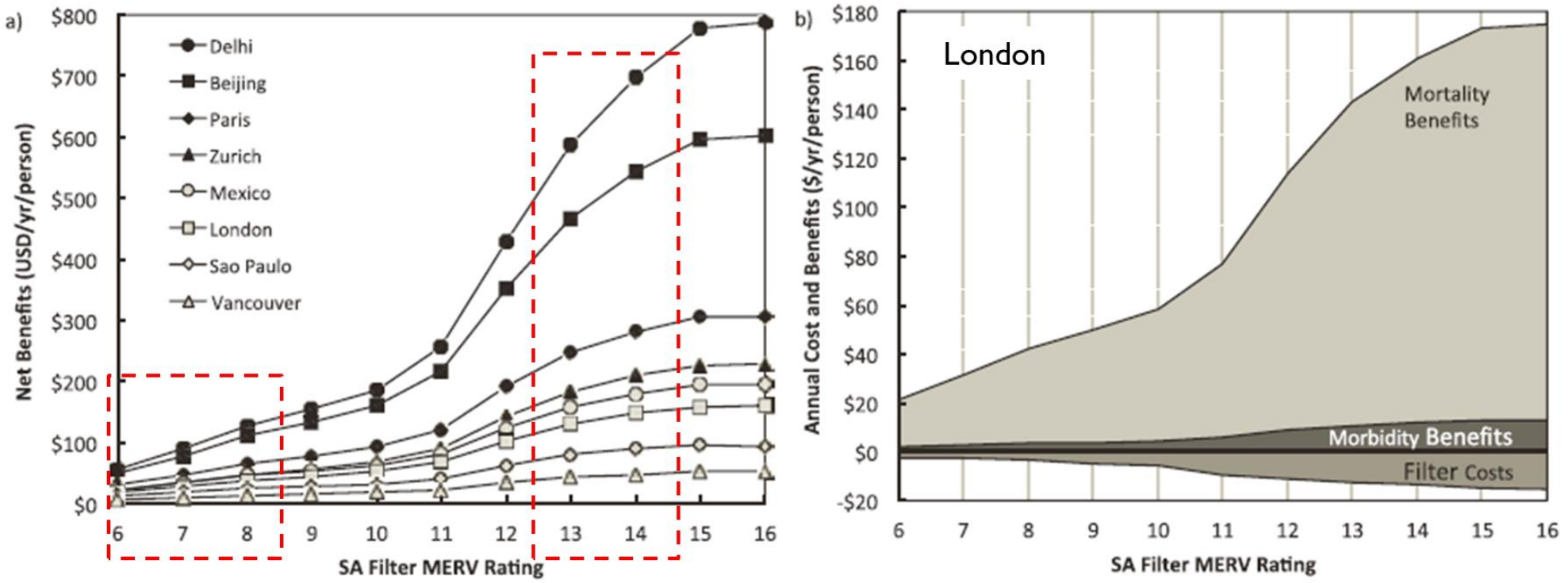
FIGURE 11.3 Predicted total and regional deposition for light exercise (nose breathing) based on ICRP deposition model. Average data for males and females.

Range	MERV 8	MERV 13
1	N/A	≥ 50%
2	≥ 20%	≥ 85%
3	≥ 70%	≥ 90%



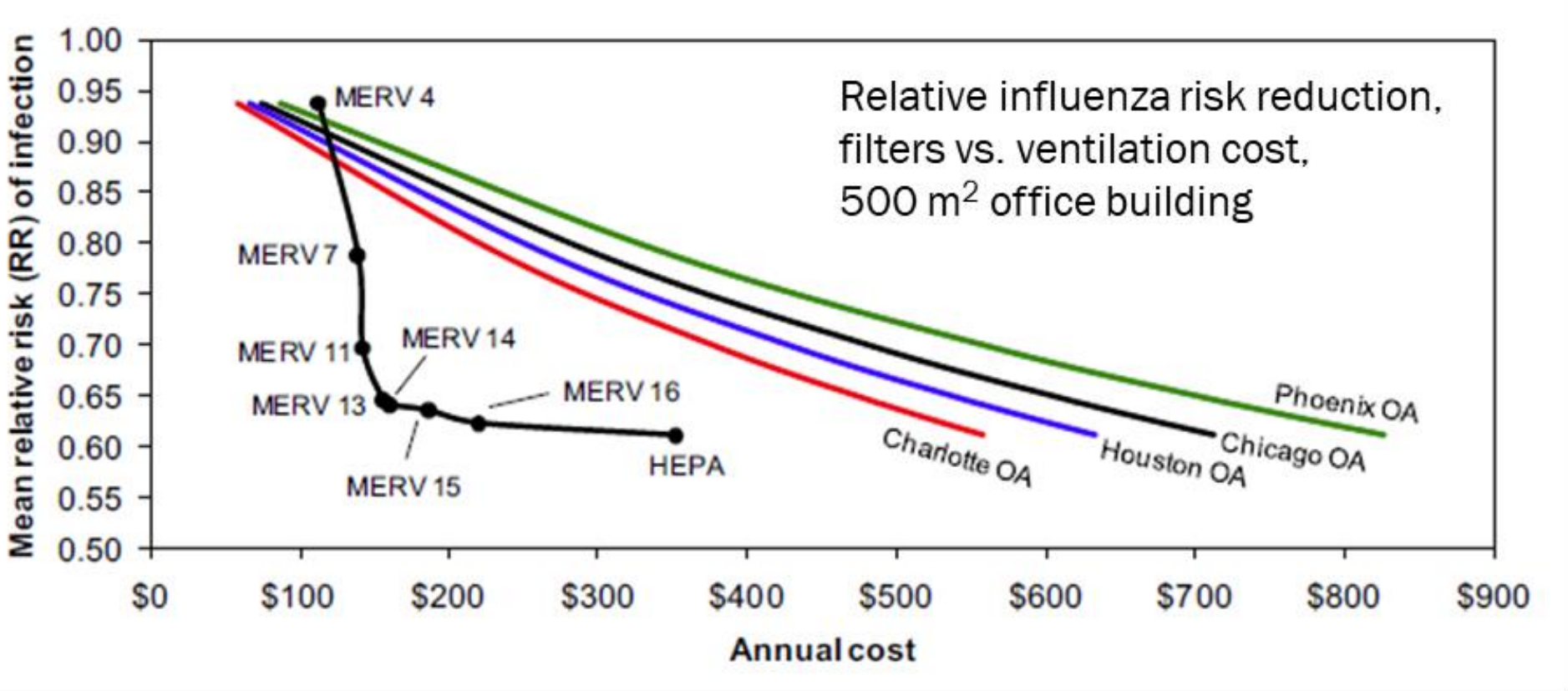
Johnson, et al. 2011. Modality of human expired aerosol size distributions. Journal of Aerosol Science 42:839-851.

Fine PM exposure affects health



(Montgomery, J., C. Reynolds, S. Rogak, S. Green. 2015. Financial Implications of Modifications to Building Filtration Systems. Building and Environment 85:17-28.)

Filtration can be more effective than ventilation



Azimi, P. and Stephens, B., 2013. HVAC filtration for controlling infectious airborne disease transmission in indoor environments: predicting risk reductions and operational costs. *Building and environment*, *70*, pp.150-160.

Air cleaners – many choices…and questions

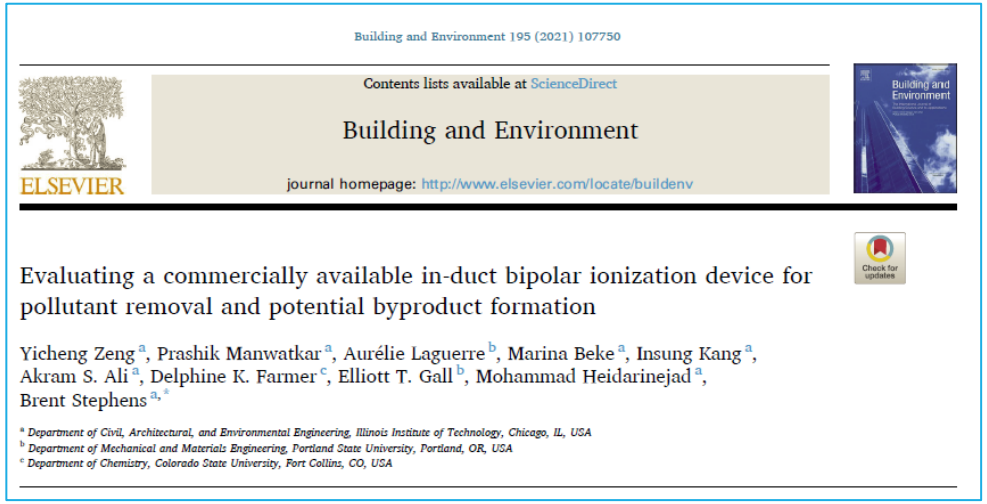
Ultraviolet Germicidal Irradiation (microorganisms)

- Current 254 nm technology
- Emerging – 222 nm far-UVC

Sorbents (gas)

Air cleaners that create reactive species (gases and particles) – *lack of standards - caveat emptor!*

- Photocatalytic Oxidation (PCO)
- Dry Hydrogen Peroxide (DHP)
- Bipolar Ionization (BPI)



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Evaluating a commercially available in-duct bipolar ionization device for pollutant removal and potential byproduct formation

Yicheng Zeng [a], Prashik Manwatkar [a], Aurélie Laguerre [b], Marina Beke [a], Insung Kang [a], Akram S. Ali [a], Delphine K. Farmer [c], Elliott T. Gall [b], Mohammad Heidarinejad [a], Brent Stephens [a, *]

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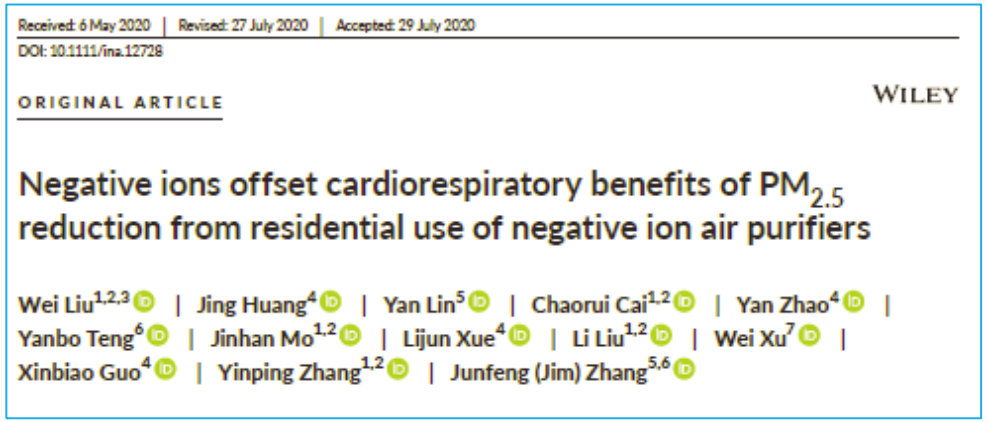

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ORIGINAL ARTICLE

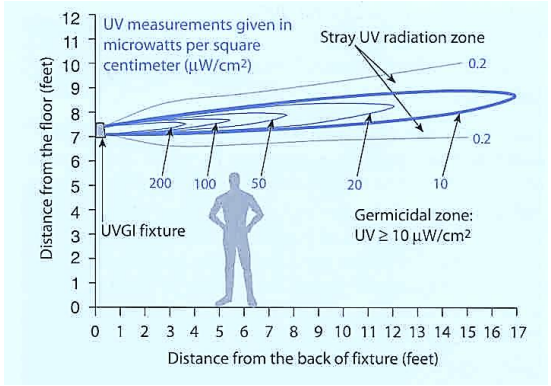
WILEY

Negative ions offset cardiorespiratory benefits of $PM_{2.5}$ reduction from residential use of negative ion air purifiers

Wei Liu[1,2,3] | Jing Huang[4] | Yan Lin[5] | Chaorui Cai[1,2] | Yan Zhao[4] | Yanbo Teng[6] | Jinhan Mo[1,2] | Lijun Xue[4] | Li Liu[1,2] | Wei Xu[7] | Xinbiao Guo[4] | Yinping Zhang[1,2] | Junfeng (Jim) Zhang[5,6]

Germicidal UV applications

Upper Air UVGI



In-Duct/Coil UVGI

Portable Surface Treatment UVGI

Takeaways

"Good" IAQ has many definitions

Case for impact of IAQ on health and wellbeing is strong

Many technologies exist to control air contaminants

Many promising technologies need further investigation and standards to support application

Challenge is to combine them in ways that achieve a high level of IAQ but do not compromise energy and environmental goals

Thank you!

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