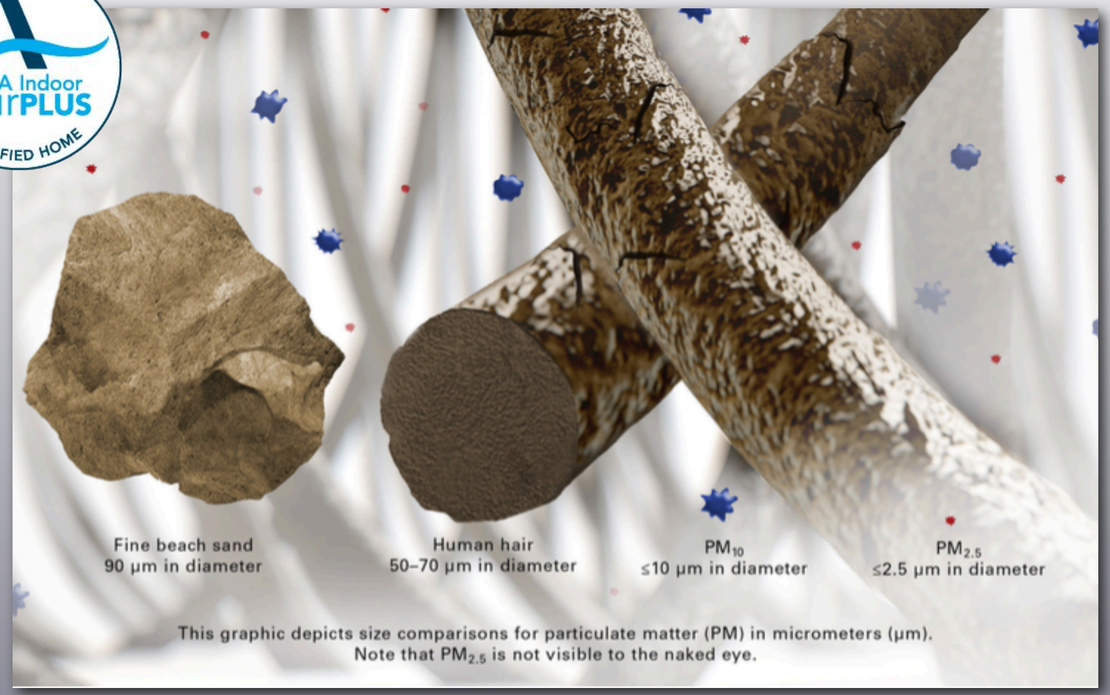
Updated EPA Guidance for Air Cleaners in the Home

EEBA Summit - San Diego - October 2018



This graphic depicts size comparisons for particulate matter (PM) in micrometers (µm).
Note that $PM_{2.5}$ is not visible to the naked eye.

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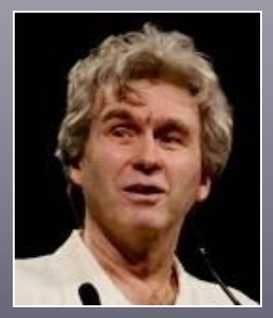
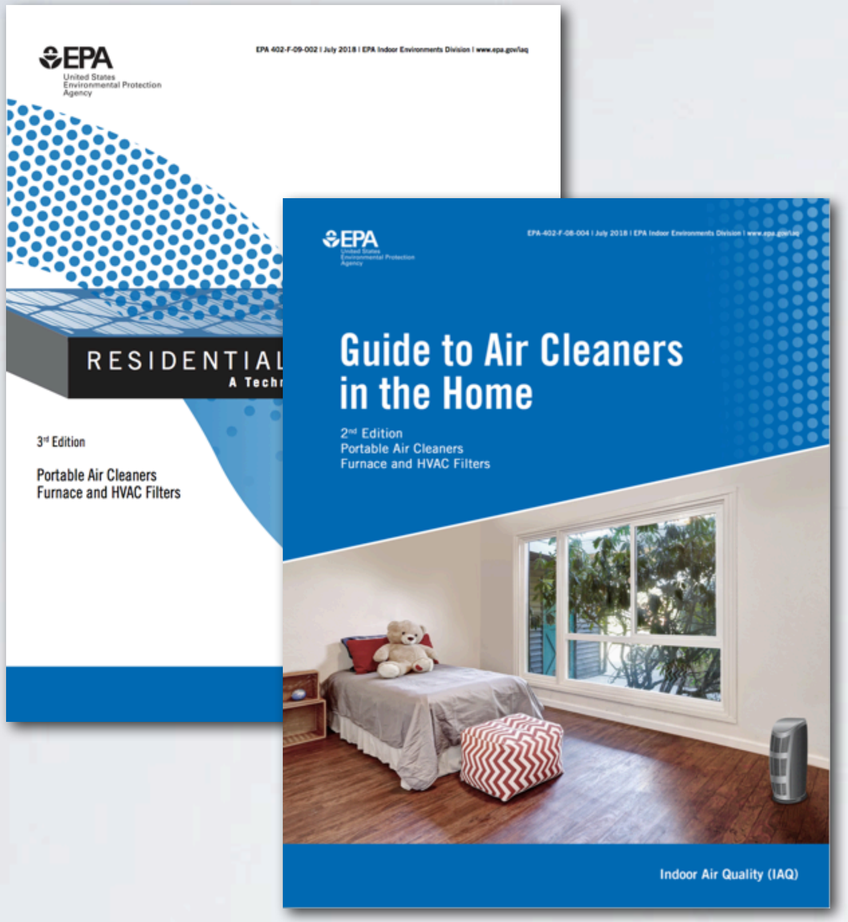


Outline



- **Introduction**
  - Speakers
  - 2018 revision of EPA Air Cleaner Guidance
- **$PM_{2.5}$ - Known Health Concerns**
- **2018 EPA Guidance for Air Cleaners**
  - Central HVAC Systems - MERV 13
  - Portable Air Cleaners - High CADR
- **Summary**

Speakers and Resources

Lew Harriman
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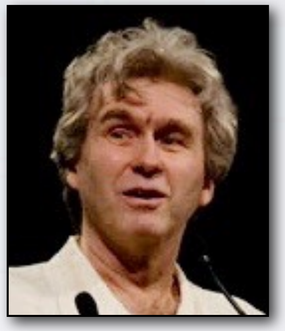

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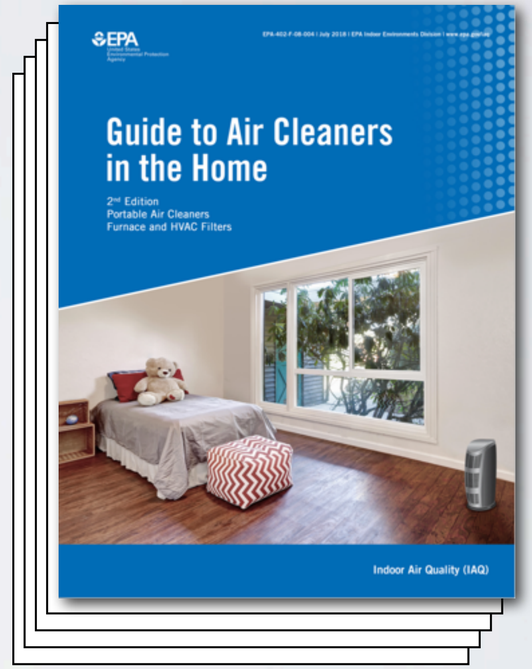
Updated EPA Guidance for Air Cleaners in the Home

Technical summary (74 pages)

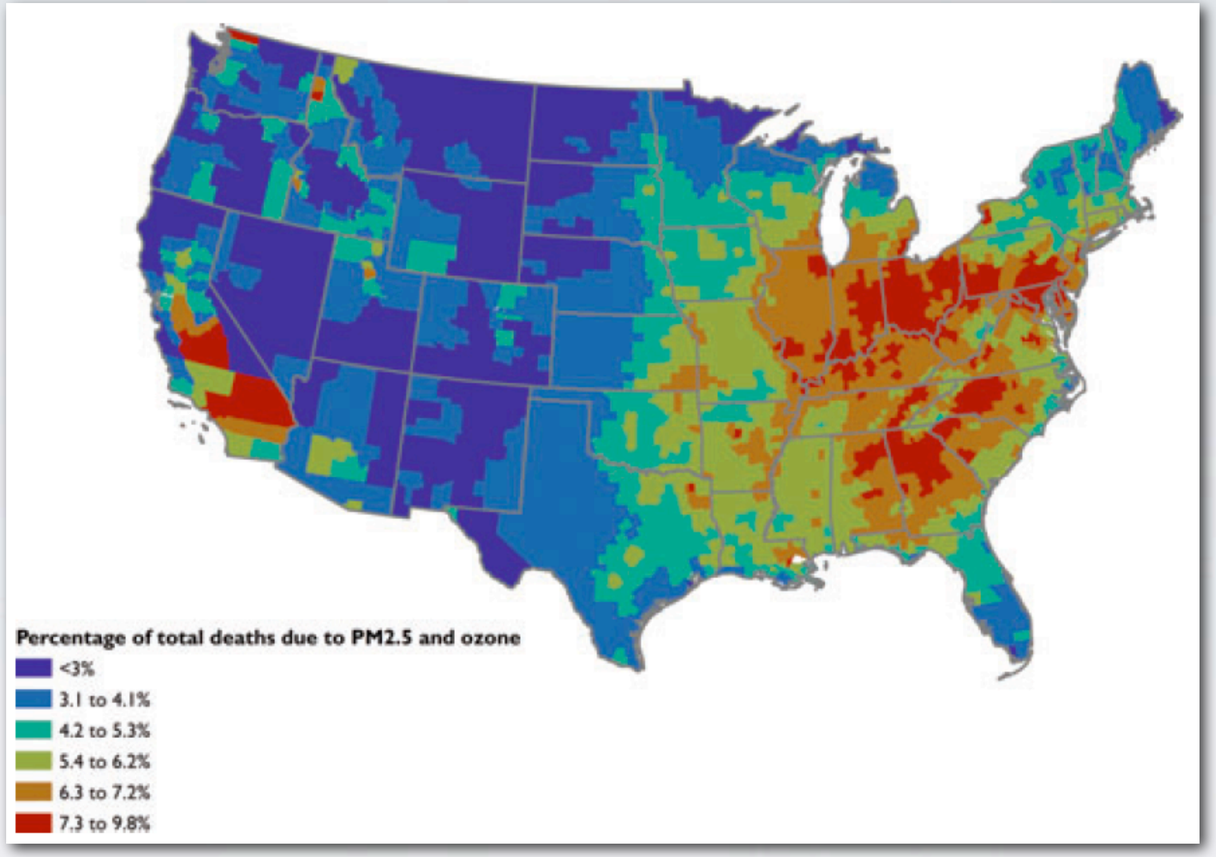
Search: "Residential Air Cleaners: A Technical Summary"



Consumer guide (8 pages)

Search: "Guide to air cleaners in the home: 2nd Edition 2018"

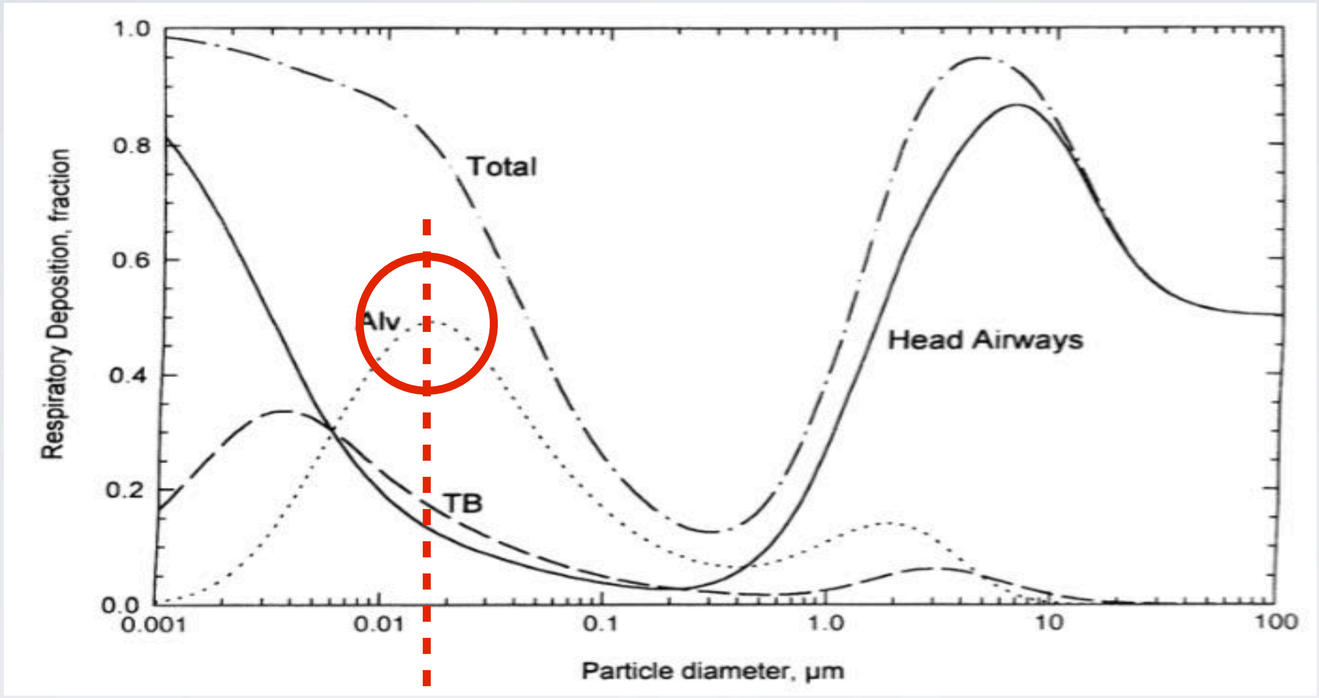
WHY WORRY?



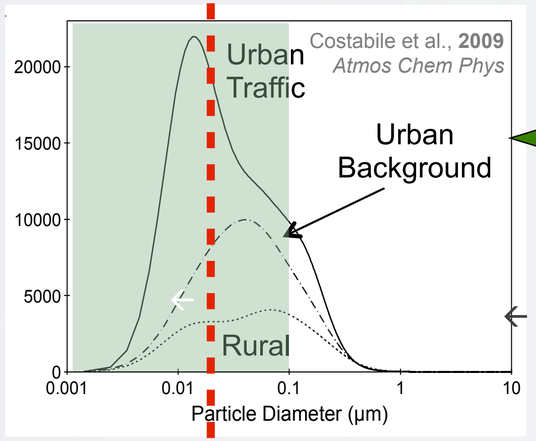
Fann et al. **2012** *Risk Analysis*

An estimated ~130,000 deaths in 2005 in the US were due to outdoor $PM_{2.5}$

RESPIRATORY SYSTEM DEPOSITION - SIZES AND LOCATIONS



← $PM_{2.5}$



Unfortunately
Those are the most common in outdoor air

Hinds **1999** *Aerosol Technol*

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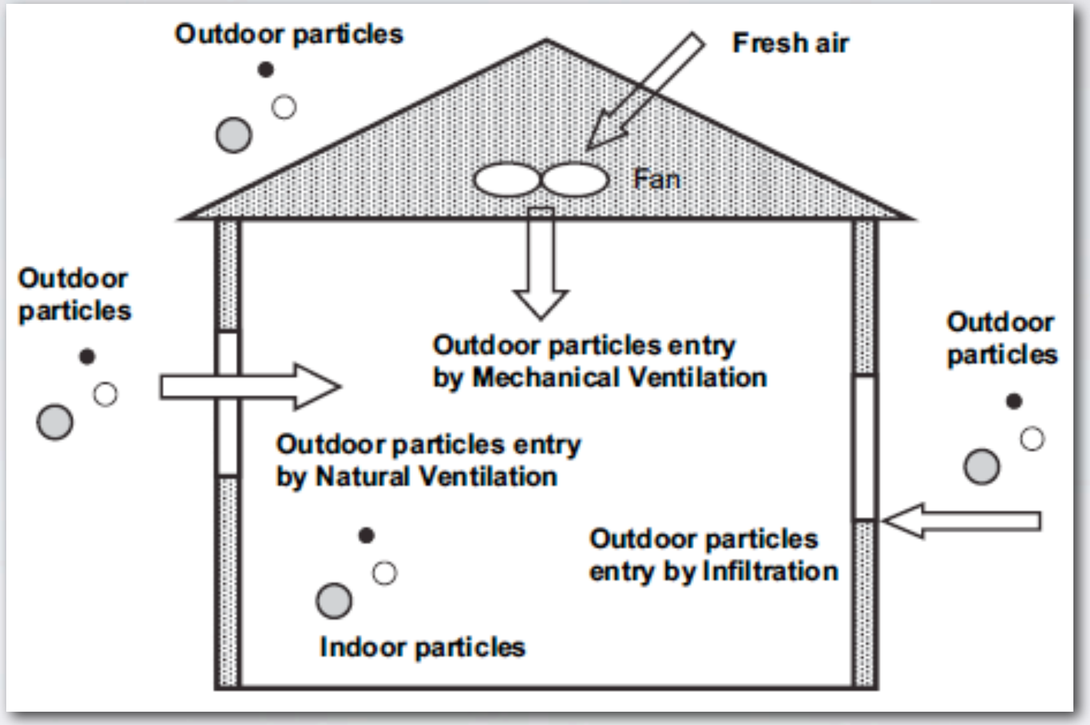
SOURCES OF INDOOR PM



Chen and Zhao, **2011** *Atmos Environ*

Most pollutant exposure occurs indoors (mostly at home)

Residential indoor air exposures account for ~**5-14%** of the **U.S. disease burden**

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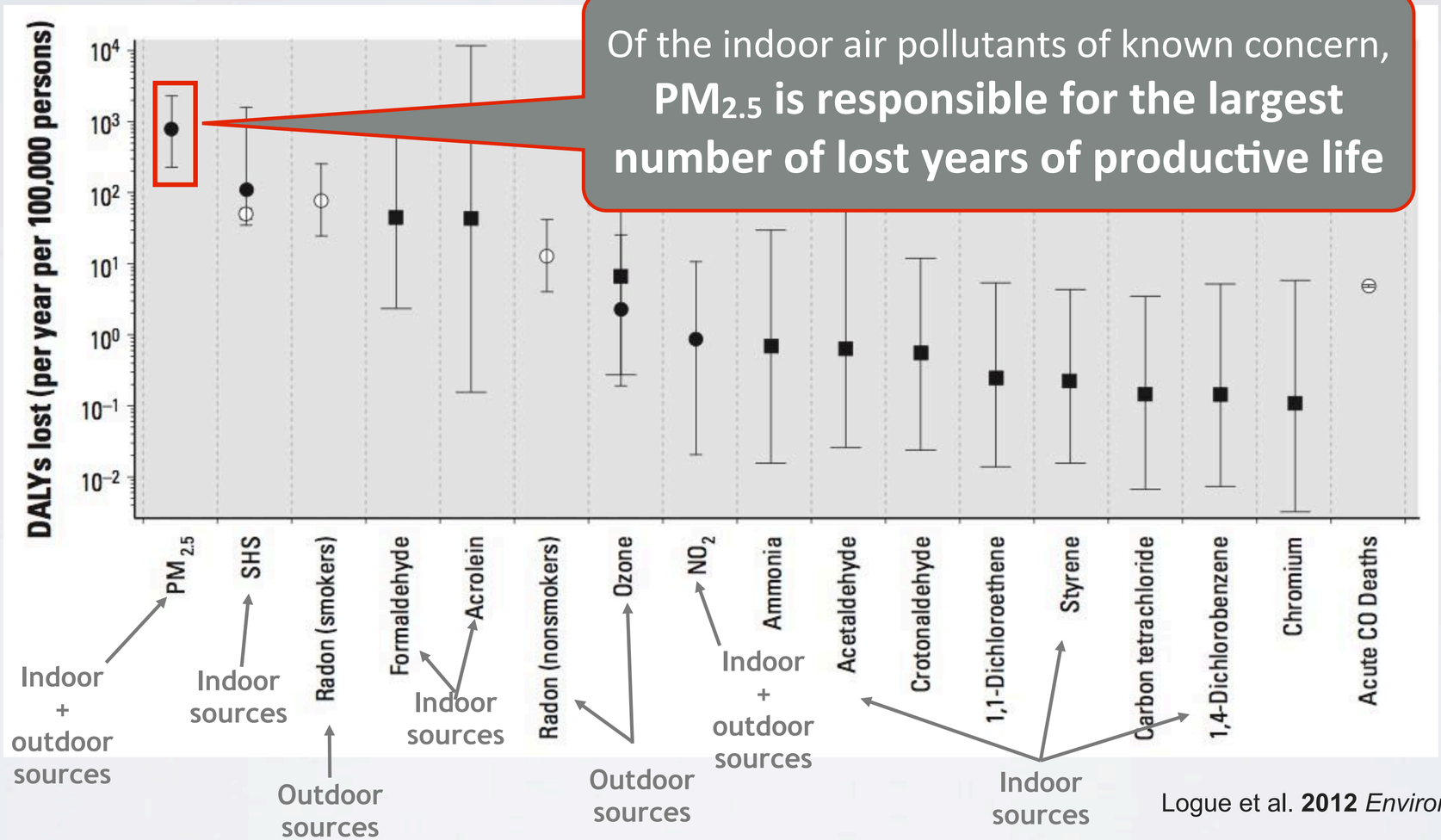
Pollutants of concern - $PM_{2.5}$ tops the list

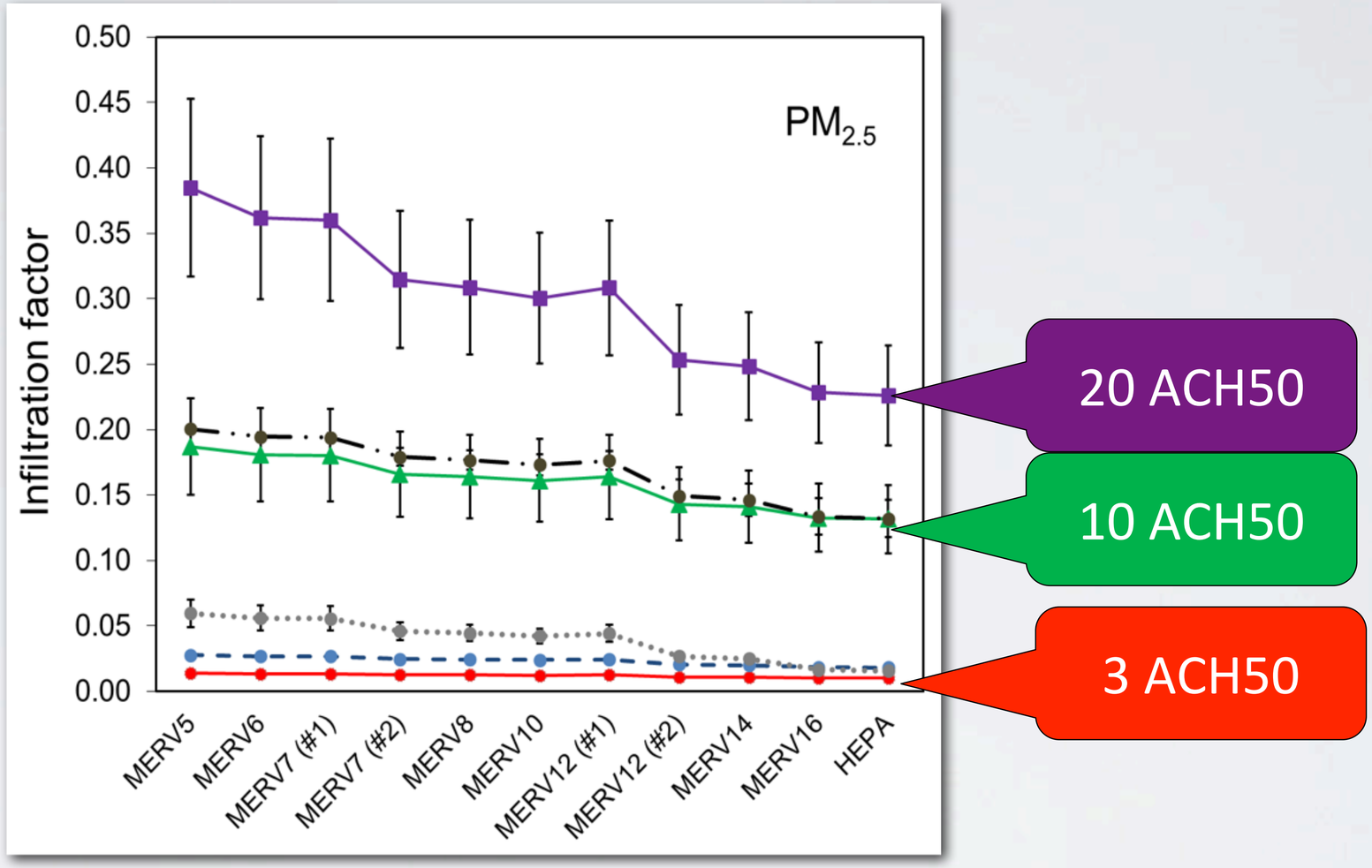
(U.S. Data - Years of productive life lost per 100,000 people)



Of the indoor air pollutants of known concern, **$PM_{2.5}$ is responsible for the largest number of lost years of productive life**

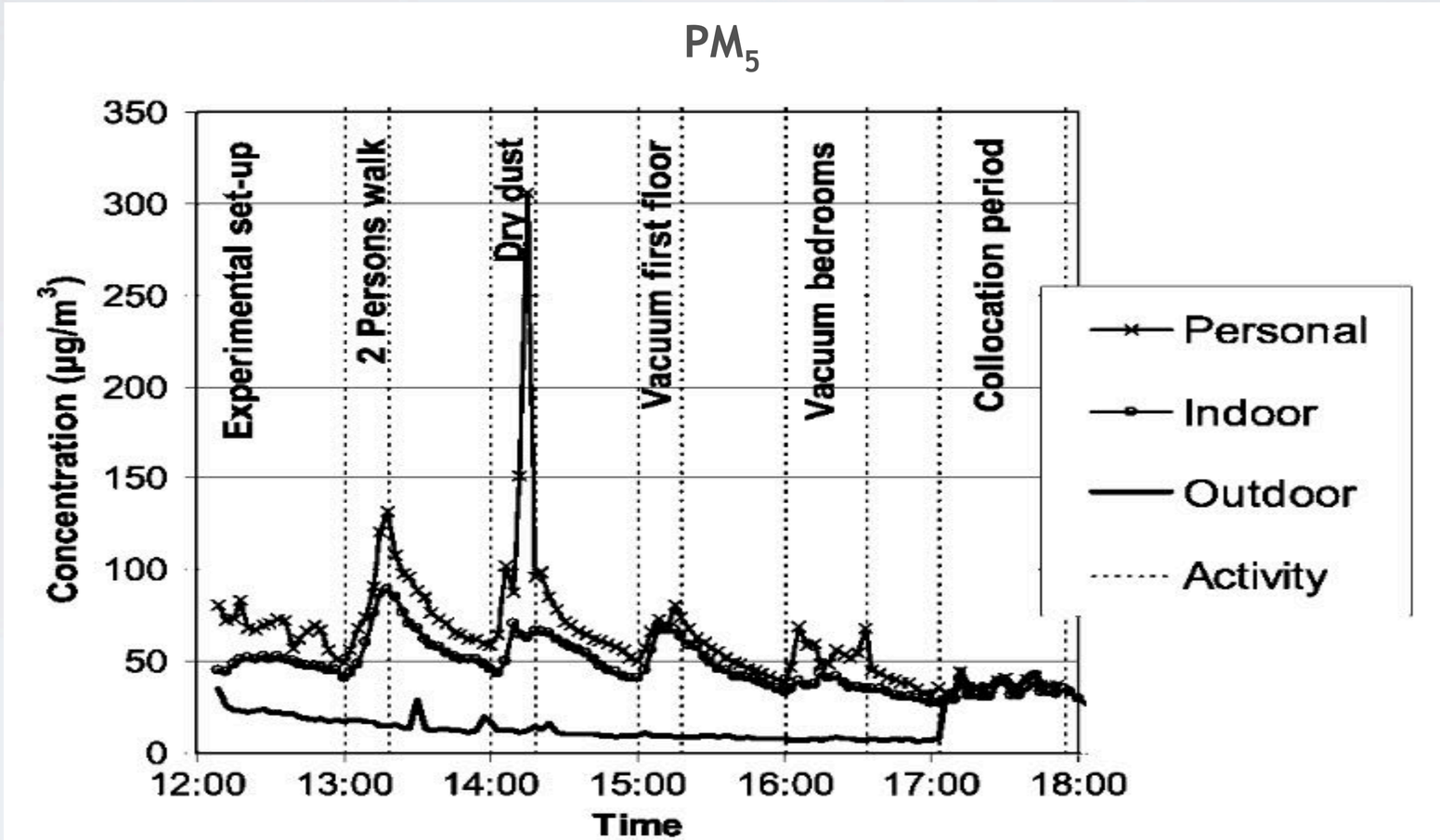
Logue et al. **2012** *Environ Health Perspectives*

Step 1 - Build houses tight, so particles can't get in



Azimi et al. **2016** *Science Technol Built Environ*

SOURCES - NORMAL ACTIVITIES



Ferro et al. **2004** *J Expo Anal Environ Epidem*

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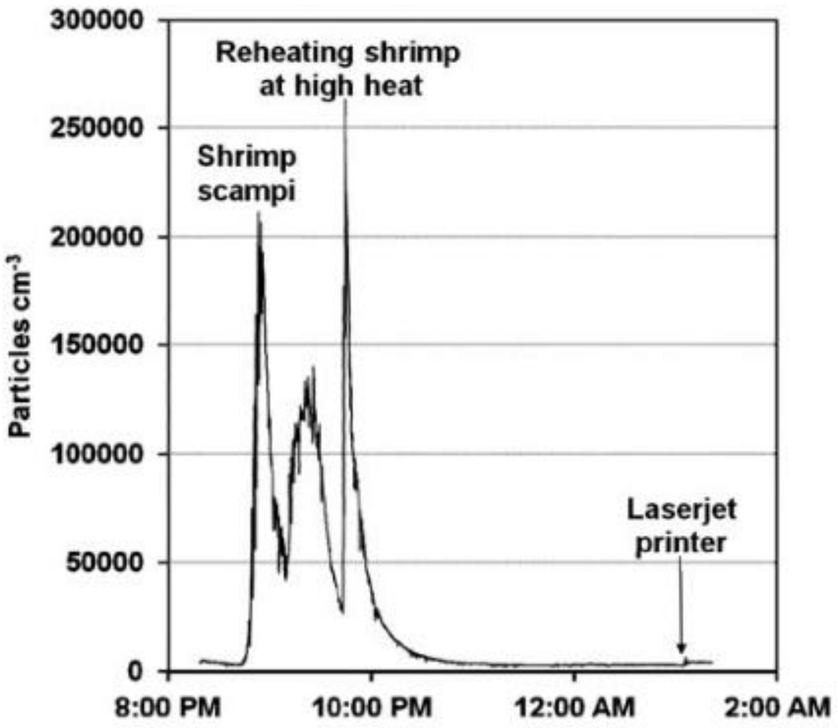
COOKING IS THE BIG ONE

Ultra fine Particles



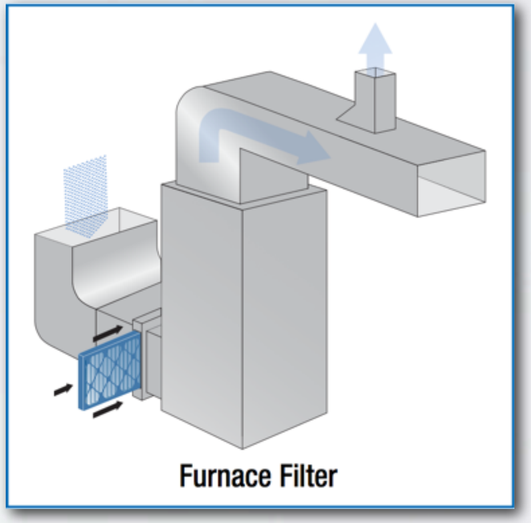
Wallace and Ott **2011** *J Expo Sci Environ Epidem*

Appliance	Event	*N*	Mean emission rate ($\times 10^{12}$) (particles/min^{1})
Gas stove and toaster oven	Cooking	23	5.11
Gas clothes dryer	Drying clothes	6	4.40
Air popper	Popping corn	4	4.26
Electric toaster	Toasting	1	3.8
Match	Lighting candles	3	3.65
Spray cleaner	Housecleaning	6	2.60
Electric toaster oven	Cooking	54	2.11
Gas stove	Cooking	95	1.89
Electric stove	Cooking	21	1.25
Cigarette	Smoking	13	0.48
Electric mixer	Preparing food	5	0.57
Candles	Burning candles	10	0.56
Curling irons	Grooming	3	0.29
Steam iron	Ironing	6	0.24
Hair dryers	Grooming	8	0.23
Space heater	Heating	3	0.13
Hair straightener	Grooming	1	0.11
Laser printer	Printing 10 pages	3	0.06
Vacuums	Housecleaning	2	0.06
Fireplace	Fire lit	1	0.003

What to do?

Exhaust at the source

Remove by filtration



Filtration can be helpful

Intervention studies show improvements in health markers

Technical Summary

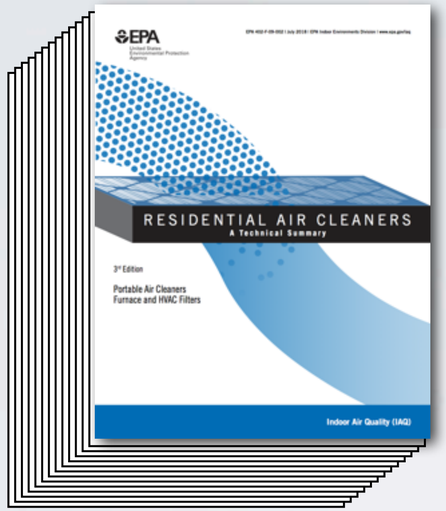


Table 4. Intervention Studies of Primarily Respiratory Health Outcomes in Homes With Subjects With Allergies or Asthma

Study	Brehler et al. (2003)	Francis et al. (2003)	Bernstein et al. (2006)	Sulser et al. (2009)
Subjects	44 adults with allergies and/or asthma	30 adults allergic to cats or dog allergen	19 mold-sensitized asthmatic children, age 5 to 17 years	30 asthmatic children sensitive to pet allergen
Type of building	Homes (24 rural, 20 urban)	Homes with cats or dogs	Homes with central forced air HVAC systems	Homes with high cat or dog allergen levels in dust
Exposures focus	General particles, pollens	Pet allergen	Allergens in dust, bacterial, and fungal counts in air and dust	Pet allergen
First filter location, type, and CADR	Bedroom outdoor air supply (fresh air, no filter)	Bedroom (HEPA, unknown CADR)	In-duct central HVAC (CREDN2000 UVGI with HEPA pre-filter)	Bedroom (220 cfm)
Second filter location, type, and CADR	n/a	Living room (HEPA, unknown CADR)	n/a	Living room (220 cfm)
Gas-phase filtration	No	No	No	No
Intervention period	2 weeks	12 months	8 weeks	12 months
Reduction in exposures	Not reported	• SS and substantial reductions in airborne cat and dog allergen in both groups • Reductions in intervention group not SS relative to reductions in control group	• Small but not SS reduction in mold and bacterial counts in indoor air with UVGI unit versus placebo • No SS difference in allergens or molds in house dust samples	No SS change in cat and dog allergen concentration in dust
Change in allergy and asthma symptoms	Subjects with seasonal allergy: • Nose↑ ↓ (30%) ↔ • Eyes↑ ↓ (42%) ↔ • Lung ↔ Subjects with perennial allergy: • Nose ↔ • Eyes ↔ • Lung ↔	n/a	First treatment period only: • Asthma symptoms ↓ • Asthma medication use ↓	Nasal ↓ Nocturnal ↓ Pediatric quality of life score ↔
Change in objective health outcomes	• Peak expiratory flow (PEF, a measure of how fast a person can exhale) in morning ↓ (5%) • PEF in daytime ↔	• Bronchial hyper-reactivity and/or asthma treatment requirements ↓ • Forced expiratory volume (FEV, how much air a person can exhale during a breath) ↔ • Forced vital capacity (total amount of air exhaled during an FEV test) ↔	Both treatment periods: • Peak expiratory flow (PEF) rate variability ↓ (~2% mean; ~59% median)	• Forced expiratory volume (FEV) ↔ • Eosinophil cationic protein (inflammation marker) ↔ • Non-SS trend toward improved bronchial hyper-responsiveness
Assessment of study strength	Strong (crossover, placebo, randomized order of exposure)	Moderate (random assignment to intervention vs. control group, no placebo)	Moderate (random assignment, placebo, crossover design), but small sample size	Strong (control group with placebo, random assignment to groups)
Author(s) main conclusion(s)	Recommends fresh air filtration systems in bedrooms.	"Small but significant improvement in combined asthma outcome."	"Central UV irradiation was effective at reducing airway hyper-responsiveness manifested as peak expiratory flow rate variability and some clinical symptoms."	"Although HEPA air cleaners retained airborne pet allergens, no effect on disease activity…was observed."

Table 4 (continued). Intervention Studies of Primarily Respiratory Health Outcomes in Homes With Subjects With Allergies or Asthma

Study	Xu et al. (2010)[a]	Butz et al. (2011)	Langhaar et al. (2011)	Park et al. (2017)[a]
Subjects	30 children with asthma	85 children with asthma[a]	215 children with asthma	16 children with asthma and/or allergic rhinitis
Type of building	Homes in New York state	Homes with smokers	Homes with smokers	Homes in California
Exposures focus	General particles and gases	Environmental tobacco smoke	Environmental tobacco smoke	General particles
First filter location, type, and CADR	Bedrooms (HEPA, ~150 cfm, with ~3 air changes per hour of outdoor air ventilation)	Bedroom (HEPA, 225 cfm)	Bedroom (HEPA, 220 cfm)	Living room (HEPA with activated carbon, ~600 cfm)
Second filter location, type, and CADR	n/a	Living room (HEPA, 225 cfm)	Main activity room (HEPA, 220 cfm)	Bedroom (HEPA with activated carbon, ~450 cfm)
Gas-phase filtration	No	Yes (activated carbon)	Yes (activated carbon and potassium permanganate zeolite)	Yes (activated carbon)
Intervention period	6 weeks	6 months	12 months	12 weeks
Reduction in exposures	• 72% ($PM_{2.5-10}$) • 59% (TVOC)	• Intervention group: SS 19.9 and 8.7 $\mu g/m^3$ (59% and 46%) decreases in $PM_{2.5}$ and PM_{10}, respectively versus control group • Control group: 3.5 and 2.4 $\mu g/m^3$ (9% and 14%) increases in $PM_{2.5}$ and PM_{10}, respectively • No SS changes in air nicotine or urine cotinine concentrations	• SS 25% reduction in particle counts >0.3 µm in intervention group relative to 5% reduction in control group • No SS reductions in particle counts >5 µm or airborne nicotine	43% (PM_{10})
Change in allergy and asthma symptoms	n/a	• Symptom-free days↑ ↓ (10%) • Slow activity days ↔ • Nocturnal cough ↔ • Wheeze ↔ • Tight chest ↔	• Asthma symptoms ↔	• Asthma control test scores ↑ (~45%) • Nasal symptom scores ↓ (~30%)
Change in objective health outcomes	• Peak expiratory flow (PEF) ↑ • Exhaled breath nitrate concentration (pulmonary inflammation marker) ↓ • Exhaled breath condensate pH (pulmonary inflammation marker) ↑	n/a	• Unscheduled asthma-related visits to a healthcare provider ↓ (25%) • Exhaled nitric oxide (inflammation indicator) ↔ • Medication use ↔	• Peak expiratory flow (PEF) ↑ (~100%)
Assessment of study strength	Weak (all participants received crossover intervention, with randomized different timings, effect size is difficult to interpret)	Moderate (random assignment to intervention vs. control group, no placebo)	Strong (control group with placebo, random assignment to groups)	Weak (randomized control and intervention groups, small sample size of 8 homes per group, no placebo, no crossover)
Author(s) main conclusion(s)	"Air cleaning in combination with ventilation can effectively reduce symptoms for asthma sufferers."[1]	Air cleaners reduce particles and symptom-free days but do not prevent exposure to secondhand smoke.	Air cleaners promising "as part of multi-faceted strategy to reduce asthma morbidity."	"Reducing indoor $PM_{2.5}$ with air purifiers may be an effective means of improving clinical outcomes in patients with allergic diseases."

Table 4
Asthma

Table 5. Intervention Studies of Primarily Cardiovascular Health Outcomes in Homes Not Targeting Subjects With Allergies or Asthma

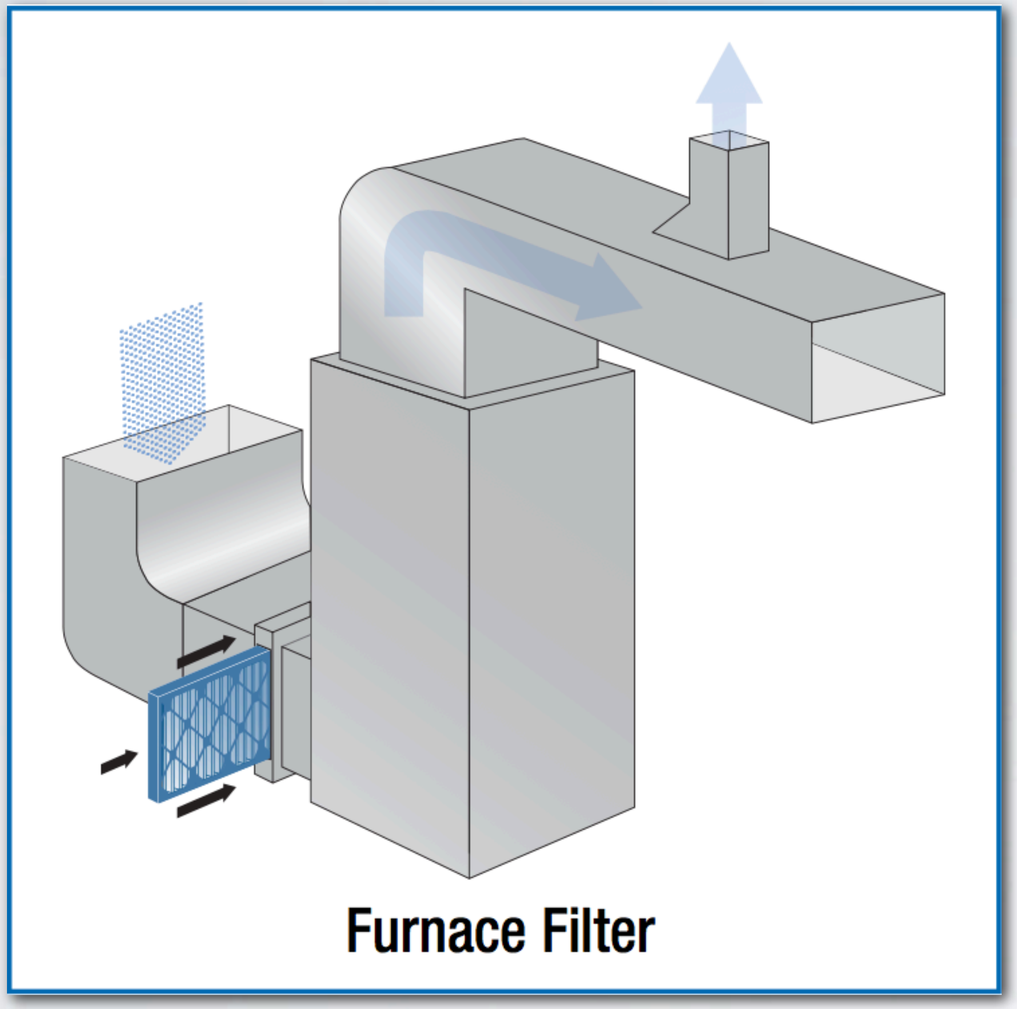
Study	Brauner et al. (2008)	Allen et al. (2011)	Lin et al. (2011)	Weichenthal et al. (2013)
Subjects	41 healthy non-smoking adults age 60–75	45 adults	60 healthy non-smoking young adults (students)	37 adults and children, 6 with asthma
Type of building	Urban homes within 350 m of a major road in Denmark	25 homes in a small city in Canada	Homes in Taiwan	First Nations homes in Canada, most with smoking
Exposures focus	General particles	Wood smoke	General particles	General particles, tobacco smoke
First filter location, type, and CADR	Bedroom (HEPA, ~320 cfm)	Bedroom of each home (HEPA, 150 cfm)	Central HVAC filter (3M Filtrete)	Main living area (224 cfm)
Second filter location, type, and CADR	Living room (HEPA, ~320 cfm)	Living room (HEPA, 300 cfm)	n/a	n/a
Gas-phase filtration	No	No	No	No
Intervention period	2 days	1 week	4 weeks	1 week
Exposure concentration without treatment	12.6 $\mu g/m^3$ ($PM_{2.5}$ geometric mean) 9.4 $\mu g/m^3$ ($PM_{2.5-10}$ geometric mean) 10,016 cm^{-3} (count 10–700 nm)	11.2 $\mu g/m^3$ ($PM_{2.5}$ mean)	22.8 ± 12.2, 24.5 ± 13.0 $\mu g/m^3$ ($PM_{2.5}$ mean)	49.0 $\mu g/m^3$ (PM_{10}) 42.5 $\mu g/m^3$ ($PM_{2.5}$) 37.5 $\mu g/m^3$ (PM_{1})
Reduction in exposures	63% ($PM_{2.5}$ geometric mean) 51% (PM_{10} geometric mean) 68% (count 10–700 nm)	60% $PM_{2.5}$ 74% levoglucosan (wood smoke marker)	~20% reduction in $PM_{2.5}$	54% (PM_{10}) 61% ($PM_{2.5}$) 62% (PM_{1})
Change in objective health outcomes	Microvascular function (coronary event predictor) ↓ (8%) Hemoglobin ↓ (1%) Inflammation biomarker ↔ Biomarker of coagulation ↔	Reactive hyperemia index (coronary event predictor) ↓ (9%) C-reactive protein (inflammation marker) ↓ (33%) Oxidative stress ↔	Systolic blood pressure ↓ (11%) Diastolic blood pressure ↓ (7%) Heart rate ↓ (7%)	Systolic blood pressure ↓ (7%) Diastolic blood pressure ↓ (6%) Forced expiratory flow (PEF) ↓ (6%) Forced vital capacity ↔ Peak expiratory flow ↓ (8%) Reactive hyperemia index (coronary event predictor) ↔
Assessment of study strength	Strong (blinded, placebo-controlled intervention, within-subject, randomized order of exposure	Strong (crossover, placebo, randomized order of exposure)	Weak (intervention periods always followed periods without intervention)	Strong (randomized double blind crossover with placebo)
Author(s) main conclusion(s)	Filtration of recirculated air may be a feasible way of reducing the risk of cardiovascular disease.	Predictors of cardiovascular morbidity can be favorably influenced by reducing particles with air cleaners.	Air filtration can reduce indoor $PM_{2.5}$ concentrations and modify the effect of $PM_{2.5}$ on blood pressure and heart rate in a healthy, young population.	Reducing indoor PM may contribute to improved lung function in First Nation communities.

Table 5 (continued). Intervention Studies of Primarily Cardiovascular Health Outcomes in Homes Not Targeting Subjects With Allergies or Asthma

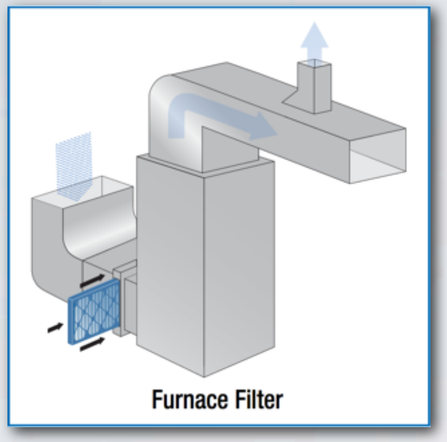
Study	Karottki et al. (2013)[a]	Chen et al. (2015)[a]	Kajbafzadeh et al. (2015)[a]	Padró-Martínez et al. (2015)[a]
Subjects	48 elderly nonsmoking adults	35 healthy university students	83 healthy adults	20 non-smoking adults
Type of building	27 homes in Denmark	Dormitories in Shanghai, China	Homes in Vancouver, British Columbia, Canada	Public housing units within 200 m of major interstate in Somerville, Massachusetts
Exposures focus	General particles	Indoor particles of outdoor origin	Traffic and woodsmoke particles	Traffic-related and general indoor particles
First filter location, type, and CADR	Living room (HEPA, unknown CADR)	Center of the room (Filtrete, 141, 116, and 97 cfm for pollen, dust, and smoke)	Living room (HEPA, 300 cfm for smoke)	Window mounted in living rooms (MERV 17, 170 cfm with outdoor air ventilation)
Second filter location, type, and CADR	Bedroom (HEPA, unknown CADR)	n/a	Bedroom (HEPA, 150 cfm for smoke)	n/a
Gas-phase filtration	No	No	No	No
Intervention period	2 weeks	2 days	1 week	3 weeks
Exposure concentration without treatment	8 $\mu g/m^3$ ($PM_{2.5}$ median) 7,669 cm^{-3} (count)	96.2 $\mu g/m^3$ ($PM_{2.5}$ mean)	7.1 $\mu g/m^3$ ($PM_{2.5}$ mean)	11,660 cm^{-3} (count, mean of medians)
Reduction in exposures	~50% ($PM_{2.5}$) ~30% (10–300 nm particle number)	57% ($PM_{2.5}$)	40% ($PM_{2.5}$)	47% (7 nm to 3 µm number concentrations, or PNC)
Change in objective health outcomes	Microvascular function ↑↔ Lung function ↔ Biomarkers of systemic inflammation ↔	Circulatory inflammatory markers: • Monocyte chemoattractant protein-1 ↓ (18%) • Interleukin-1β ↓ (68%) • Myeloperoxidase ↓ (33%) Circulatory coagulation markers: • Soluble CD40 ligand ↓ (65%) Systolic blood pressure ↓ (3%) Diastolic blood pressure ↓ (5%) Fractional exhaled nitrous oxide ↓ (17%) Several other biomarkers of inflammation, coagulation, vasoconstriction or lung function ↔	Biomarkers of systemic inflammation: • C reactive protein ↓↑ • Interleukin-6 ↔ • Band cells ↔ Microvascular endothelial function ↔ Reactive hyperaemia index ↔	Biomarkers of systemic inflammation and coagulation: • Interleukin-6 (IL-6) ↑ • C reactive protein ↔ • Tumor necrosis factor alpha-receptor II (TNF-RII) ↔ • Fibrinogen ↔ Systolic blood pressure ↔ Diastolic blood pressure ↔
Assessment of study strength	Strong (randomized, double-blind, crossover intervention)	Strong (randomized, double-blind crossover with placebo)	Strong (randomized, single-blind crossover with placebo)	Moderate (randomized, double-blind crossover with placebo, small sample sizes)
Author(s) main conclusion(s)	"Substantial exposure contrasts in the bedroom" observed.	The study "demonstrated clear cardiopulmonary benefits of indoor air purification among young, healthy adults in a Chinese city with severe ambient particulate air pollution."	The "association between C-reactive protein and indoor $PM_{2.5}$ among healthy adults in traffic-impacted areas is consistent with the hypothesis that traffic-related particles (even at low concentrations) play an important role in the cardiovascular effects of the urban PM mixture."	"HEPA filtration remains a promising, but not fully realized intervention." Associations between decreased PNC and increased IL-6 could be due to confounding factors, interference with anti-inflammatory medication use, or exposure misclassification due to time-activity patterns.

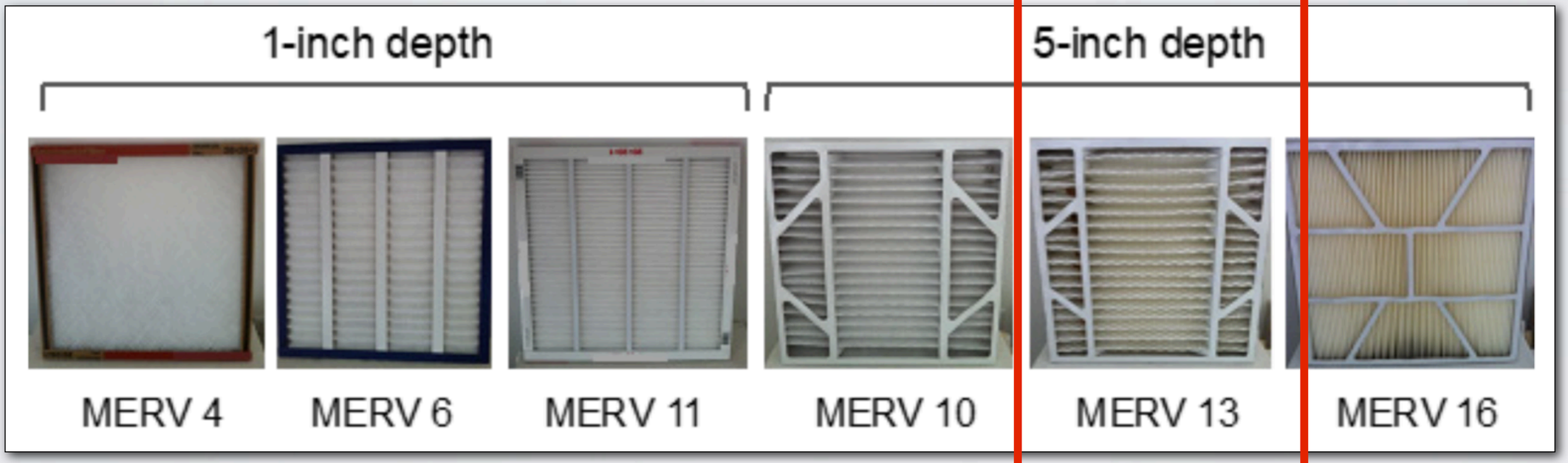
Table 5
Cardiovascular Functions Inflammation

Air Cleaner Alternatives - Central systems + Portables



Central system air filters: EPA Recommends **MERV 13**





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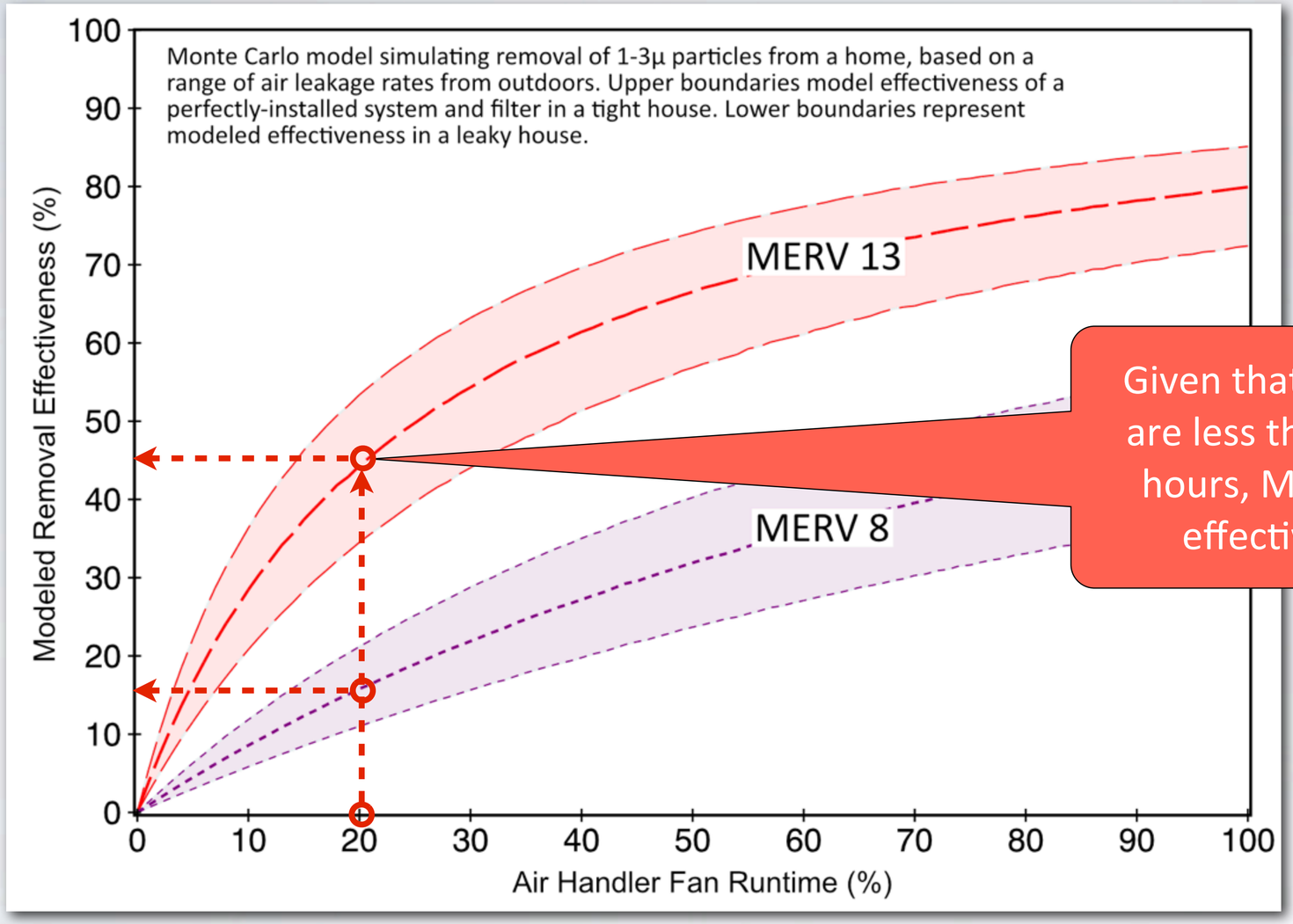
Central filtration could reduce indoor $PM_{2.5}$...

BUT... furnaces and AC systems don't run much!

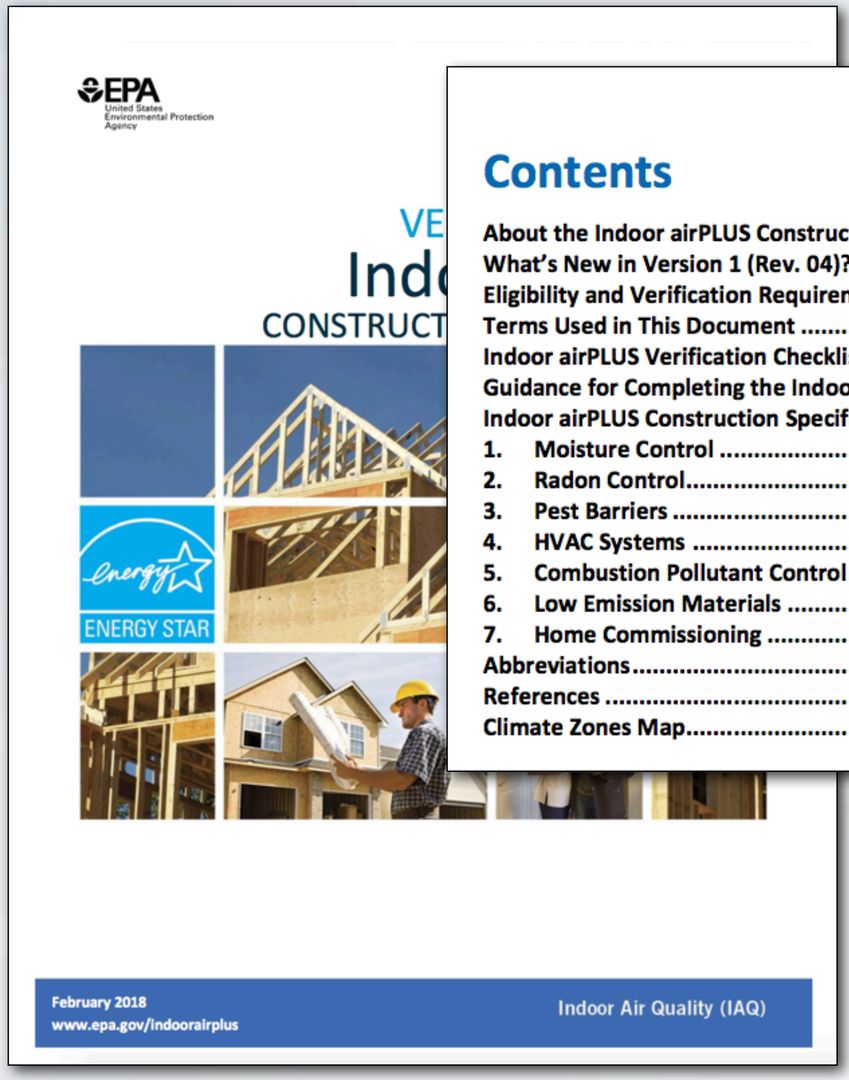


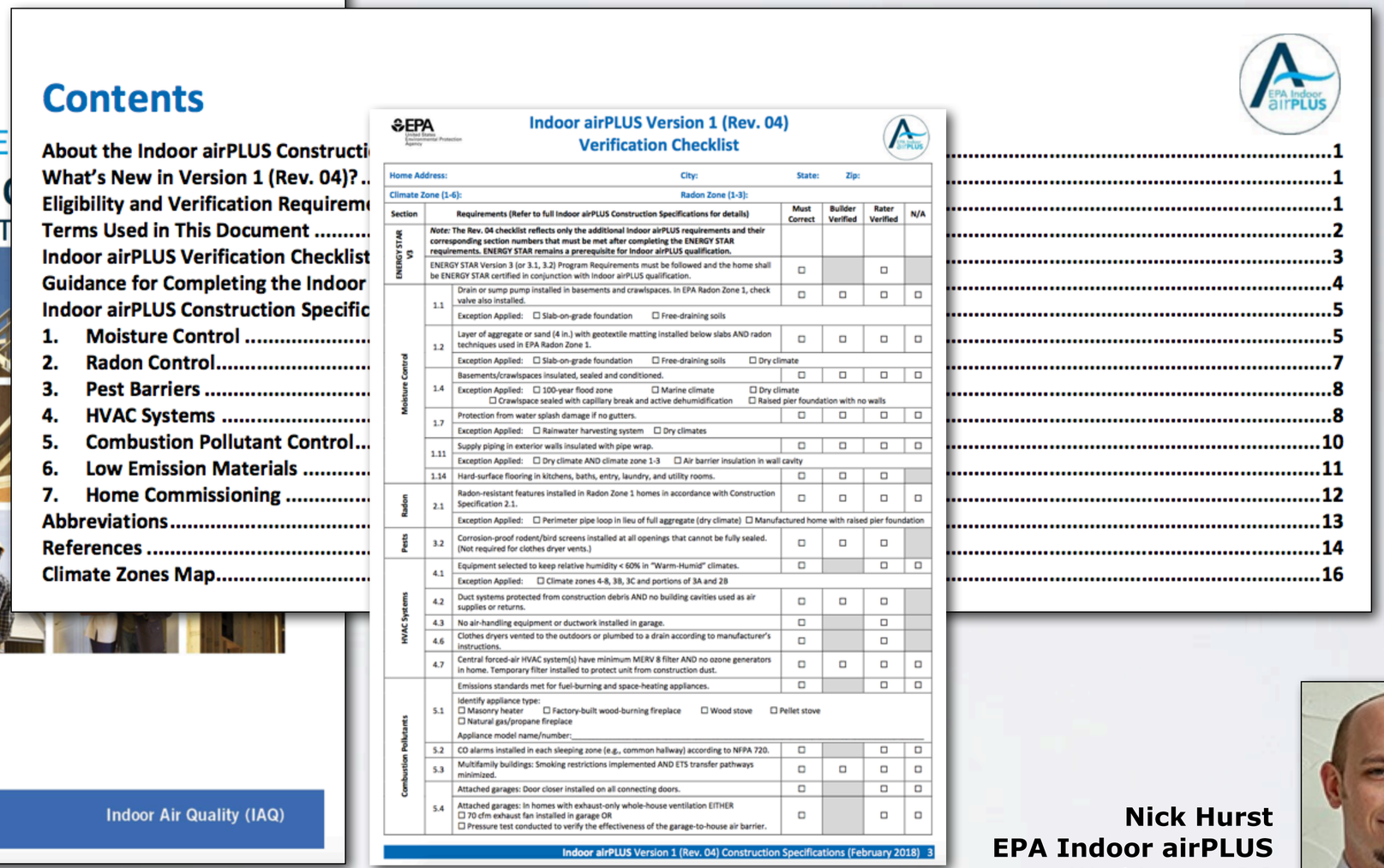
Given that typical run-times are less than 20% of annual hours, MERV 13 is a more effective filter choice

Model, analysis and graph courtesy of
Marianne Touchie and Jeff Siegel - U. Toronto

Indoor airPLUS

Comprehensive specifics + branded certainty for builders





Contents

EPA United States Environmental Protection Agency

Indoor airPLUS Version 1 (Rev. 04)
Verification Checklist

Home Address: City: State: Zip:

Climate Zone (1-6): Radon Zone (1-3):

Section		Requirements (Refer to full Indoor airPLUS Construction Specifications for details)	Must Correct	Builder Verified	Rater Verified	N/A
ENERGY STAR V3		***Note:*** **The Rev. 04 checklist reflects only the additional Indoor airPLUS requirements and their corresponding section numbers that must be met after completing the ENERGY STAR requirements. ENERGY STAR remains a prerequisite for Indoor airPLUS qualification.**				
		ENERGY STAR Version 3 (or 3.1, 3.2) Program Requirements must be followed and the home shall be ENERGY STAR certified in conjunction with Indoor airPLUS qualification.	☐		☐	
Moisture Control	1.1	Drain or sump pump installed in basements and crawlspaces. In EPA Radon Zone 1, check valve also installed.	☐	☐	☐	☐
		Exception Applied: ☐ Slab-on-grade foundation ☐ Free-draining soils				
	1.2	Layer of aggregate or sand (4 in.) with geotextile matting installed below slabs AND radon techniques used in EPA Radon Zone 1.	☐	☐	☐	☐
		Exception Applied: ☐ Slab-on-grade foundation ☐ Free-draining soils ☐ Dry climate				
	1.4	Basements/crawlspaces insulated, sealed and conditioned.	☐	☐	☐	☐
		Exception Applied: ☐ 100-year flood zone ☐ Marine climate ☐ Dry climate ☐ Crawlspace sealed with capillary break and active dehumidification ☐ Raised pier foundation with no walls				
	1.7	Protection from water splash damage if no gutters.	☐	☐	☐	☐
		Exception Applied: ☐ Rainwater harvesting system ☐ Dry climates				
	1.11	Supply piping in exterior walls insulated with pipe wrap.	☐	☐	☐	☐
		Exception Applied: ☐ Dry climate AND climate zone 1-3 ☐ Air barrier insulation in wall cavity				
	1.14	Hard-surface flooring in kitchens, baths, entry, laundry, and utility rooms.	☐	☐	☐	
Radon	2.1	Radon-resistant features installed in Radon Zone 1 homes in accordance with Construction Specification 2.1.	☐	☐	☐	☐
		Exception Applied: ☐ Perimeter pipe loop in lieu of full aggregate (dry climate) ☐ Manufactured home with raised pier foundation				
Pests	3.2	Corrosion-proof rodent/bird screens installed at all openings that cannot be fully sealed. (Not required for clothes dryer vents.)	☐	☐	☐	
HVAC Systems	4.1	Equipment selected to keep relative humidity < 60% in "Warm-Humid" climates.	☐		☐	☐
		Exception Applied: ☐ Climate zones 4-8, 3B, 3C and portions of 3A and 2B				
	4.2	Duct systems protected from construction debris AND no building cavities used as air supplies or returns.	☐	☐	☐	
	4.3	No air-handling equipment or ductwork installed in garage.	☐		☐	
	4.6	Clothes dryers vented to the outdoors or plumbed to a drain according to manufacturer's instructions.	☐		☐	
	4.7	Central forced-air HVAC system(s) have minimum MERV 8 filter AND no ozone generators in home. Temporary filter installed to protect unit from construction dust.	☐	☐	☐	☐
Combustion Pollutants		Emissions standards met for fuel-burning and space-heating appliances.	☐		☐	☐
	5.1	Identify appliance type: ☐ Masonry heater ☐ Factory-built wood-burning fireplace ☐ Wood stove ☐ Pellet stove ☐ Natural gas/propane fireplace Appliance model name/number:_____				
	5.2	CO alarms installed in each sleeping zone (e.g., common hallway) according to NFPA 720.	☐		☐	☐
	5.3	Multifamily buildings: Smoking restrictions implemented AND ETS transfer pathways minimized.	☐	☐	☐	☐
		Attached garages: Door closer installed on all connecting doors.	☐		☐	☐
	5.4	Attached garages: In homes with exhaust-only whole-house ventilation EITHER ☐ 70 cfm exhaust fan installed in garage OR ☐ Pressure test conducted to verify the effectiveness of the garage-to-house air barrier.	☐		☐	☐

Indoor airPLUS Version 1 (Rev. 04) Construction Specifications (February 2018) 3

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2018 EPA Guide to Air Cleaners in the Home
EEBA - San Diego 2018

Indoor airPLUS - Air cleaning requirement
… **installation** matters!

4.5 Mechanical Whole-Dwelling Ventilation

NOTE: Completion of the ENERGY STAR requirements satisfies the following Indoor airPLUS requirements:

- ✓ *Provide mechanical whole-dwelling ventilation meeting all requirements of ASHRAE 62.2-2010 or later (HVAC-D 2).*
- ✓ *Test airflows to ensure they meet ASHRAE 62.2-2010 or later minimum requirements (Rater-F 7.1).*

Whole-house ventilation (ASHRAE 62.2-2010)

Installation **matters**... MUST really measure airflows!

Install only HVAC filters that are rated MERV 8 or higher according to ASHRAE 52.2-2007 (at approximately 295 fpm).

MERV 8 (minimum)

Advisory: EPA recommends, but does not require, filters rated at MERV 13 or higher to reduce exposure to fine particles. Filters perform best when the filter rack design includes the following features, which are also included in some manufacturers' filter media boxes:

MERV 13 (recommended)

- Flexible, air-tight (e.g., closed-cell foam) gasket material on the surface that contacts the air-leaving (downstream) side of the filter.
- Friction fit or spring clips installed on the upstream side of the filter to hold it firmly in place.

Air-tight filter rack (recommended)

Portable Air Cleaners: EPA Recommends **High CADR**

Intervention Studies Showing **Effective** Indoor $PM_{2.5}$ Reduction	
Central Filtration	Portable HEPA
Heroux et al 2010	Allen et al, 2011
Singer et al, 2016	Barn et al, 2008
	Bruner et al, 2008
	Butz et al, 2011
	Chen at al, 2015
	Cui et al, 2018
	Kajbafazadeh et al, 2015
	Karottki et al, 2013
	Park et al, 2017
	Shao et al, 2017
	Weichenthal et al, 2013
	Xu et al, 2010

CADR: Clean Air Delivery Rate - The AHAM certification

0.09 - 1.0 µm

0.5- 3.0 µm

5.0 - 11.0 µm

Size of the room from which 80% of initial concentration 24,000 to 36,000 particles/cc of smoke particles (0.09 to 1.0µm) will be removed (per hour), provided that...

a. Ceilings are 8ft or lower

b. Unit operates continuously

c. Less than one (1) ach air exchange with other rooms

d. No air exchange with outdoors

e. No particle generation in the space

"AHAM 2/3 rule"

Select a portable air cleaner that has a smoke CADR (cfm) ≥ 2/3 of the floor area (ft^2)

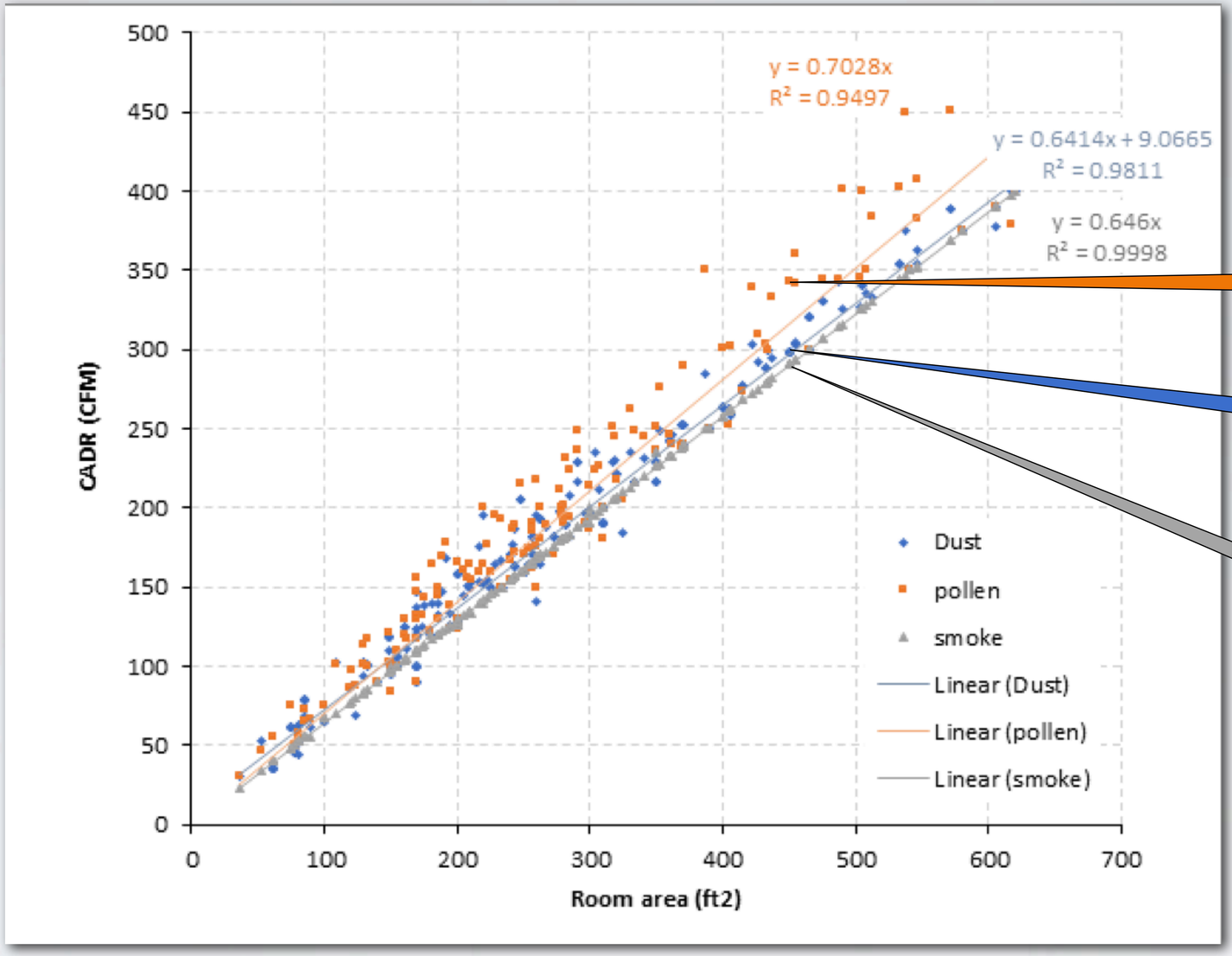
450 ft^2

450 ft^2 x 0.66 = 297

OK

Analysis of AHAM air cleaner certification measurements confirm that (almost always)

When smoke CADR is OK... CADR's for others are even better

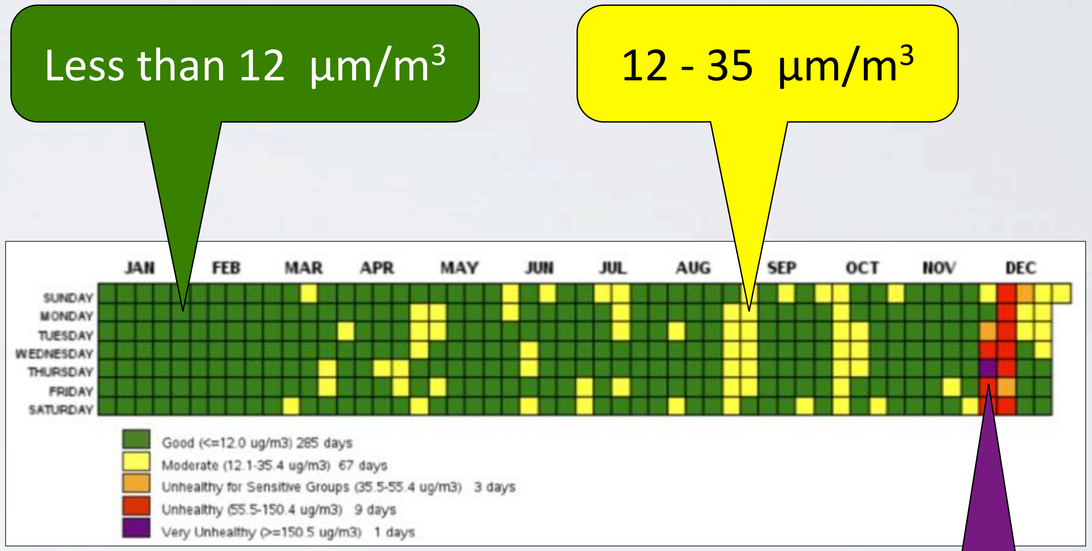


Pollen CADR
345 cfm

Dust CADR
300 cfm

Smoke CADR
295 cfm

Portables can provide useful **mitigation of wildfire $PM_{2.5}$**



PM2.5 concentration - Santa Barbara, CA - 2017
Source: EPA
(Google search: “EPA Outdoor Air Quality Data”)

Portables can provide improvements for homes with ductless min-splits and VRF equipment

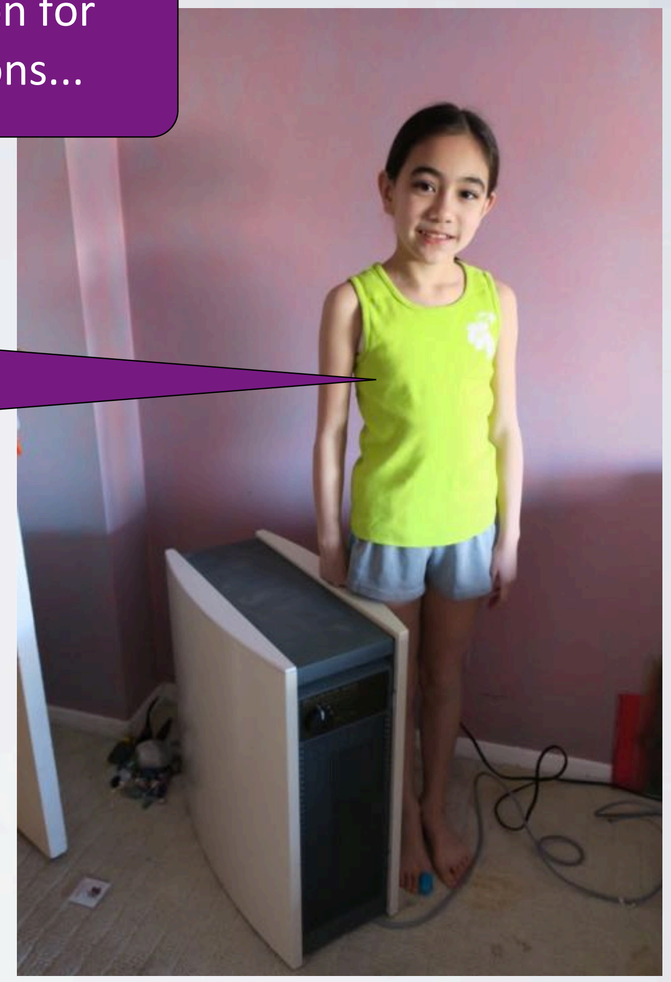
Generally speaking…

- Minisplit filters protect equipment, but are not usually rated for $PM_{2.5}$ removal
- Efficient houses may not need much cooling/heating air flow **(less air flow = less air filtration)**

Bedroom (sleeping) represents many hours of exposure

Portables can provide economical protection for vulnerable populations...

...especially for children who live next to sources of $PM_{2.5}$ like highways and farms

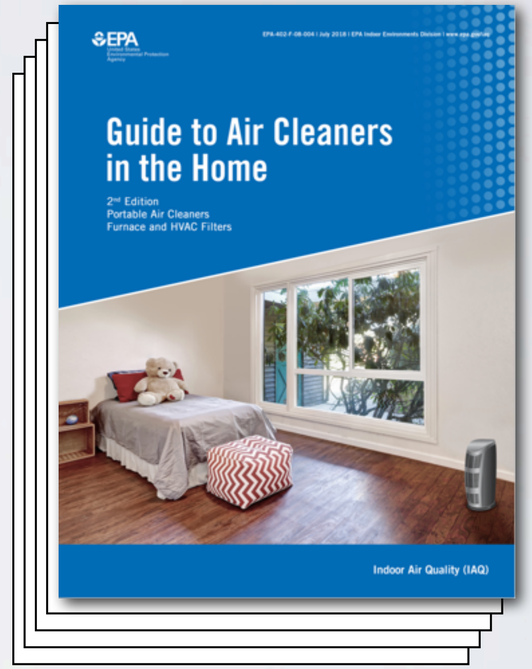


Summary

Technically-robust guidance is available for builders and consumers

Technical summary (74 pages)

Search: "Residential Air Cleaners: A Technical Summary"



Consumer guide (8 pages)

Search: "Guide to air cleaners in the home: 2nd Edition 2018"