Air Filtration for Clean Air and Good Health*

September 24, 2014

National Air Filtration Association
2014 Annual Convention
Aspen, CO

*Review of health implications supported by the US EPA, Indoor Environments Division

Outline

- Effects of particle filtration on health
- Role filter efficiency and flow rate
- Suggestions for improving filtration products and practices
- Opportunities for filtration industry

Review of Health Implications: Scope

Only Considers Particle filtration

- minimal data available on health benefits of gas phase filtration

Most studies from homes

Excluded

- Ion generators
- Health care facility applications
  - e.g., immune compromised subjects, surgery
- Developing country settings
  - e.g., with indoor unvented biomass cooking or kerosene lighting
- Industrial applications

Review Methods

Sources of data

1. Refereed archival journal articles or equivalent
2. Applied minimum study quality criteria
   - Intervention studies, with blinding, statistical analysis, within subject comparison or well-selected control group

Compiled & analyzed results in categories

1. Prior reviews
   - *Clearing the* Air by Institute of Medicine [2000], 18 studies before 1998
   - Three other reviews, almost entirely of papers included IOM's review
2. Most recent meta-analysis of top quality studies [McDonald et al., 2002]
3. New intervention studies (16 studies)
4. Four studies that modeled impacts of using air filtration to reduce health impacts associated with outdoor air particles

Clearing the Air [National Academy of Sciences, Institute of Medicine, 2000]

Key Findings of IOM

- Many studies had weaknesses

- Main conclusion
  - "data suggest that air cleaners are helpful in some situations in reducing allergy or asthma symptoms, particularly seasonal symptoms, but it is clear that air cleaning, as applied in the studies, is not consistently and highly effective in reducing symptoms." (p. 384)

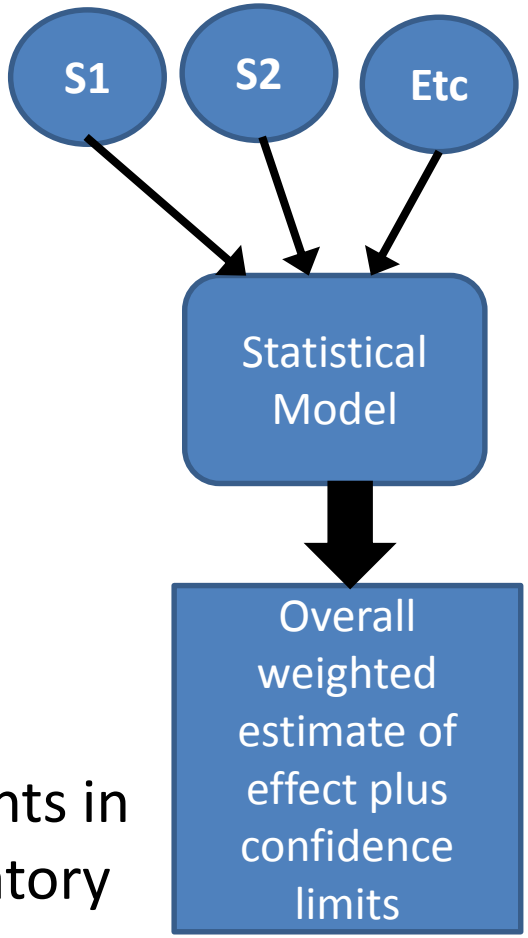
Other reviews

Three subsequent reviews, largely of the same studies, have similar conclusions

Meta-Analysis (McDonald et al., 2002)

Scope

- 10 randomized trials of residential filtration
- in homes of subjects with asthma
- 9 of 10 trials in Institute of Medicine's review



Overall findings

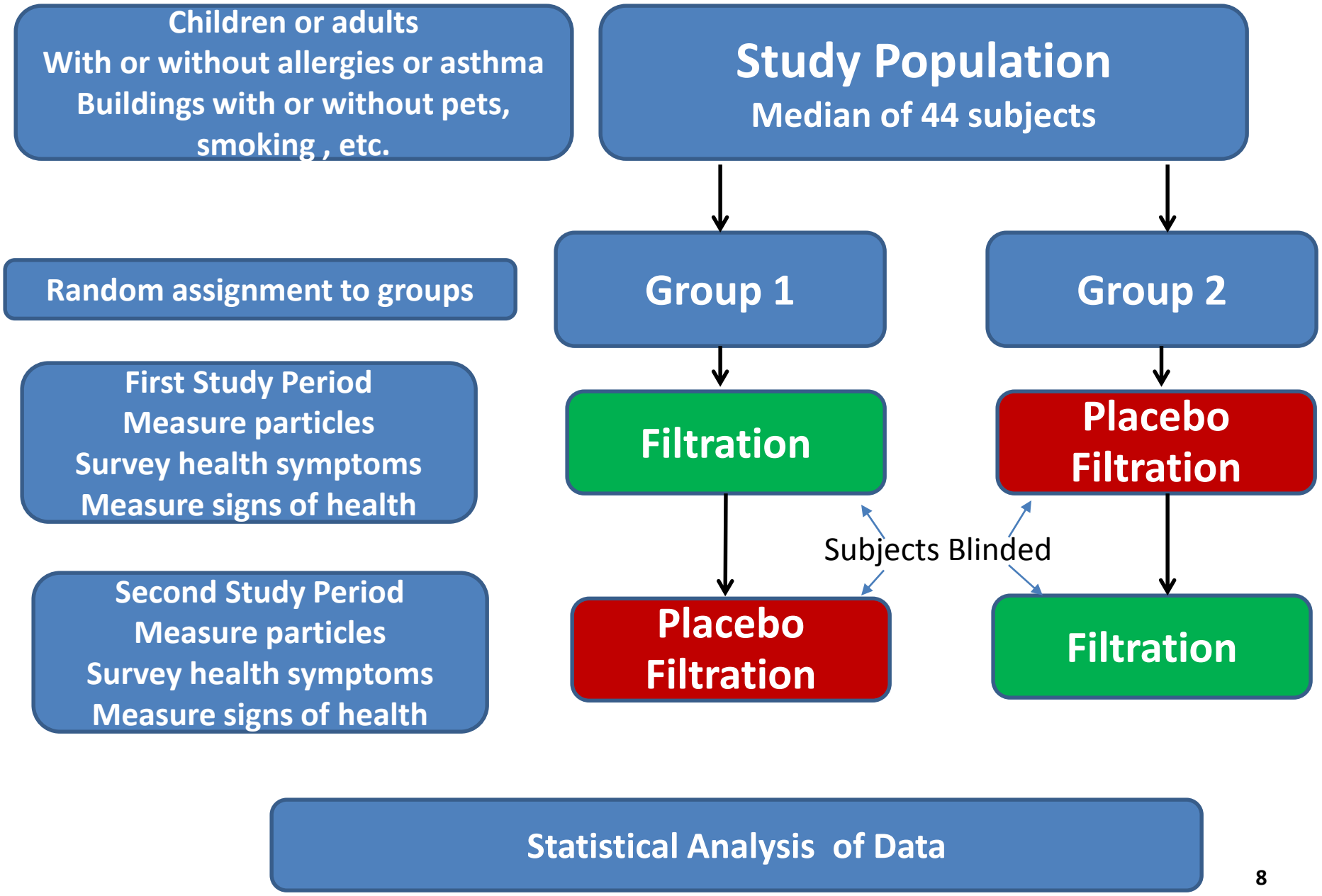
- Statistically significant improvements in*:
  - total symptoms (approx. 5-8%)
  - sleep disturbance (approx. 10%)
- No overall statistically significant improvements in nasal symptoms, medication use, peak expiratory flow

*Improvements not statistically significant when more conservative analysis model was used

Characteristics of 16 Newer Studies (not within prior reviews)

- All are intervention studies
- Large majority had strong designs (placebos, cross-overs, etc.)
- Many include objective (measured) health-related outcomes as well as health symptom surveys
- 13 of 16 performed in homes
- Often measured substantial (>50%) reductions in indoor particles

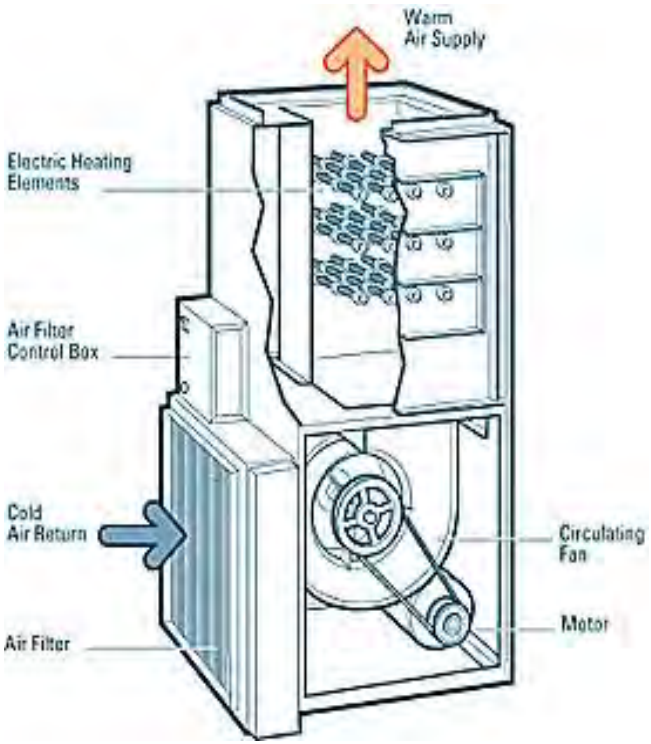
Example Study Design



Types of Filtration Systems Used in Studies

Traditional Portable Systems with Fans and High Efficiency Filters
Usually two per house (bedroom & living room)

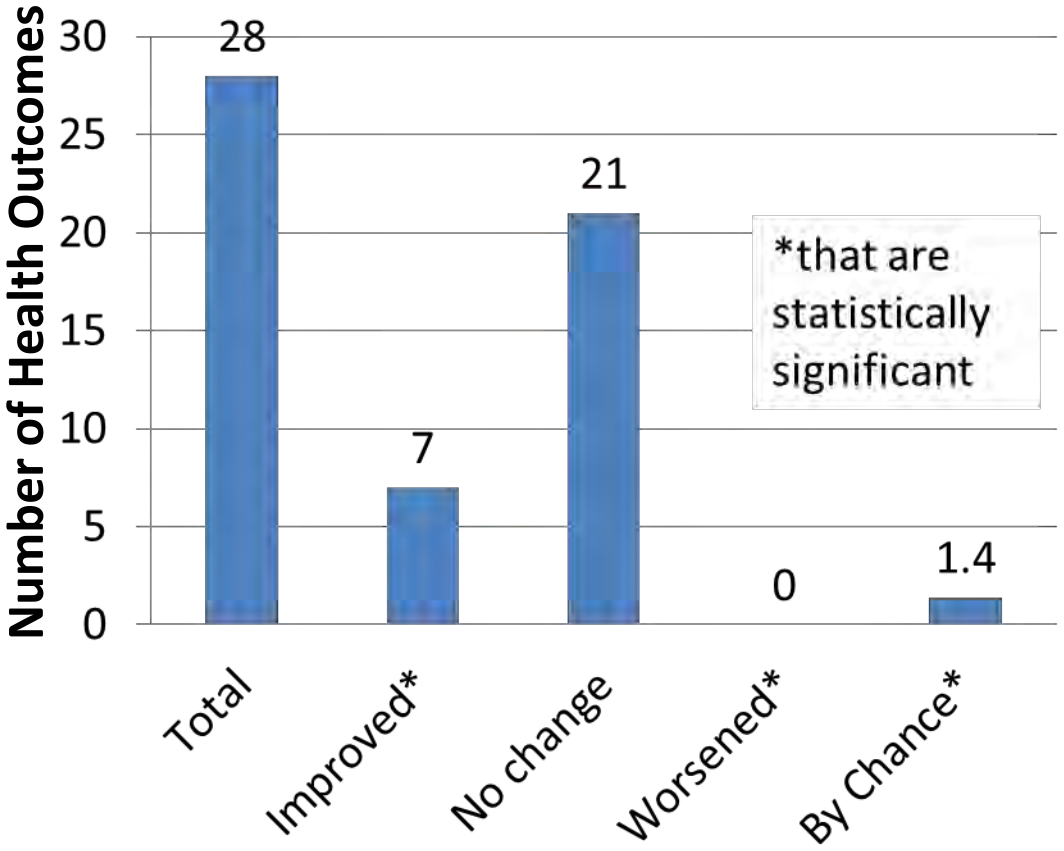
Various Filter Systems that Deliver Filtered air to Breathing Zone During Sleep



Improve Filter Efficiency in Heating, Ventilating, and Air Conditioning System

Five New Intervention Studies in Homes of Subjects with Allergies and Asthma

4 of five homes had pets or smoking

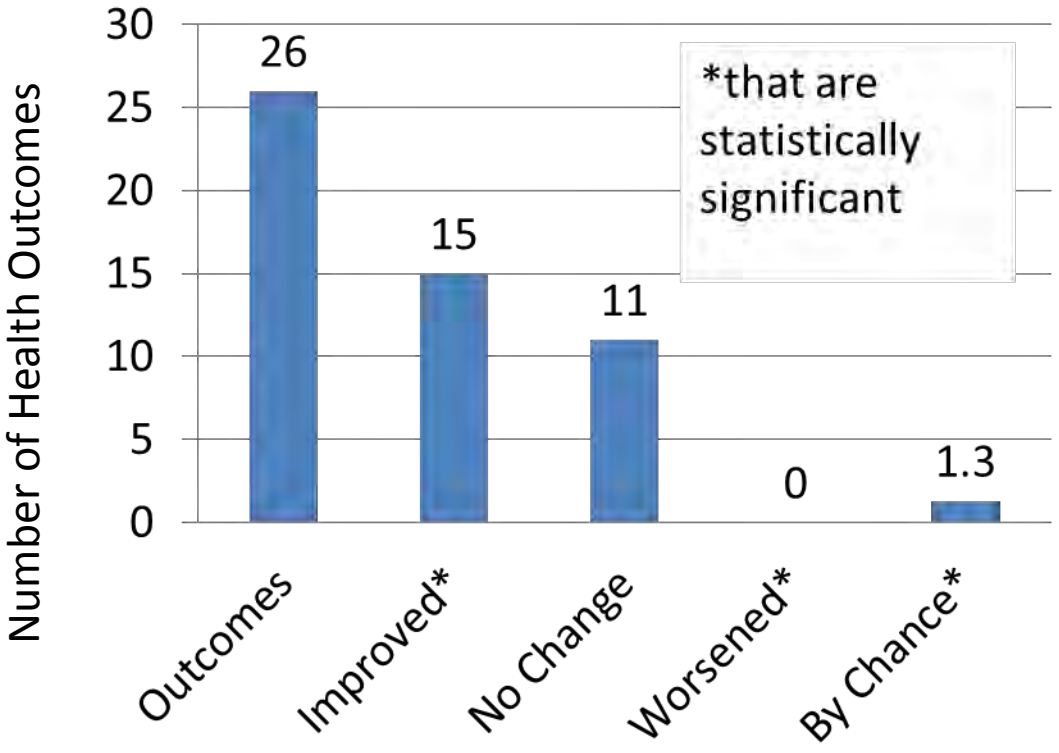


Magnitudes of improvements were moderate, for example:

- 30% - 42% for nose and eye symptoms (not consistent)
- 5% for peak expiratory flow in morning
- 25% for unscheduled asthma healthcare visits (from study of homes w/ smokers)

Four New Intervention Studies in Homes

With Filtered Air Provided in Breathing Zone of Allergic or Asthmatic Subjects when in Bed



All studies report moderate health improvements, for example:

- 15% more improvements in asthma quality of life score
- 9% higher asthma quality of life scores
- 22% lower exhaled nitric oxide (inflammation marker)
- 8% - 12% improvements in symptom scores (overnight and upon waking)

- One study had weak design and incomplete analysis
- Three studies involved support by air cleaner supplier
- Two studies report very large particle concentration reductions in breathing zone

Four New Intervention Studies in Homes

Not Targeting Allergic or Asthmatic Subjects

Scenario	↔ No impact ↓ Statistically significant improvement ↓ ↔ Mixed results
Homes with wood smoke	Coronary event predictor* ↓ (9.4%) Inflammation marker ↓ (33%) Oxidative stress ↔
Homes near major road	Coronary event predictor* ↓ (8.1%) Inflammation marker ↔ Hemoglobin ↓ (0.9%) Biomarker of coagulation ↔
Homes with smoking	Coronary event predictor* ↔ Blood pressure ↓ (~6-7%) Spirometry outcomes ↓ ↔ (4-8%)
Homes without special particle sources (weaker study design)	Blood pressure ↓ (~7-11%) Heart rate ↓ (~11%)

*blood flow in peripheral arteries after period of occlusion

No health symptom data from any study

Three New Intervention Studies in Offices and Classrooms

Not Targeting Allergic or Asthmatic Subjects

Building type	↔No impact ↓ Statistically significant improvement ↓ ↔ Mixed results ↑ Statistically significant worsening
Offices	Various Symptoms ↔
Offices	Various Symptoms ↔ Nasal area and volume ↓↔ Peak expiratory flow ↓
Classrooms	Various Symptoms ↔ ↑

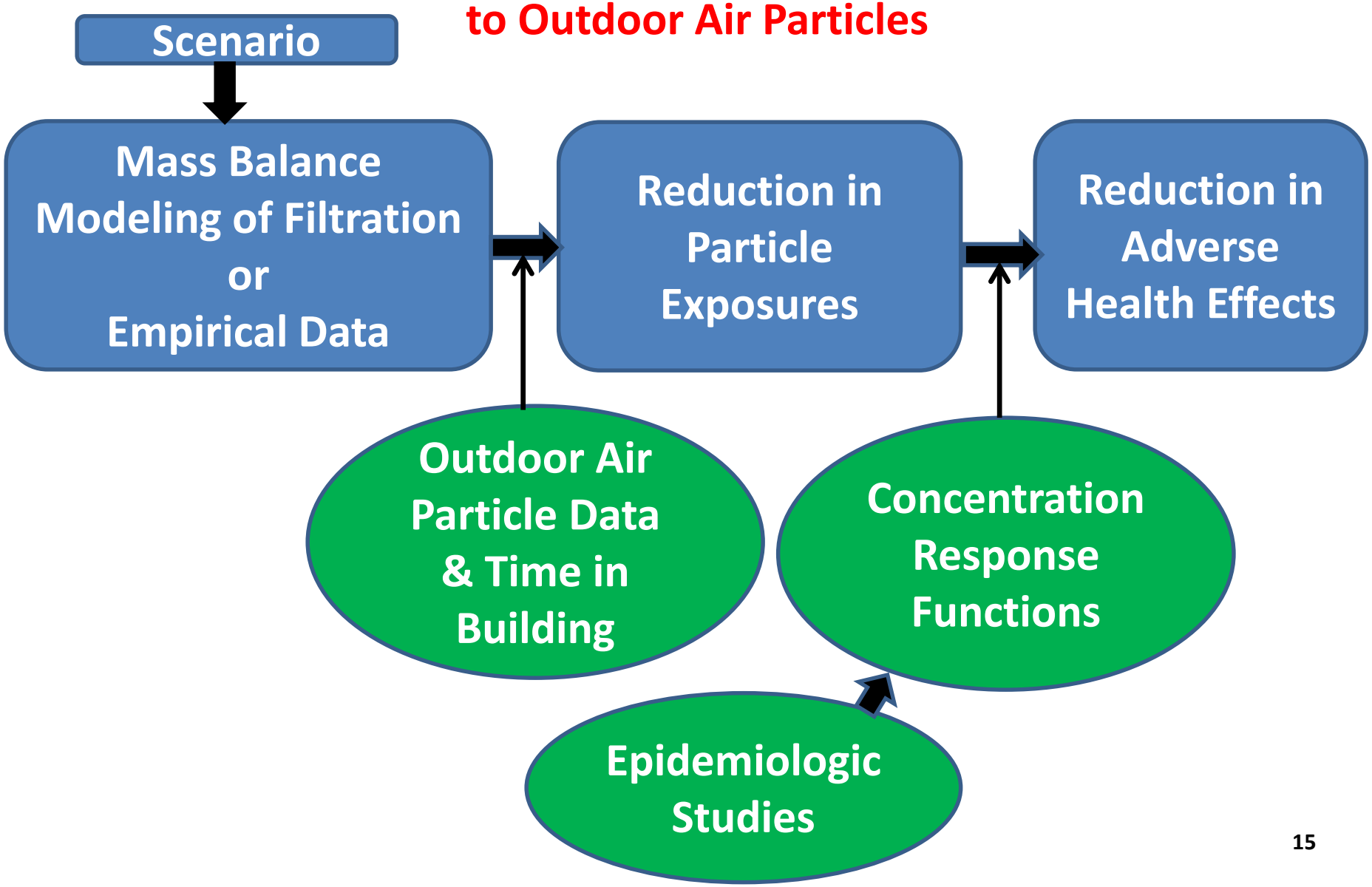
Known Health Effects of Outdoor Air Particles

- Premature death in people with heart or lung disease
- Nonfatal heart attacks
- Irregular heartbeat
- Aggravated asthma
- Decreased lung function
- Increased respiratory symptoms, such as irritation of the airways, coughing or difficulty breathing

- Globally 3.2 million deaths (5 x the population of Denver) per year and 76 million disability-adjusted life years (Lim et al 2010, Lancet, WHO Study)

Modeled Improvements in Health

From Use of Using Filters to Reduce Indoor Exposures to Outdoor Air Particles



Modeled Health Benefits

Using Filtration to Reduce Exposures to Outdoor Air Particles

Scenario	Projections
Filtration vs. no filtration (offices in N. Europe using 100% outdoor air)	• For 30% to 80% reduction in indoor PM_{10} → estimated 7% to 18% reduction in PM_{10}-exposure • $ value of health benefits are 17 to 67 times filtration costs
Add filters to homes and occupational buildings without filters (Europe)	• 27% reduction in $PM_{2.5}$ exposures from outdoor air • 27% reduction in $PM_{2.5}$- related health effects (if ~ linear) • 27,000 to 100,000 avoided deaths per year in Europe
Use high efficiency filtration in home HVAC, fan run continuously (Ohio homes)	For 2.7 million residents in homes, converting from low 14% PM2.5) to high (90% PM 2.5) efficiency filters prevents annually: ○ 700 premature deaths (260 per 1 million residents) ○ 380 respiratory and cardiovascular hospital admissions ○ 560 asthma-related ER visits ○ 130,000 asthma exacerbations (~ 50 per 1000 residents)

Modeled Health Benefits (cont.)

Using Filtration to Reduce Exposures to Outdoor Air Particles

Scenario	Projections
Increase filter efficiency for PM_{10} from 40% to 85% (Singapore offices)	Estimated decreases in PM-related health effects*: • 14% reduction in mortality, asthma exacerbations, restricted activity days, and work loss days in adults • 14% reduction in ER admissions for age < 65 • 8% reduction in chronic bronchitis in adults • Annual health cost savings is $890 per worker • Implementation cost < $20 per worker

*higher outdoor air PM in Singapore than in most of US

Health Review Summary

- Filtration sometimes improves acute health outcomes in subjects with allergies and asthma when allergen sources are present
  - Only a fraction of health outcomes improved
  - Adverse effects improved moderately

- Systems that delivered filtered air to breathing zone of sleeping allergic or asthmatic subjects may be more consistently effective in improving health than room or whole-house systems
  - Previously, *Clearing the Air* [IOM, 2000] stated:

    "……supplying cleaned air to the breathing zone may be more effective than attempting to clean the air in entire rooms or buildings."

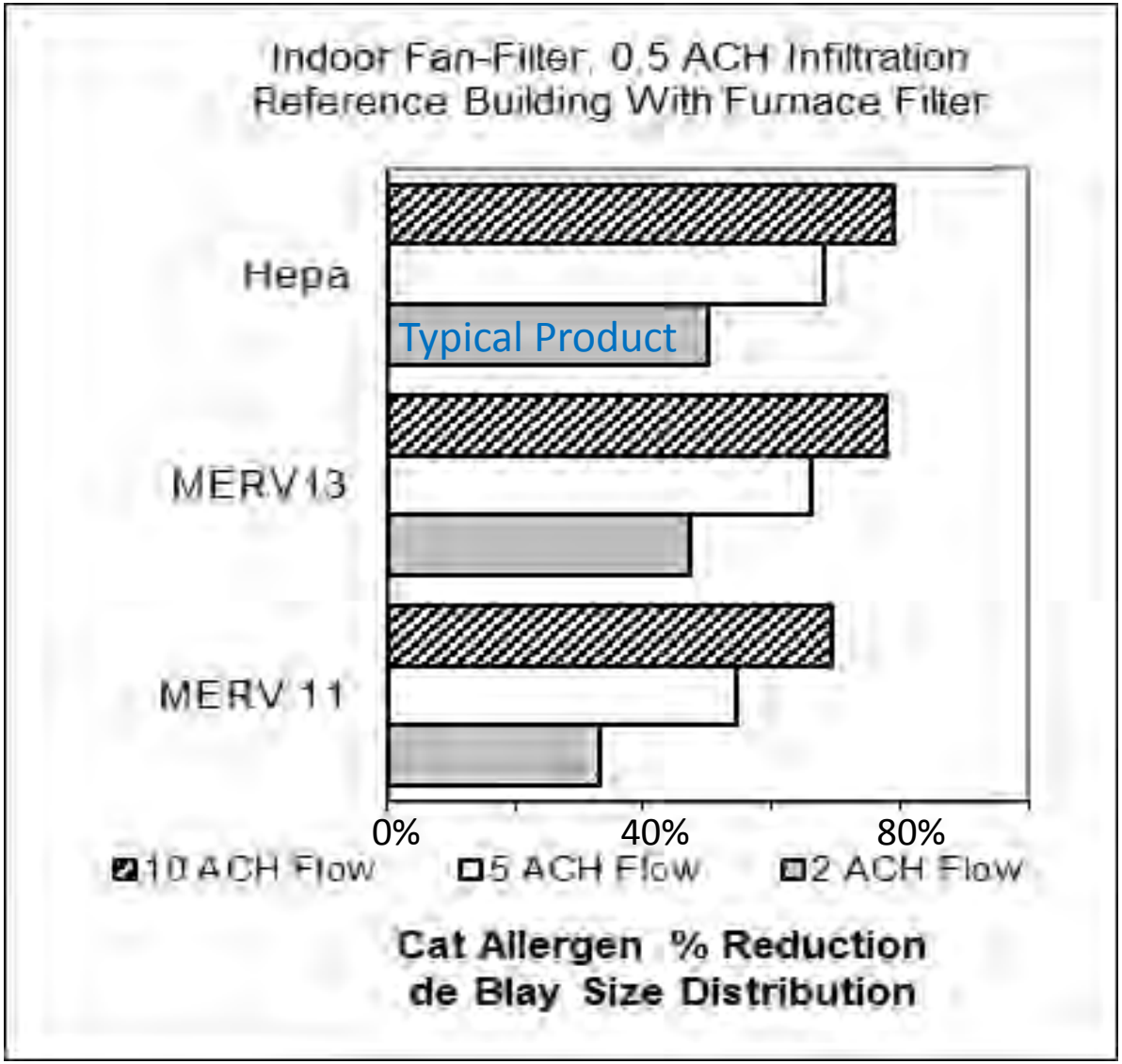
Health Review Summary (cont.)

- Evidence of reductions in acute health outcomes, from filtration in homes, offices, and schools in subjects without allergies and asthma is limited

- Modeled health benefits from use of filtration to reduce indoor exposures to outdoor air particles are quite large
- Notable are the reductions in markers of future adverse coronary events in 2 of 3 studies , which support the modeled health benefits of using filtration to reduce particles from outdoor air

What type of filtration systems do we need to improve health?

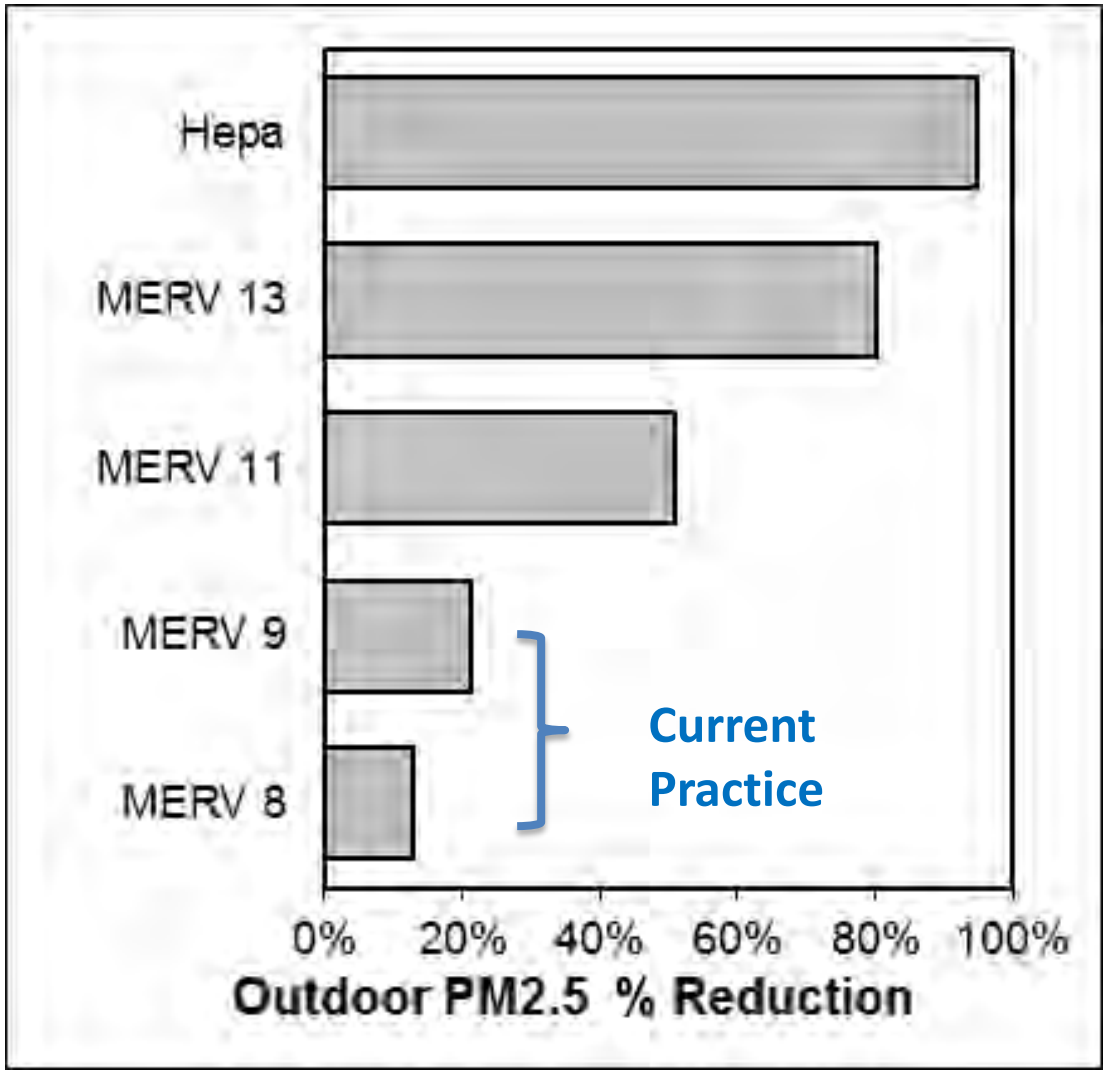
Modeled Residential Allergen Control: Effects of Filter Efficiency and Flow Rate



Source: Fisk et al (2002) Indoor Air J.

Modeled Control of PM2.5 from Outdoor Air in an Office

1 ACH Ventilation, 0.25 ACH Infiltration, 4 ACH Recirculation



Source: Fisk et al (2002) Indoor Air J.

Filtration and Health
Common Products and What is Needed #1

Application	Key Contaminants	Common Product	Needed
• Homes • People with allergies and asthma	• Allergens from dust mites, pets, molds, pollens • Mostly > 1 micron • PM2.5?	• Portable air cleaner with HEPA filter • Some with objectionable noise level (turned off or used at low fan speeds) • Uses more energy than a modern refrigerator • Expensive filter replacement	• For allergens, MERV 11 – 13 almost as good as HEPA • For PM2.5 MERV 13 almost as good as HEPA • Quiet products • Maximize flow rates, not filter efficiency • Better energy efficiency

Filtration and Health
Common Products and What is Needed #2

Application	Key Contaminants	Common Product	Needed
• Homes, HVAC filtration • General population	• PM 2.5 from outdoor air and indoor sources	• MERV 6 to 7?	MERV 11 - 13

Filtration and Health
Common Products and What is Needed #3

Application	Key Contaminants	Common Product	Needed
• Offices, HVAC supply air filtration • General population	• PM 2.5 from outdoor air and indoor sources	• MERV 7 to 8?	MERV 11 - 13

Opportunities For Filtration Industry to Improve Health

- Widespread use of higher efficiency low pressure drop filters in HVAC of homes and commercial buildings
  - Health benefits appear much larger than costs
    - Improved allergies and asthma are not the dominant benefits
  - Need to make the case, better demonstrate benefits vs. costs
- Quieter, more energy efficient stand-alone fan-filters for homes, with high air flow rates
  - Not necessary to use HEPA filters (marketing challenge?)
- Possibly:
  - Systems supplying clean air to the breathing zone when sleeping, primarily for asthmatics
  - Systems to reduce common respiratory infections (need evidence)

Path Forward

- Better quantify benefits and educate customers
- Raise minimum filtration efficiency requirements in standards
- More energy efficient systems

More Information

www.iaqscience.lbl.gov