Portable Indoor Air Cleaners and Human Behavior

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Content & Learning Objectives

Pollutants indoors

- How to clean the air in your home
- Behaviors

Why use portable air filters?

- Where, when, and how are these filters used?

How effective are they?

- Theoretical versus actual performance
- Impact on portable filters on exposure and health

Behavior and use

- Barriers to use
- Encouraging filter use

How to clean the air in your home

Guidance given to caregivers of children with asthma in Detroit and elsewhere

1. Don't **smoke** indoors, or allow others to smoke indoors.
2. If you have a **portable air filter**, put it in your child's room and use it all the time. People who turn it on and off tend to leave it off for long periods of time, which reduces its effectiveness.
3. Instead of rags, use a **micro-fiber furniture duster** when dusting (e.g., Swiffer, Clean Green, Rubbermaid). It picks up dust better than ordinary rags, which tend to spread dust around rather than pick it up.
4. To clean floors, use a **vacuum cleaner** instead of a broom. If you need to use a broom, sweep gently. Vigorous sweeping can throw dust back into the air and under furniture and appliances.
5. If you have forced-air heat or central air conditioning, **use a good furnace filter** to reduce particulate matter. The standard furnace filter (costing $1-5, often colored blue) does **not** improve air quality. Look at the Minimum Efficiency Reporting Value ("**MERV**") number, which is the efficiency of the filter for removing particles from the air. A filter with a MERV of 13 or more is generally a good choice. These cost from $15-60. Change filters every three months.
6. Don't use **air fresheners** & minimize use of **mothballs** & **deodorizers**.

Change behavior to improve environment & health

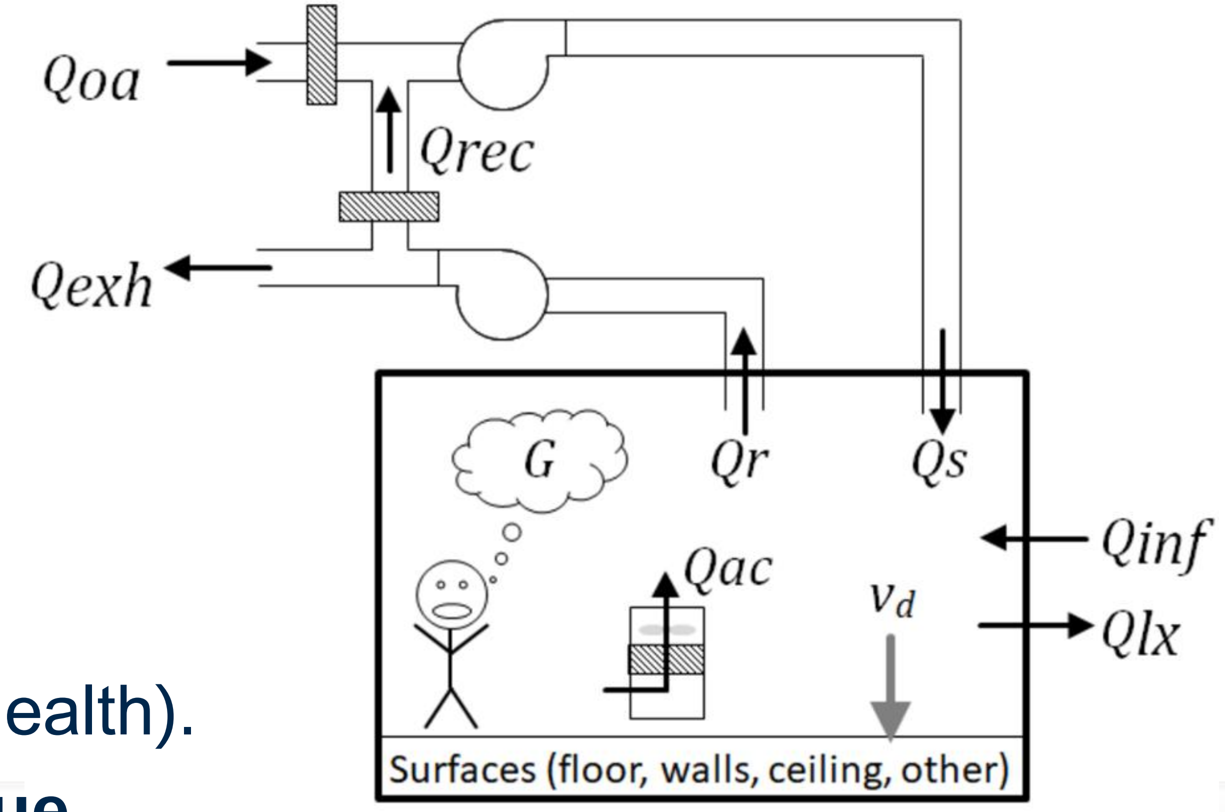
Interventions – multi-level approach to health behavior can be most effective

1. ***Individual*** – people at high risk
2. ***Community*** – modifying environments and using peer influence (with media, screening, community organizations, and sometimes motivating rules, restrictions, taxes, etc.)

   *Target 1 & 2 with **Community Health Worker** (CHW) intervention*
3. ***National*** – messaging, regulations, codes, and other actions at the national level

Applies to decisions affecting

- Indoor emissions and pollutant levels
- Exhaust fan operation
- HVAC systems and ventilation rates
- Filters – purchase and operation
- Outdoor emissions and pollutant levels



A "**systems approach**" should be taken for the building (and health).

Each indoor environment and household & community is **unique**.

An important research goal is to identify effective behavior change techniques

NIST, Fate and Transport of Indoor Microbiological Aerosols (FaTIMA)

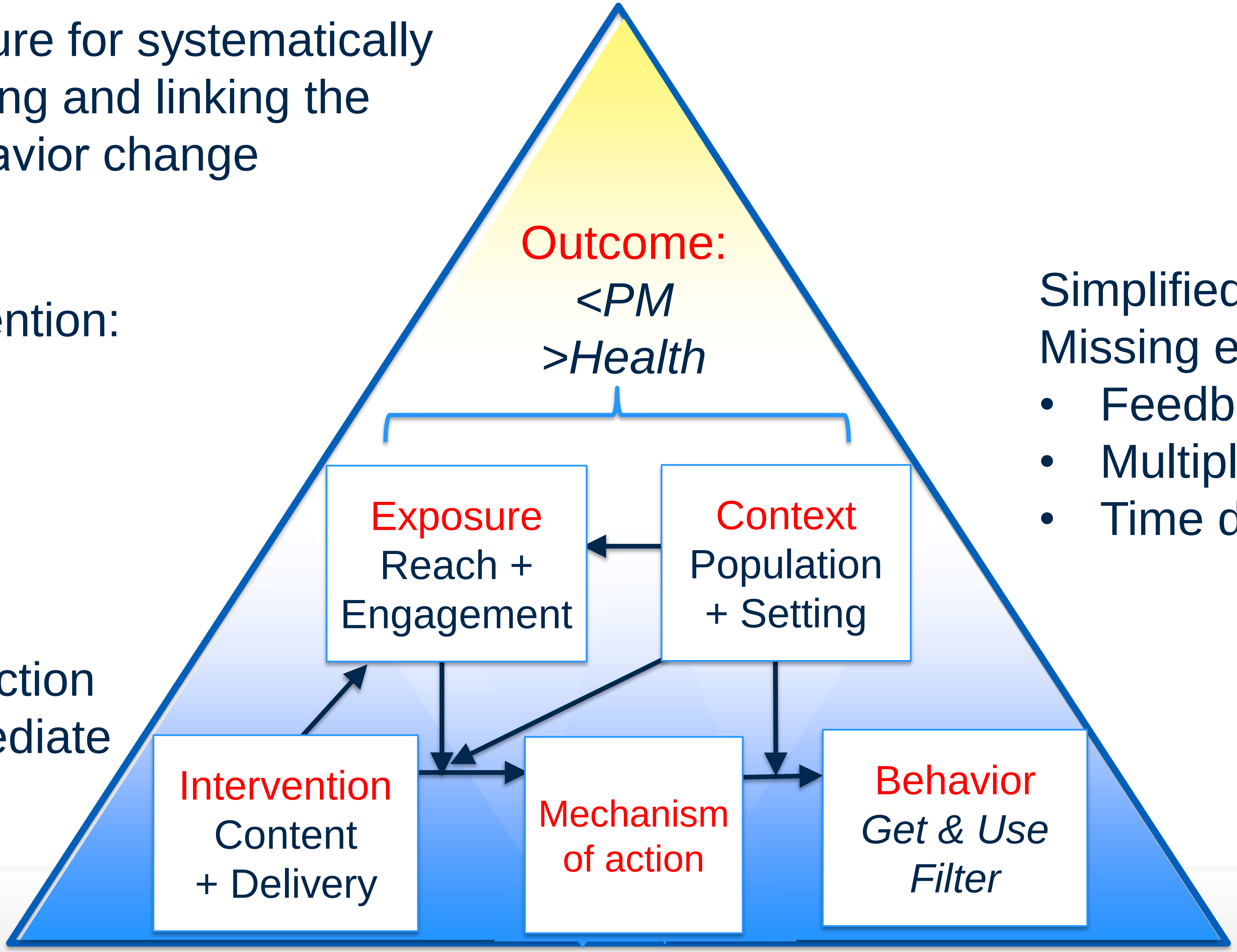
How does an intervention produce a particular outcome?

Conceptual structure for systematically representing, sorting and linking the “elements” of behavior change

Content of intervention:

- Messaging
- Subsidy
- Provision

Exposure and mechanisms of action moderate and mediate behavior



Simplified diagram
Missing elements:

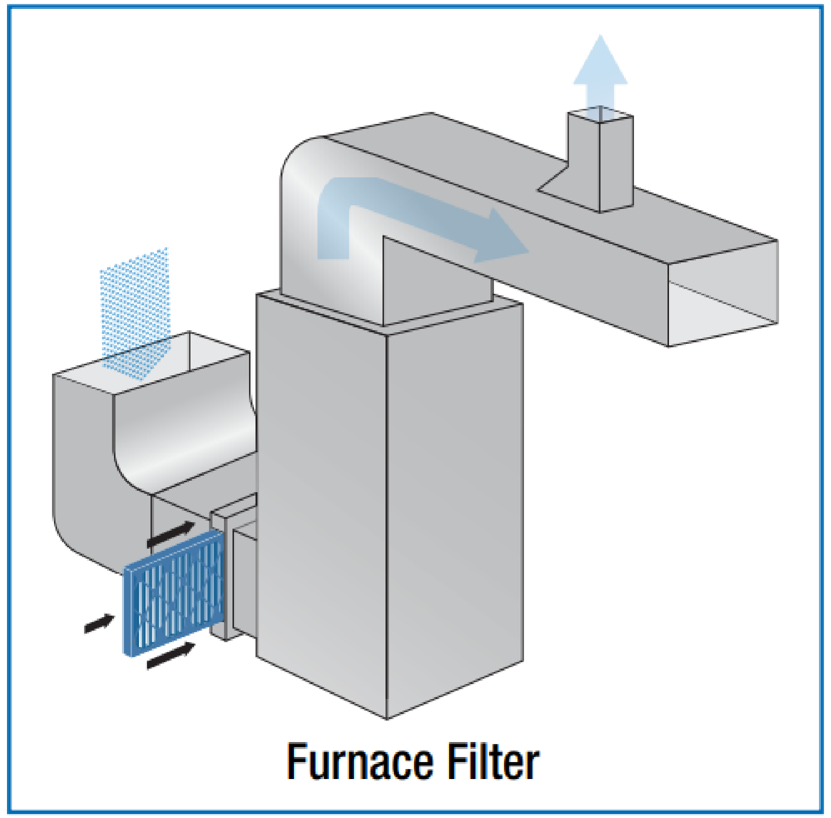
- Feedback loops
- Multiple behaviors
- Time dimension

Adapted from from Michie et al. Transl Behav Med, Volume 8, Issue 2, April 2018

When are portable units selected?

Portable room air cleaners (“purifiers”) are self-contained and portable devices that clean the air in a single room or specific area.

In-duct air cleaners are permanently installed in ductwork of central heating, ventilating, and air-conditioning (HVAC) systems and clean the air throughout the conditioned space.



Choose portable units when:

- Space does not have any filtration – spaces with steam radiators, baseboard heating, split system, natural ventilation, etc.
- Filters in HVAC system cannot be upgraded
- More air cleaning in a space is desired to reduce risk, e.g., limited duty cycle of forced air system (<25% of time in heating/cooling season), inadequate air flow, local sources, critical environment, etc.
- Removal of gaseous and biological contaminants is desired and not performed by the HVAC system

How well do portable units really work?

Filters ***can*** substantially reduce PM exposures, as suggested in both theoretical and experimental studies.

In practice, are filters effective?

- Air cleaning: performance evaluations are mixed - filters often do not live up to expectations.
- Health: Several studies suggest decreased frequency of asthma symptoms, but studies are inconsistent.

Possible explanations concerns in the field and literature

- Filter's "clean air delivery rate" & PM removal may be inadequate
- Air change rates affect performance and are rarely measured.
- Performance evaluations have had limitations, e.g., limited monitoring, no control over emission sources, uncontrolled seasonal variation, and small sample size.
- Placement, by-pass, filter deterioration, etc.
- Filters are only effective if used (run time)

Filter intervention in epidemiological study of children with asthma

House

Air Filter

We recruited 126 families in Detroit and placed portable air filters into the bedrooms of children with asthma and measured air pollutants, including particulate matter, to see the impact on air quality and the child's health.

Your Child

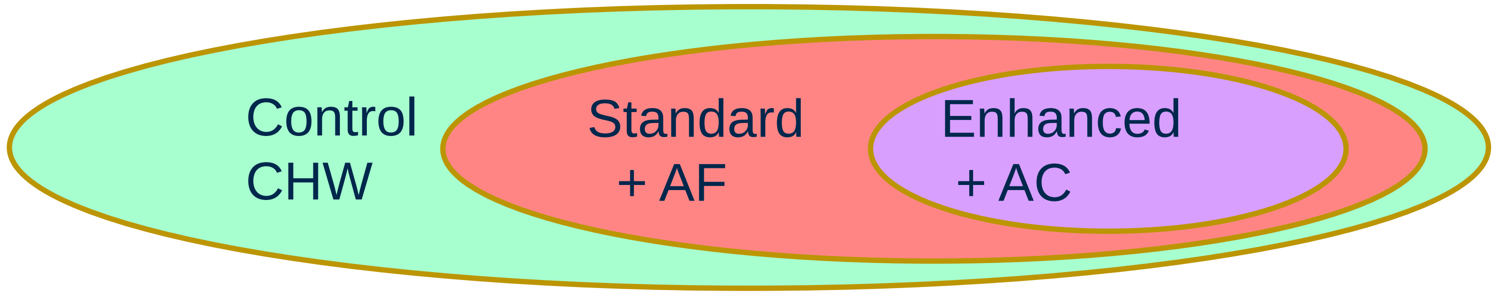
Air Sampler

Study design

Intervention study examining homes with a child with persistent asthma using CBPR approach.

Recruit and randomize households into three groups:

- “control group” receiving only community health worker (CHW) home asthma education visits (n=37);
- “standard” intervention group receiving a filter and CHW visits (n=47);
- “enhanced” intervention group receiving the filter, the CHW visits, plus an air conditioner (n=42).



Conduct periodic indoor monitoring and health assessments over year-long period. Assessments included:

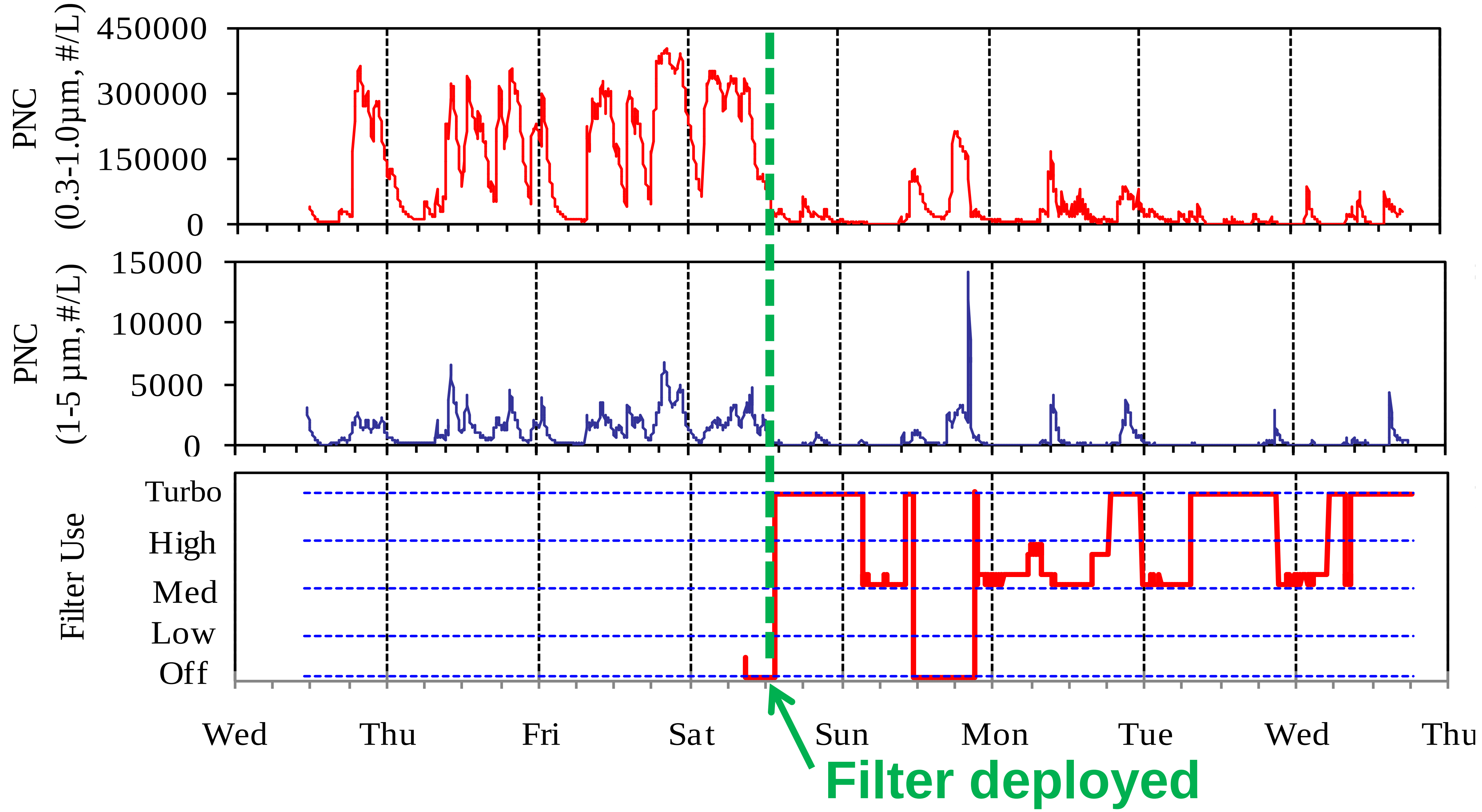
- Baseline visits: one week-long initial visit, filter installed midway, initial walkthrough, caregiver survey, medication use, spirometry, etc.
- Seasonal visits: 2 or 3 subsequent week-long visits, same measurements.

IEQ measurements included PM measurements: gravimetric, PM optical, CO_2, volatile organic compounds, environmental tobacco smoke, air exchange rates, filter use, temperature and RH

Home walkthrough and participant survey

Conduct study as community-based participatory research (CBPR) engaging the Community Action Against Asthma (CAAA) partnership.

How well did the portable filters work in this application?



Particle number counts (0.3-1.0 μm)

Particle number counts (1-5 μm)

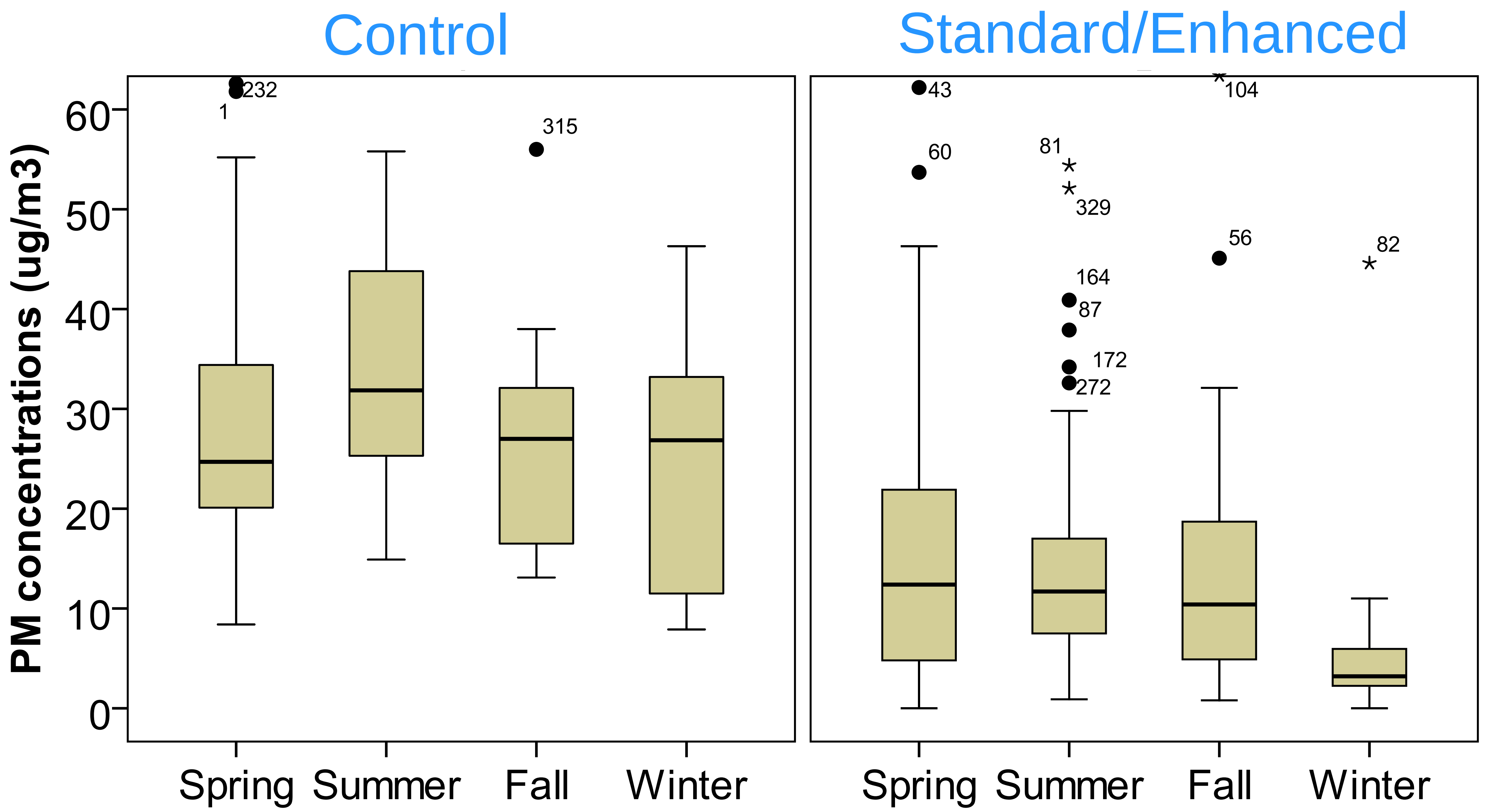
Air filter use (fan speed)

Filters produced a very high level of PM reductions – about 50% to nearly 80%

The plots above show that when the air filter was deployed (on Saturday), levels of *small particles* (top red line) *dropped considerably*. These particles are produced by combustion sources, such as diesel engines and cigarettes.

Levels of *larger particles* (center blue line) *dropped almost as much*. These particles are produced by vacuuming, wind blown dust, and other mechanical processes.

Seasonal summary of PM concentrations



Overall impact of portable filter during monitored periods

Compared to the control group, the intervention groups were 50-91% lower in PM (53-91% lower in 0.3-1.0 µm PNCs, and 64-93% lower in 1-5 µm PNCs, not shown here).

Another filter study … what's new?

Susceptible population … low income, minority, high rates of asthma

Studied in community setting

Unusually complete suite of IAQ and house measurements

Includes tracer measurements for ETS, AERs

Three PM measures, VOCs, CO_2

Seasonal assessments, carried out for about a year in each household

Accounts for daily and seasonal variability

Allows before/after comparisons and long term evaluations

Provision of air conditioner as well as air filter

Allows residents to limit use of fans and otherwise control AERs

Analysis uses multivariate (GEE) models with imputation

Controls multiple covariates, confounders, & lowers uncertainties

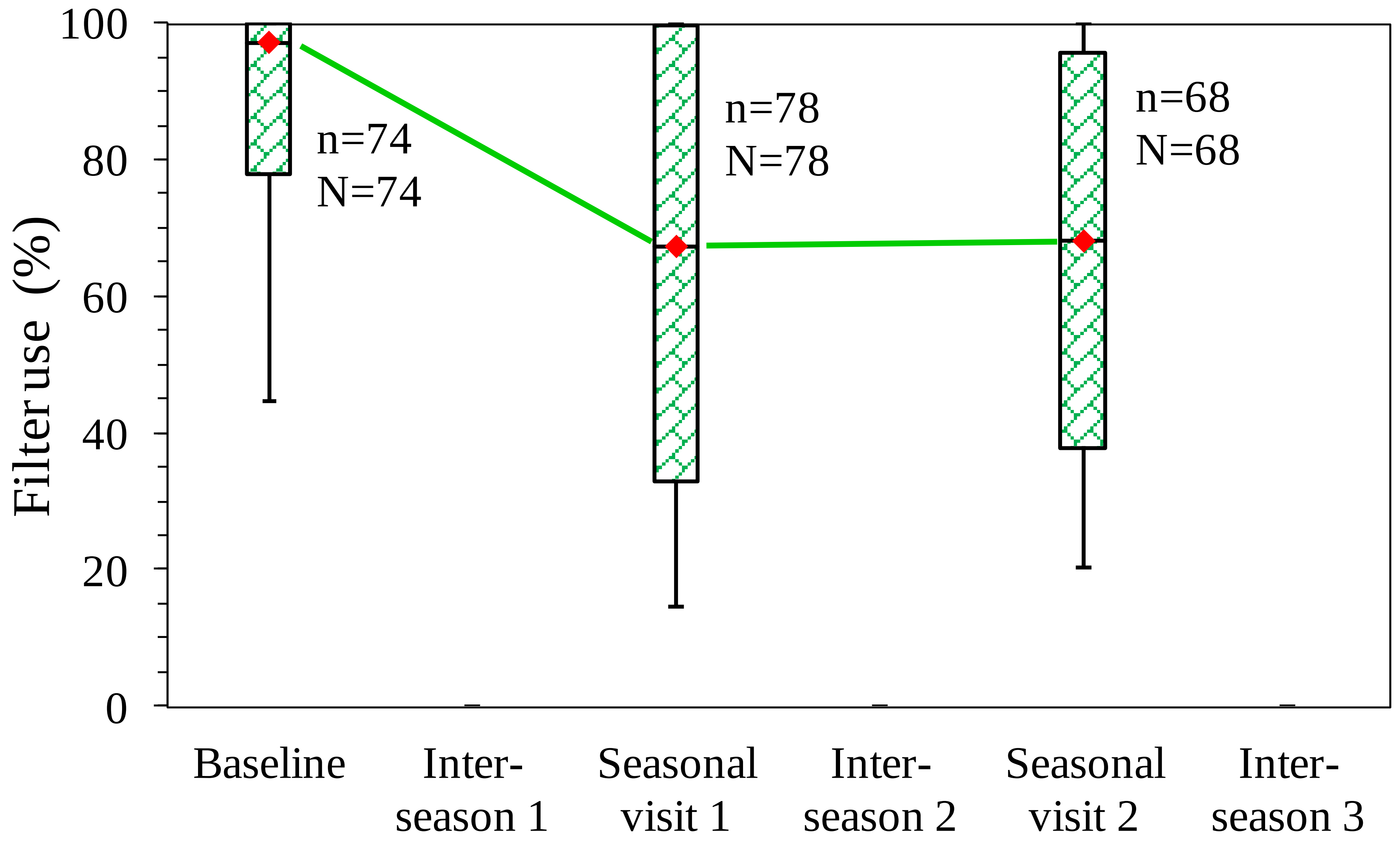
Representative?

Many older homes, central AC uncommon, indoor ETS quite common, occupancy ~4, child with asthma present

Monitoring of how filters are actually used

Behavior turns out to be a substantial source of variation

How do occupants use portable filters?



Typical filter use during the baseline week was 97%.

During the next monitoring period, a seasonal visit, use dropped to 68%.

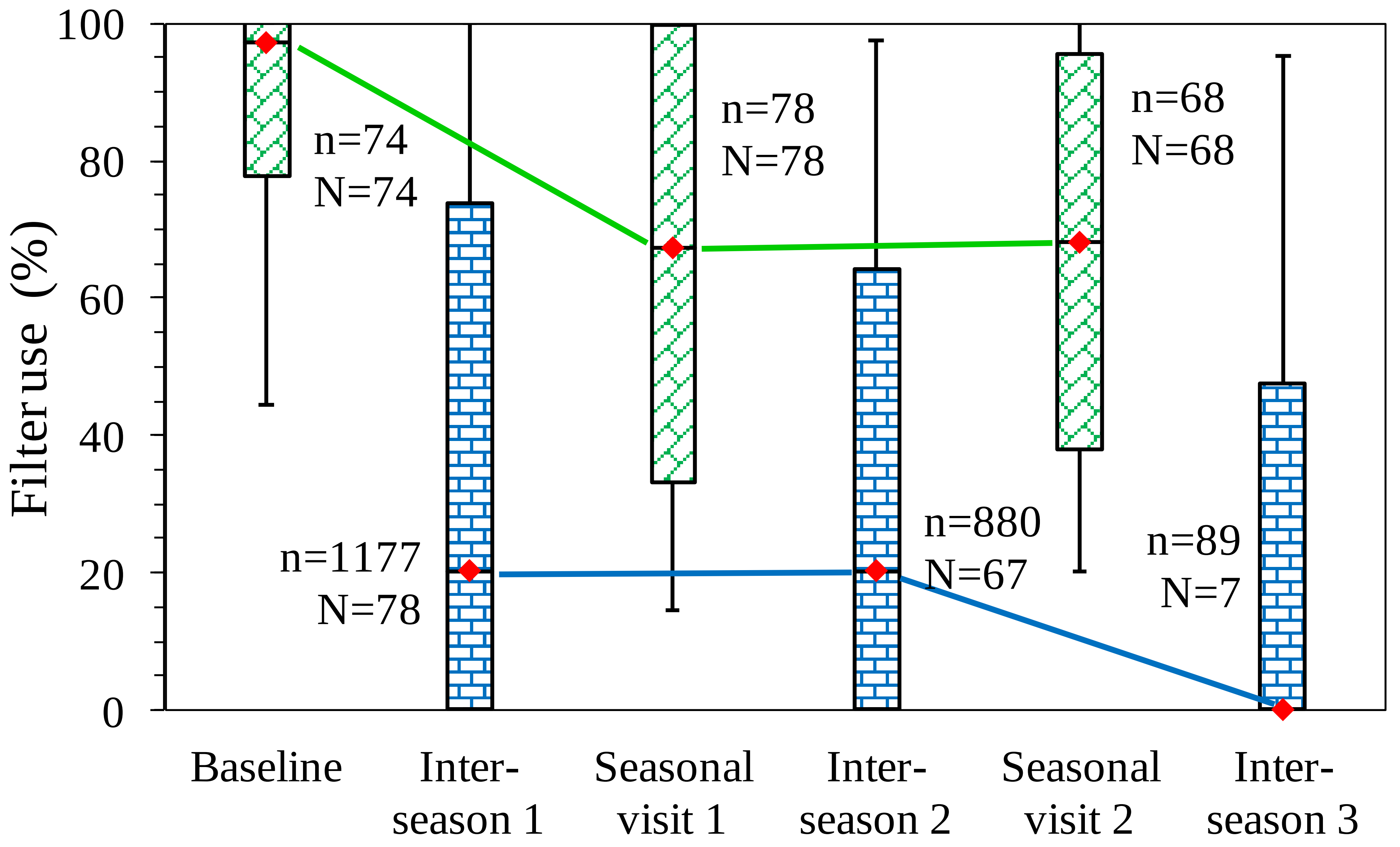
During the third weeklong monitoring visit, the use was similar, 67%.

Great variability across homes.

Some decline over time, but use remained quite high. Visits had considerable interaction with field staff, both for IAQ measurements and wellness care for child.

Novelty effect - initially high use with introduction of the filter followed by a decrease afterwards

How do occupants use portable filters?



Blue bars show use during the "inter-season" periods.

Use of filters dropped to average of 26% across the study.

The much lower use is problematic.

Possibly, the participants discounted the benefit of the filter.

During the study period, electricity rates increased. Electricity cost may have been a factor for these mostly low income households, although the study subsidized electricity cost

Observation or **Hawthorne** or **good behavior** effect - reflecting participants' understanding of expectations and intended use of filters, when study staff were present

Economy effect - associated with perception of filter cost. **Noise & draft issues**.

Annual electricity use and costs for portable air cleaners

Air cleaner type	Reference	Power draw (W)	Airflow rate (cfm)	Annual electricity use (kWh)			Annual electricity costs[1]		
				Assumed runtime					
				20%	50%	100%	20%	50%	100%
ESP	Waring et al. (2008)	102	500	179	447	894	$21	$54	$107
HEPA 1		206	182	361	902	1,805	$43	$108	$217
HEPA 2		103	340	180	451	902	$22	$54	$108
Ion generator 1		8	36	14	35	70	$2	$4	$8
Ion generator 2		5	<18	9	22	44	$1	$3	$5
HEPA 1	Sultan et al. (2011)	167	267	293	731	1,463	$35	$88	$176
HEPA 2		226	571	396	990	1,980	$48	$119	$238
Fibrous electret		135	463	237	591	1,183	$28	$71	$142
HEPA 3 + activated carbon		98	146	172	429	858	$21	$52	$103
ESP		98	473	172	429	858	$21	$52	$103
Ion generator 1		46	112	81	201	403	$10	$24	$48
Ion generator 2		45	382	79	197	394	$9	$24	$47
Plasma + HEPA		110	344	193	482	964	$23	$58	$116
PCO 1		444	913	778	1,945	3,889	$93	$233	$467
PCO 2		14	8	25	61	123	$3	$7	$15
UVGI		16	12	28	70	140	$3	$8	$17

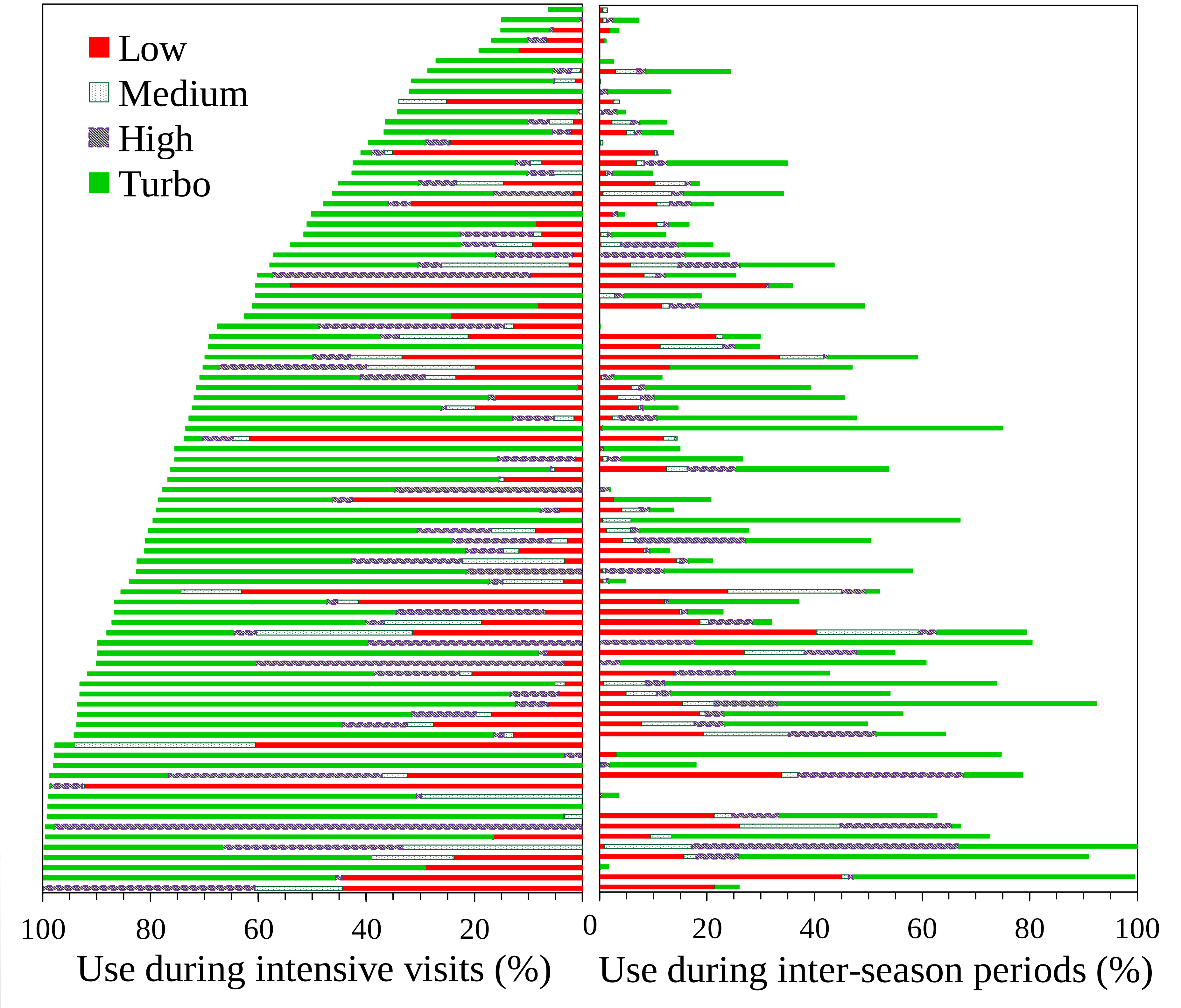
[1]Assuming $0.12/kWh constant electricity cost.

US EPA, Residential Air Cleaners A Technical Summary. 3rd Edition. Portable Air Cleaners Furnace and HVAC Filters. EPA 402-F-09-002 | July 2018 | EPA Indoor Environments Division | www.epa.gov/iaq

Variability of use among participants

Intensive

Observed weeks



Interseason

Unobserved periods

Some study findings

Portable air filters can work! High run times (>75%) leads to 69 – 80% PM removal.

But …. effectiveness depends on use – behavior!

- Patterns of filter use are dynamic and vary greatly across households.
- Typical patterns were: (1) high use when observed; (2) much lower use when unobserved; (3) users and non-users; 4) use declined with time.
- Overall, filter use was unexpectedly low among participants.

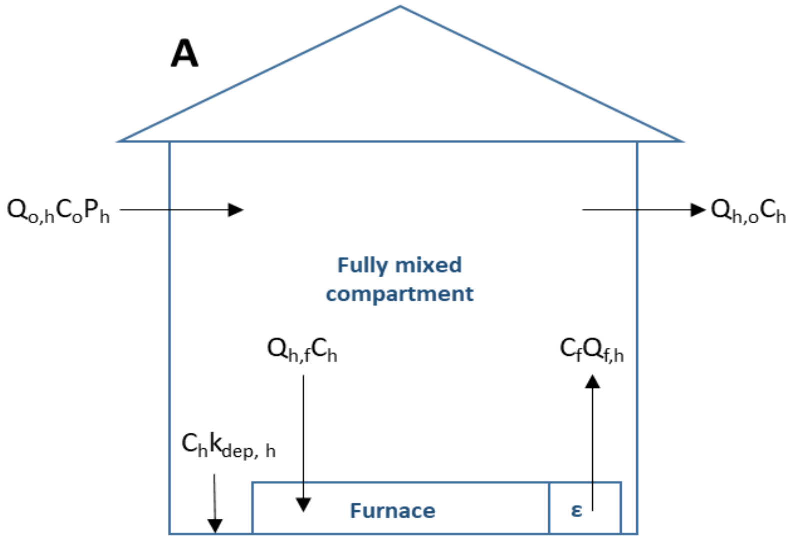
Health implications

- In the children, we saw no significant impact on asthma symptoms and inflammatory markers
- Many possible reasons, including exposure misclassification due to filter use
- Multiple exposure compartments
    - Primary ones for kids: home, school, transport (bus/car), outdoors

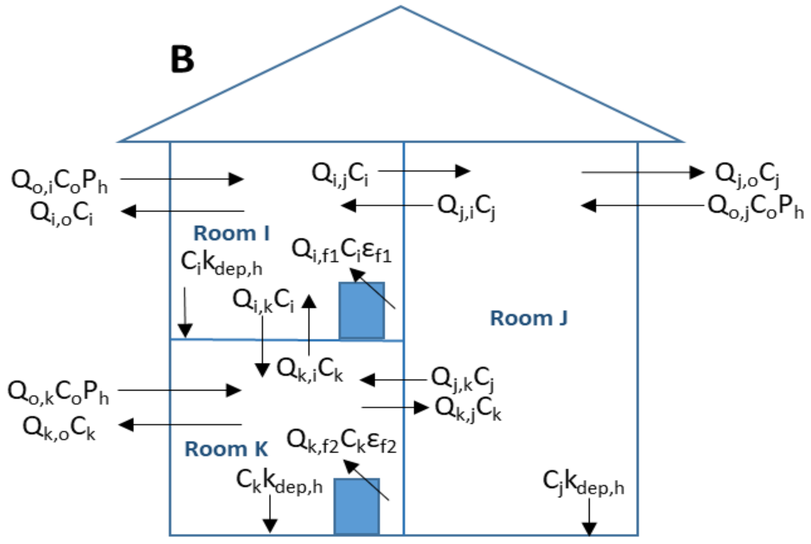
What are the potential asthma-related health benefits of filters in schools & homes?

Modeling approach used

- Estimate indoor exposures to ambient $PM_{2.5}$ using IAQ models
- Determine the “equivalent” exposure concentration that considers time-activity patterns
- Estimate health benefits of using filters in schools and homes
- Calculate marginal costs of increasing filter use



85% of homes in Detroit have forced air systems



15% of homes in Detroit use radiator/baseboard heaters

Mean (SD) indoor/outdoor concentration ratios in classrooms and homes by filter type

Classrooms				Homes with forced-air system				Bedrooms		Living Rooms		Other rooms	
Filter rating													
5	8	12	14	5	8	12	14	NA	HEPA	NA	HEPA	NA	HEPA
0.86 (0.09)	0.46 (0.11)	0.17 (0.04)	0.15 (0.04)	0.57 (0.16)	0.38 (0.16)	0.26 (0.13)	0.25 (0.13)	0.57 (0.16)	0.09 (0.06)	0.54 (0.16)	0.06 (0.05)	0.57 (0.16)	0.39 (0.13)

-46% -80% -34% -54% -84% -87% -32%

Potential asthma-related health benefits of filters in homes

	Annual avoided impacts (95% CI) due to filters in homes		
Outcome (cases)	<u>MERV 8</u>	<u>MERV 12</u>	<u>MERV 14</u>
Hospitalization	2 (0–3)	3 (1–4)	3 [illegible]
Asthma ED visit	33 (9–55)	48 (13–78)	[illegible]
Cough	19,000 (0–34,000)	27,000 (0–48,000)	[illegible]
Wheeze	1,600 (270–2,800)	2,200 (380–3,900)	[illegible] (390–4,000)
Shortness of breath	2,000 (0–3,900)	2,800 (0–5,600)	2,900 (0–5,800)
DALYs (years)	24 (0–44)	35 (0–64)	36 (0–65)
Monetized ($million)	1.3 (0–2.4)	1.9 (0–3.4)	2.0 (0–3.5)
% Reduction in DALYs	11	16	16

Marginal costs per household:
$175 per year (forced air)
$494 per year (stand alone)

Potential asthma-related health benefits of filters in homes

1. $PM_{2.5}$ exposures account for 6.5% of asthma outcomes for children living in and near Detroit, MI
2. Installing filters in classrooms would reduce annual asthma burdens 8-17%
3. Installing filters in homes of children with asthma would reduce annual asthma burdens 11-16%
4. Marginal costs per year are low for drop-in filters ($40-60 per year in classrooms and $151-175 per year in homes – but questions about actual long-term performance). Marginal costs are higher homes without forced-air systems ($494 per year)

Summary: Portable indoor air cleaners and human behavior

1. Provision of portable filters should be considered an active intervention requiring behavioral change. Multilevel interventions may be most effective
2. Filter use should be monitored in trials to reduce exposure misclassification.
3. Low run-time helps may explain some of the variation seen in previous studies

What makes for a successful behavioral intervention?

- Simple messaging.
- Learning and acting on information – but no guarantee. However, if message is "permeated" (impact so deeply that cannot be ignored), behavior will change.
- Possibly facilitated by consideration of externalities (helping or hurting others) & peer effects (what others are doing) and multilevel approaches (household → community → nation)

Can portable air cleaners be engineered to encourage appropriate behaviors?

- Reduce size, cost (initial and operating), noise, drafts → increase technical acceptability
- Increase information and enhance awareness wrt filters → might encourage "good" behaviors → incorporate use and IAQ sensors in units, and provide feedback to user
- Improve controls – automatic (smart, timer, PM and occupant sensing) compared to manual controls → reduce cost and nuisance impacts

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