The ROCIS Low Cost Monitoring Project (LCMP): Opportunities & implications

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- Wednesday, Sept. 22, 2021
- **League of Women Voters of Greater Pgh**
- Find this presentation here:
- http://rocis.org/past-rocis-events

Reducing

Outdoor

Contaminants in

Indoor

Spaces

“Rock-us” or “Raucous”

“A Southwestern Pennsylvania initiative to reduce the impact of exterior pollution in indoor spaces”

Most of our exposure to outdoor pollution happens INSIDE buildings.

https://www.iaqscience.lbl.gov

Focus on Particles

Also referred to as Particulate Matter (PM)

Pittsburgh's Air Quality is Poor

Rebecca Droke/Post-Gazette

9th

People Most at Risk in the U.S. from Year-Round Particle Pollution (Annual $PM_{2.5}$)*

1st

Worst City East of the Rockies for Year-Round and Short-Term $PM_{2.5}$

16th

People Most at Risk in the U.S. from Short-Term Particle Pollution (24-hour $PM_{2.5}$)*

*Pittsburgh-New Castle-Weirton (PA-WV-OH)

American Lung Association State of the Air Report 2020 http://www.stateoftheair.org/assets/SOTA-2020.pdf

U.S. Environmental Protection Agency (EPA):

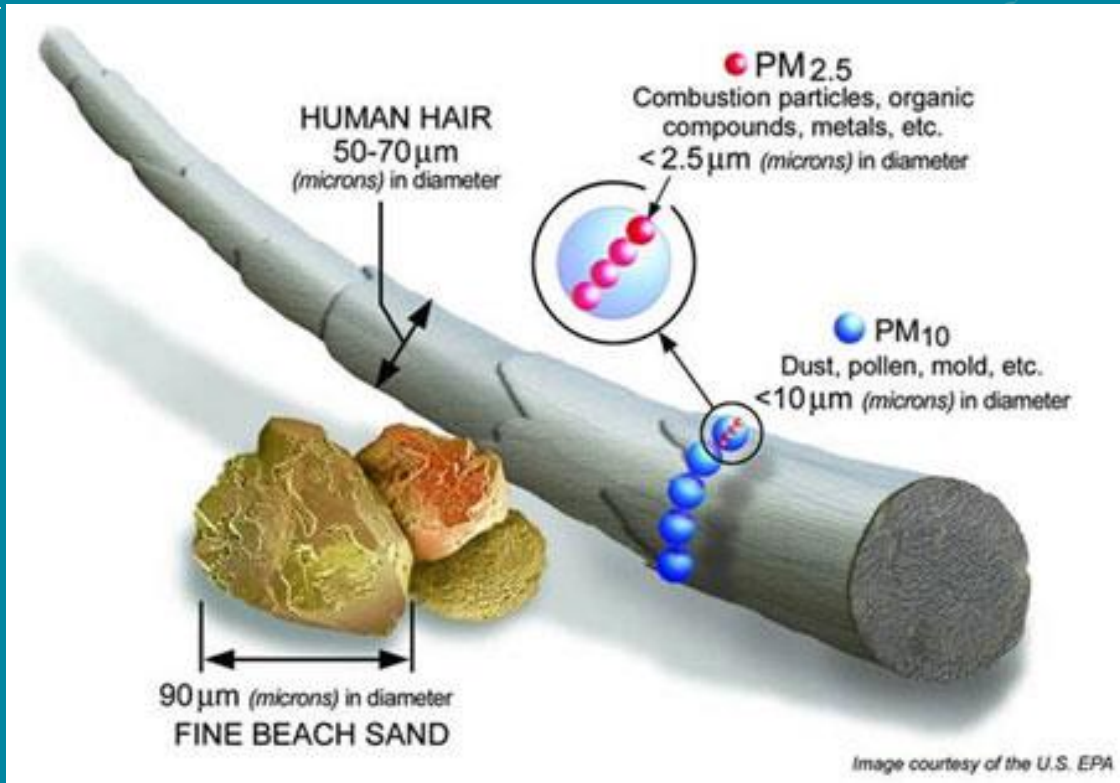
Particulate matter (PM), also known as particle pollution, is a complex mixture of extremely small particles & liquid droplets that get into the air. Once inhaled, these particles can affect the heart & lungs & cause serious health effects.

Particles (PM)

Dylos 1700
Our work horse!

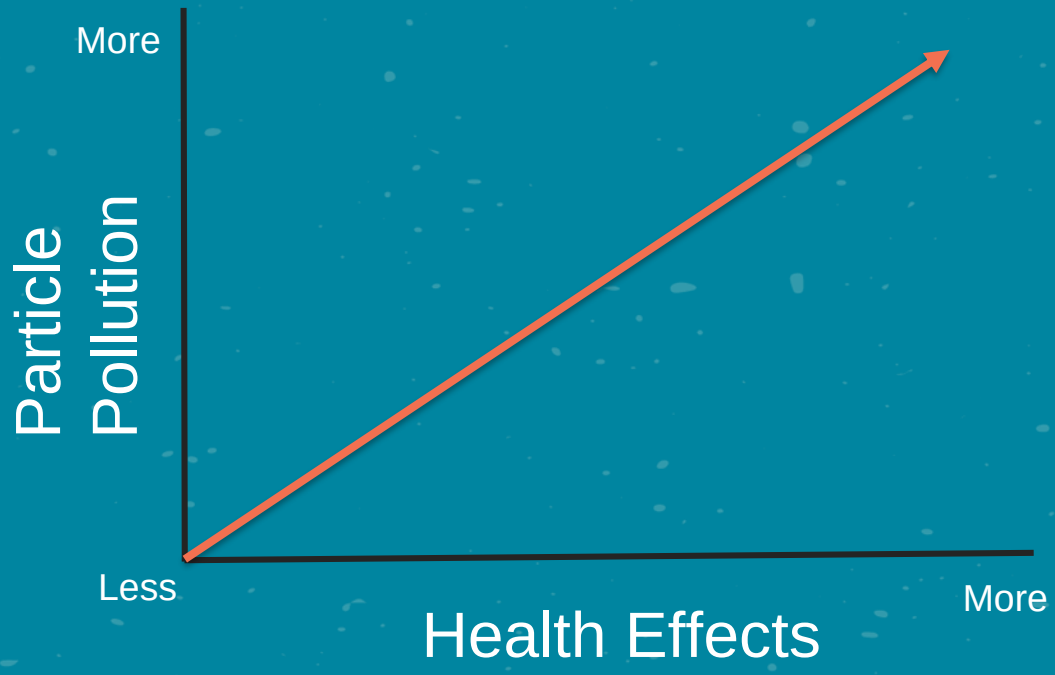
$PM_{2.5}$: Particulate matter <2.5 µm in diameter

ROCIS LCMP Dylos: Particles > 0.5 µm (1/100 of human hair!)



Health Concerns - Particles

- Differ in toxicity
- Can be adverse synergy with other co-pollutants
- Fine & ultrafine particles can be vehicles to increase exposure of toxic contaminants such as SVOCs & metals
- Our premise: “Precautionary principle” – avoid or minimize your exposure



A clear concentration-response relationship between particle pollution & health effects has been established by scientific studies.

Higher particle concentration is associated with increased impacts to health.

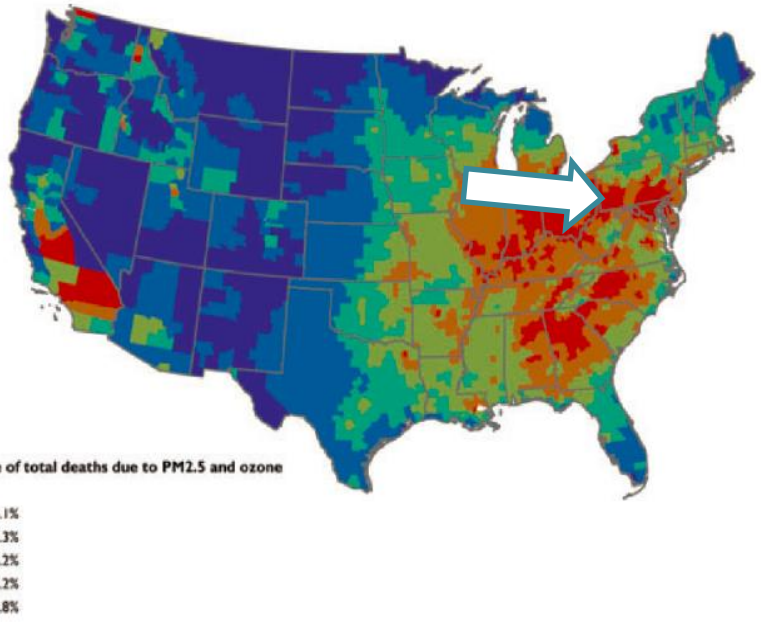
https://www.epa.gov/pmcourse/particle-pollution-exposure

Outdoor Particles (PM) & Human Health

"Our best estimates of the US mortality burden associated with total $PM_{2.5}$ exposure in 2012 range from ~230,000 to ~300,000 deaths."

Azimi, P., & Stephens, B. (2018). *Journal of exposure science & environmental epidemiology.*

Outdoor particulate matter and human health



Fann et al. 2012 *Risk Analysis*

Health Concerns - <$PM_{2.5}$

Established PM-associated diseases:

cardiovascular disease, asthma, & lung cancer

Recent associations with PM exposure include:

idiopathic pulmonary fibrosis, type 2 diabetes, Alzheimer's disease, & decreased cognitive function as well as premature birth

Loxham, M., & Nieuwenhuijsen, M. J. (2019). *Particle and fibre toxicology*

ROCIS LCMP

Low Cost Monitoring Project

- Started in 2015
- Mostly homes, some workplaces
- 390 participants

LCMP Objectives

1. Learn how low-cost monitors empower occupants
2. Examine the impacts of outdoor on indoor air
3. Explore Interventions to improve indoor air quality
4. Develop champions!

LCMP Design

Not a Regulatory Focus

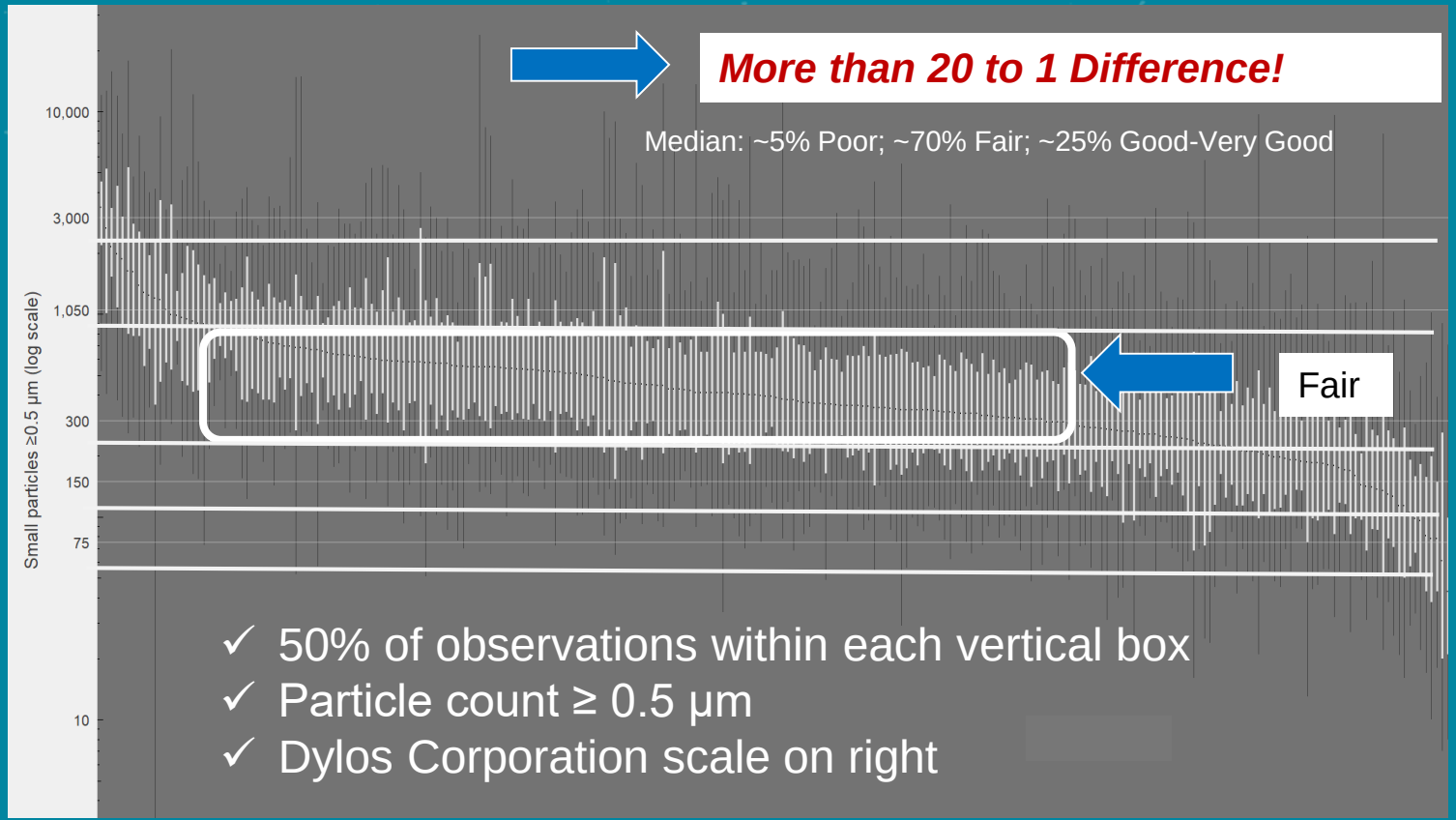
- Measuring particle count, not mass; 1-min. resolution
- Focus on indoor / outdoor comparison
- Proof of concept – exploration of interventions

Making Sense out of Millions of Data Points!

On FaceBook *Andreas von der Heydt*, the VP of Chewy,
identified the difference between Raw Data and the Stories Data can tell.

Indoor Particle Distribution

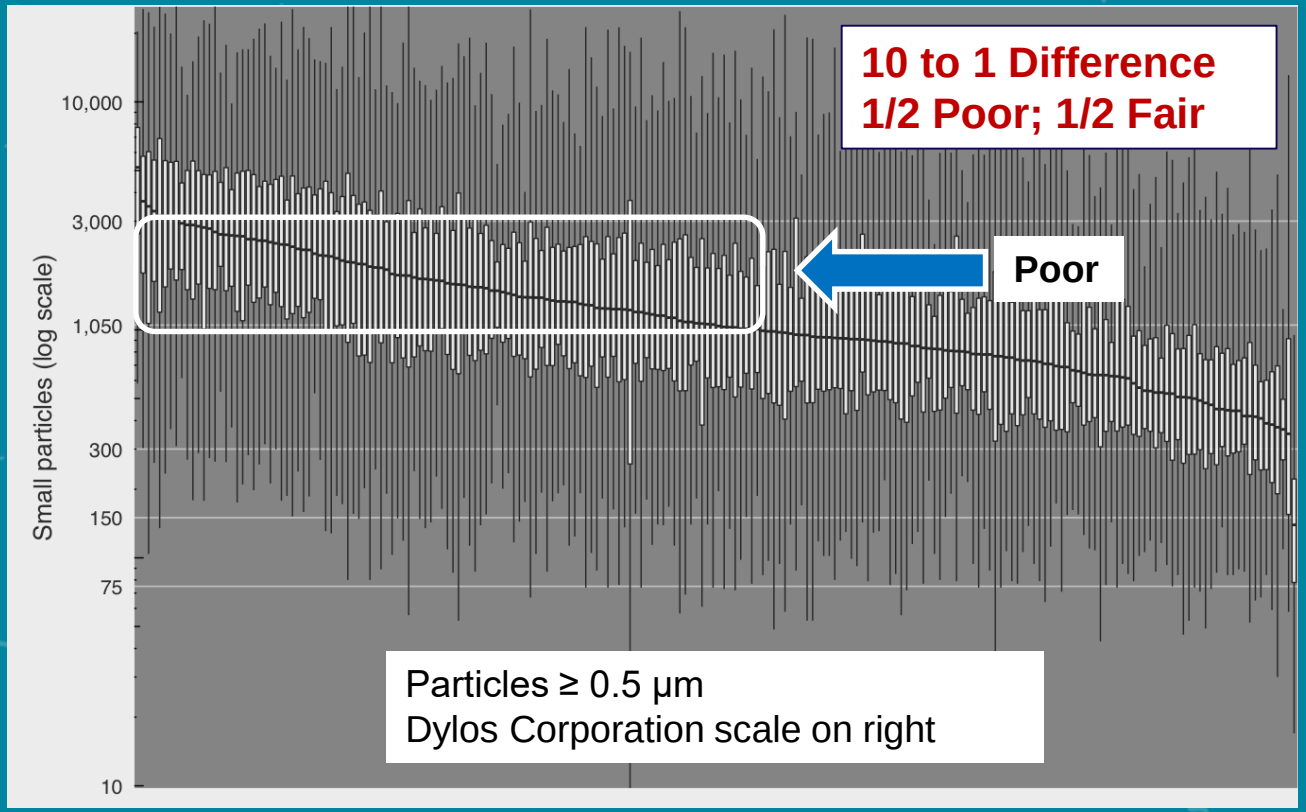
250 LCMP Residential Sites



- ✓ 50% of observations within each vertical box
- ✓ Particle count ≥ 0.5 µm
- ✓ Dylos Corporation scale on right

Outdoor Particle Distribution

All Sites



LCMP Cohorts

- **Participants borrow monitoring equipment to measure:**
  - **Particles (0.5+ & 2.5+ µm)**
  - **Carbon dioxide (CO_2)**
  - **Carbon monoxide (CO)**
  - **Radon**
  - **Temperature**
  - **Relative humidity**

- **During the course of the 4-week cohort, participants:**
  - **Learn from the ROCIS team**
  - **Benefit from each other's experiences**
  - **Receive weekly individualized feedback in response to their data, observations, & questions**

Good Readings
≠
Good Indoor Air Quality

Know the limitations of our particle monitoring

What we cannot easily monitor could be important!

4 Strategies to Reduce Indoor Particles

- **Reduce air exchange from outside**
  - Close windows
  - Tighten home or building
- **Reduce indoor sources**
  - Use an effective ducted kitchen hood!
  - Use induction cook top & other good practices w/ cooking
- **Reduce resuspension**
  - HEPA vacuum
  - Thoroughly clean hard surfaces
  - Walk-off mats
  - Get rid of carpets, old upholstered furniture
- **Filter the air**
  - Portable air cleaners
  - DIY Fan Filters
  - Central air handler (furnace, AC,or ventilation)

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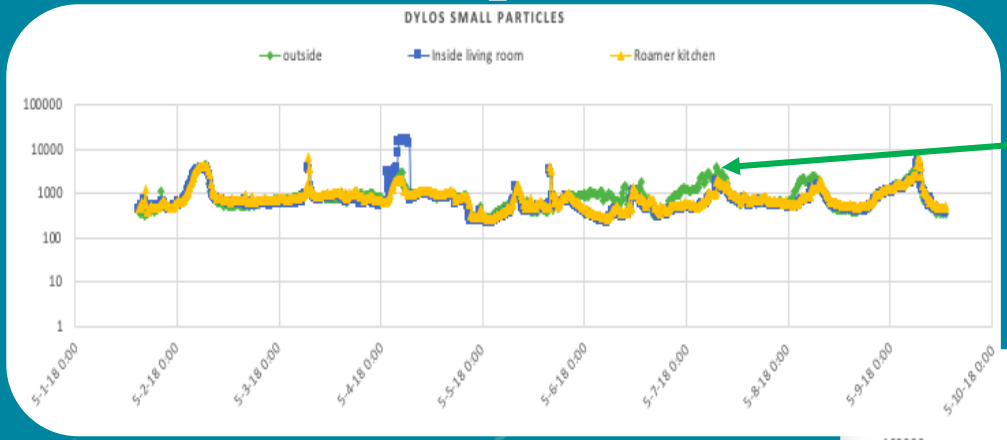
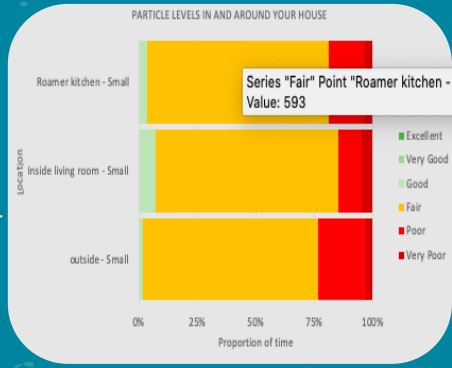
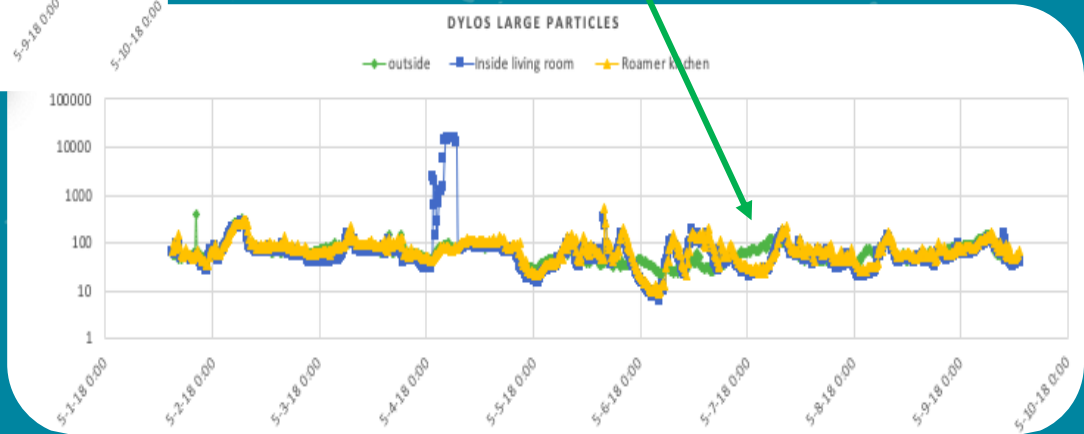
House with Wide Open Windows





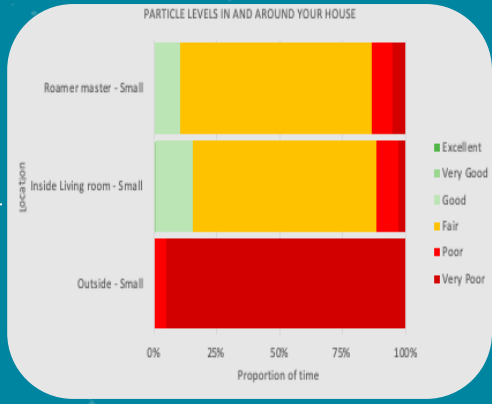
Outdoor

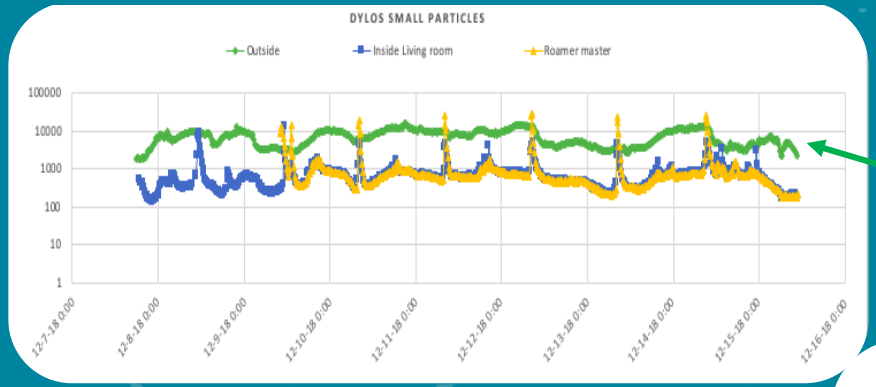
Dylos Large



Green (O), Blue (I), Yellow (R)

1941 House in Winter with High Outside Particle Counts

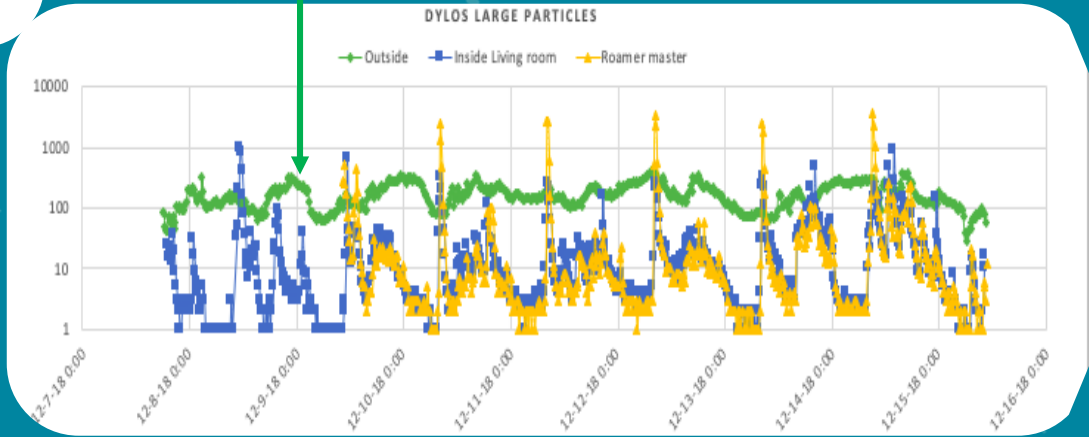




Dylos Small

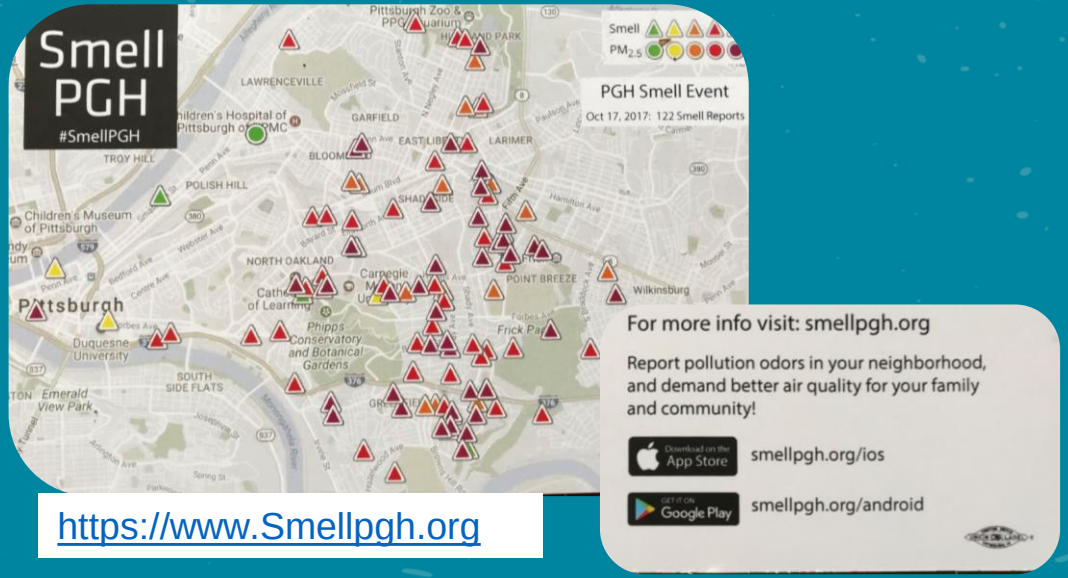
Outdoor

Dylos Large

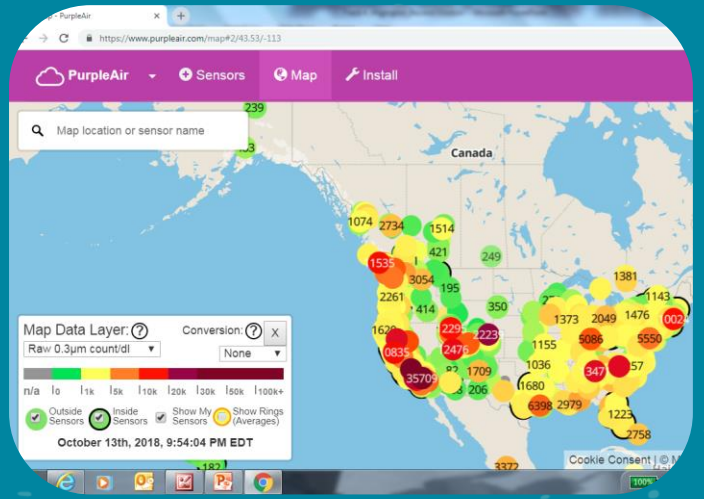


Green (O), Blue (I), Yellow (R)

Resources: Smell PGH, PurpleAir, & Breathe Collaborative



https://www.Smellpgh.org



https://www.purpleair.com/gmap

19-03-22_breathe_factsheet.pdf (breatheproject.org)

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Reduce Cooking Emissions

Check out ROCIS guidance document & webpage

- ROCIS ISSUE BRIEF, *Ducted Range Hoods: Recommendations for New and Existing Homes*

http://rocis.org/kitchen-range-hoods

Webinar Recording from 12/2020

Induction Cooktops “Trick the Pot” into Creating its Own Heat

Benefits!

- ✓ Minimize gas combustion products
- ✓ Better temperature control
- ✓ Very responsive
- ✓ Lower surface temperature

More Cooking Considerations!

Particle generation during cooking:

- ***Vented*** range hood?
- Cooking style (steam vs. fry)
- Use of lids
- Heat: High & fast vs low & slow?
- When to add salt & pepper?
- Various oils vs. butter?

COOKING OIL SMOKE POINT CHART

KNOWYOURPRODUCE.COM

450°F+

AVOCADO OIL 520
RICE BRAN OIL 490
ALGAE OIL 485
CLARIFIED BUTTER (GHEE) 485
SOY BEAN OIL 450
PEANUT OIL 450

400°F

SUNFLOWER OIL 440
CORN OIL 440
OLIVE OIL 410
VEGETABLE OIL 400
CANOLA OIL 400
GRAPESEED OIL 392

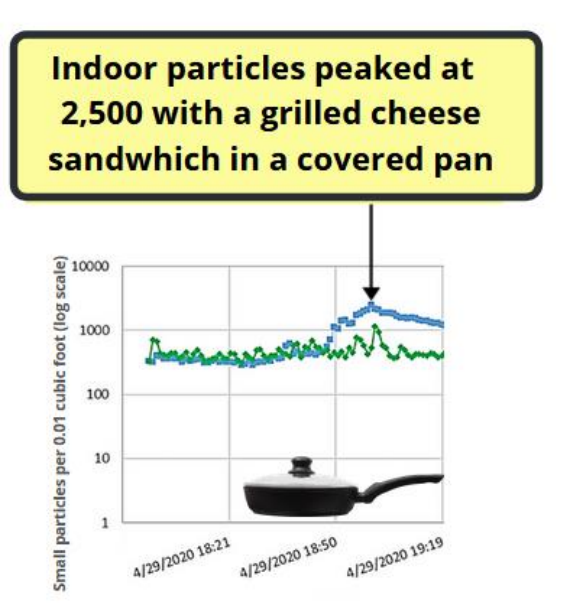
350°F

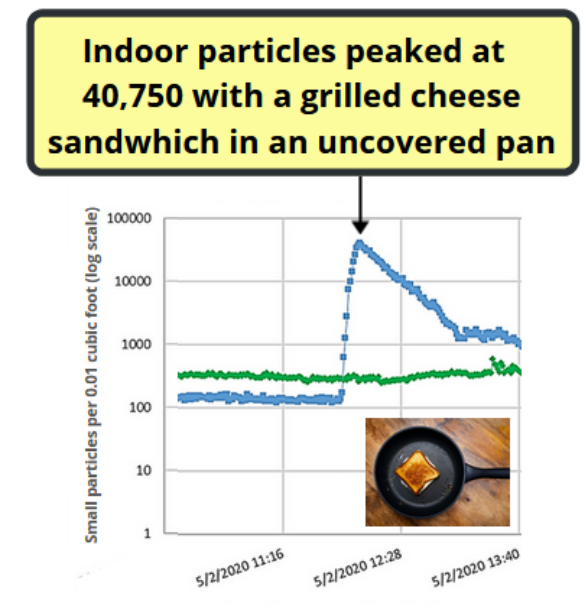
LARD 370
VEGETABLE SHORTENING 360
EXTRA VIRGIN OLIVE OIL 350
COCONUT OIL 350
BUTTER 350
SESAME OIL (REFINED) 350

DON'T COOK WITH

TOASTED OILS AND SOME SEED OILS
These oils have a very low smoke point, it's best to add these oils once you remove the food from the heat.

Data, Story, Behavior Change





"After reflecting on both of these cooking experiences and looking at the data for particle counts, it seems that covering the cooking surface may make a bigger difference in keeping particles from escaping into the indoor environment than some of the other actions. I recognize the importance of these behavior changes more than before and will consciously try to use them moving forward." - ROCIS participant Sara

Other Indoor-Generated Sources

Here's what we have seen:

- Humidifier using tap water (not distilled water)
- Cleaning products
- Recreational combustion
  - Cigarettes, vaping…
  - Candles, incense, diffusers

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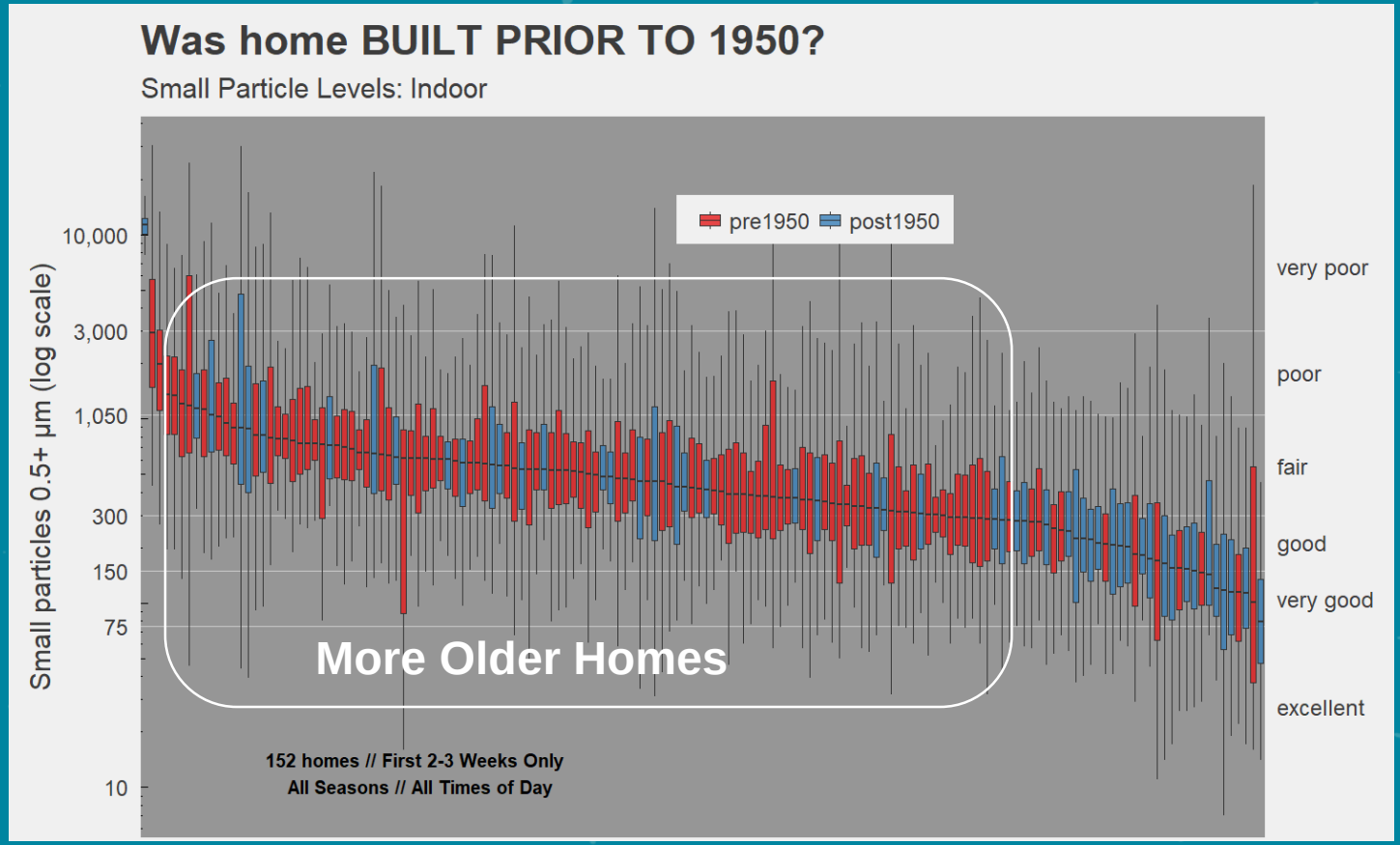
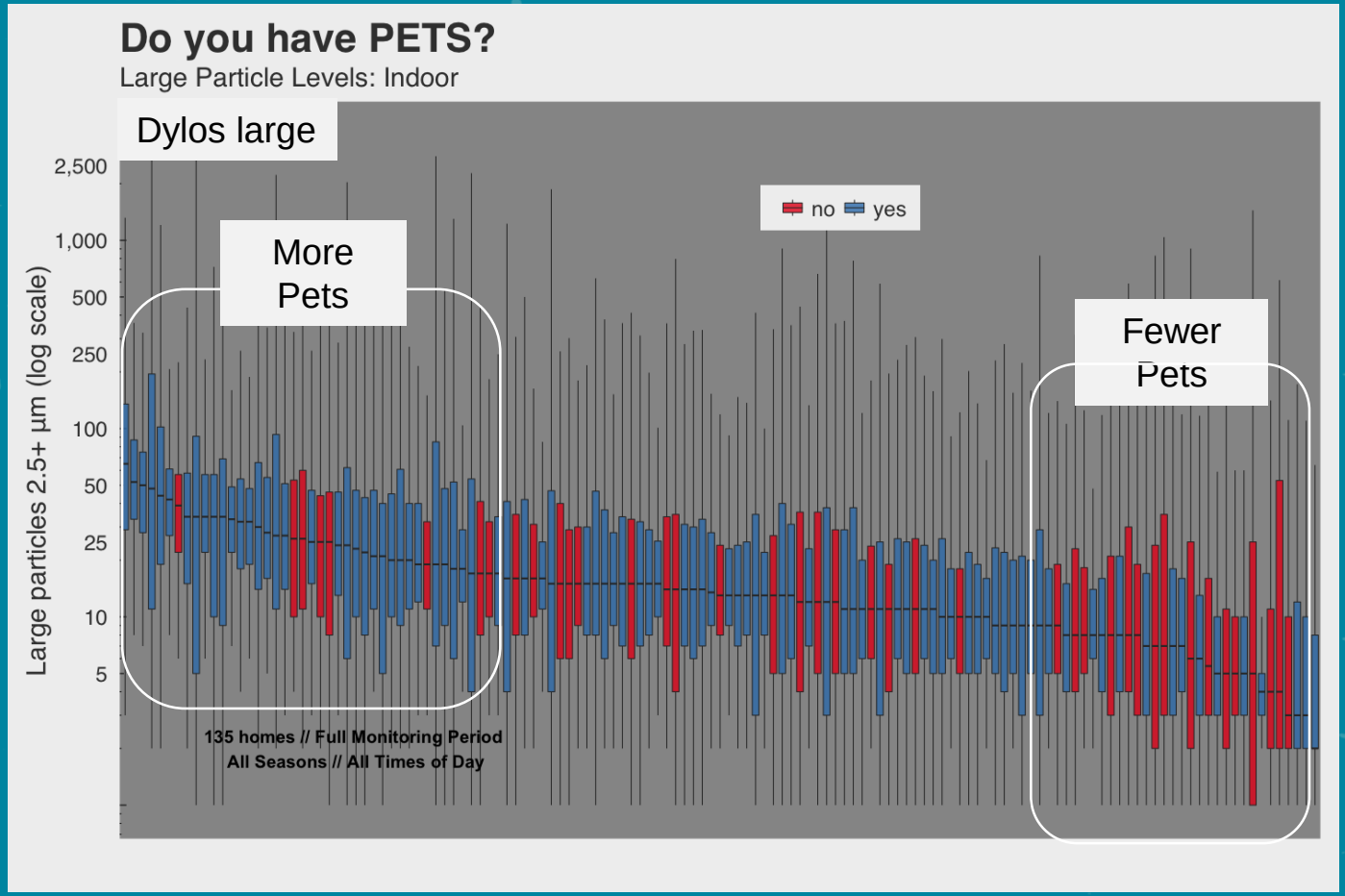
Particle Distribution by Site vs HCS Data

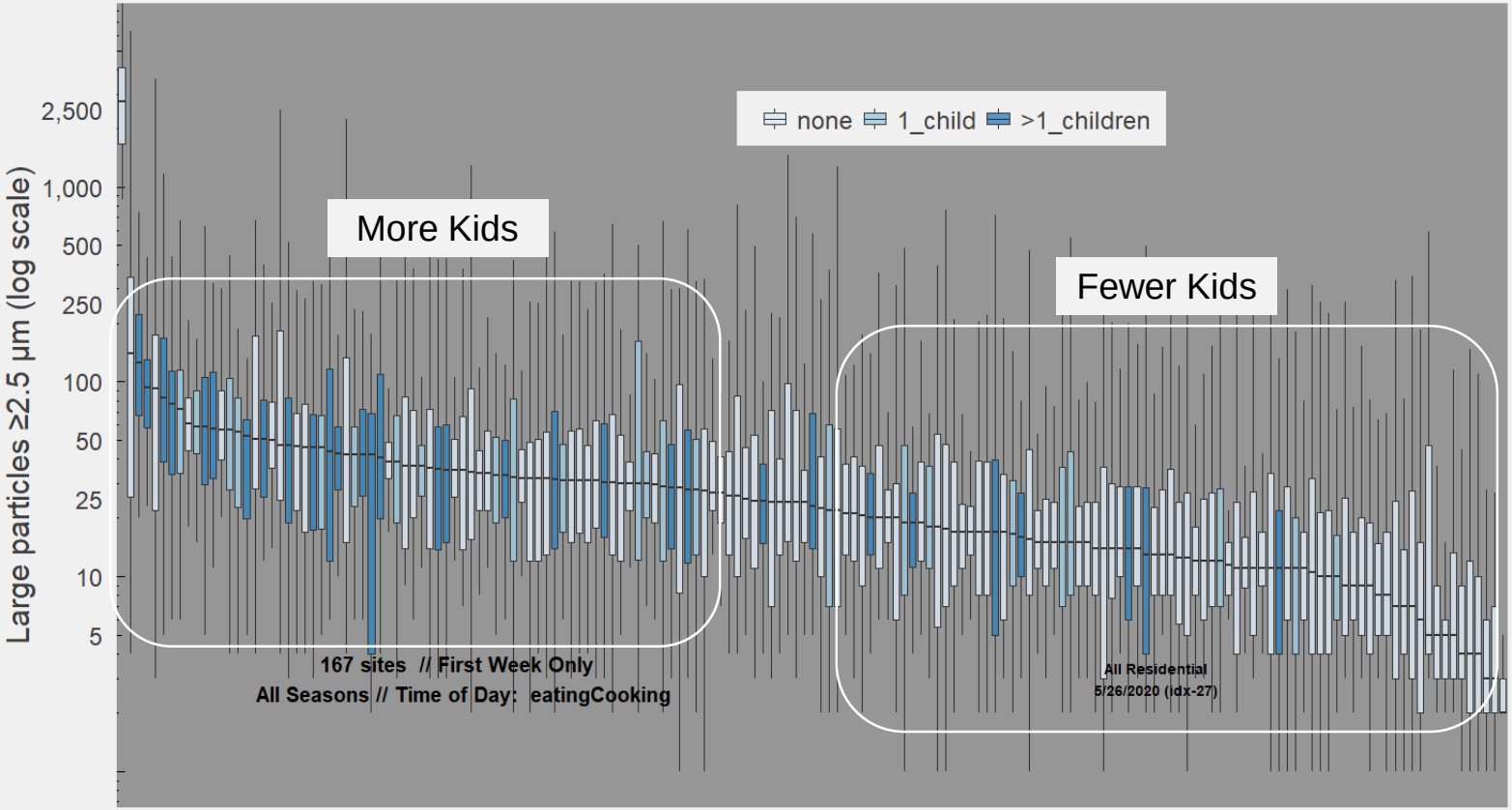
- Household Characterization Survey (HCS) Data - Pre
- Some insights


Was home BUILT PRIOR TO 1950?
Small Particle Levels: Indoor
Small particles 0.5+ µm (log scale)
10,000
3,000
1,050
300
150
75
10
pre1950
post1950
very poor
poor
fair
good
very good
excellent
More Older Homes
152 homes // First 2-3 Weeks Only
All Seasons // All Times of Day


Do you have PETS?
Large Particle Levels: Indoor
Dylos large
Large particles 2.5+ µm (log scale)
2,500
1,000
500
250
100
50
25
10
5
no
yes
More Pets
Fewer Pets
135 homes // Full Monitoring Period
All Seasons // All Times of Day

Number of CHILDREN LIVING THERE?

Large Particle Levels: Indoor



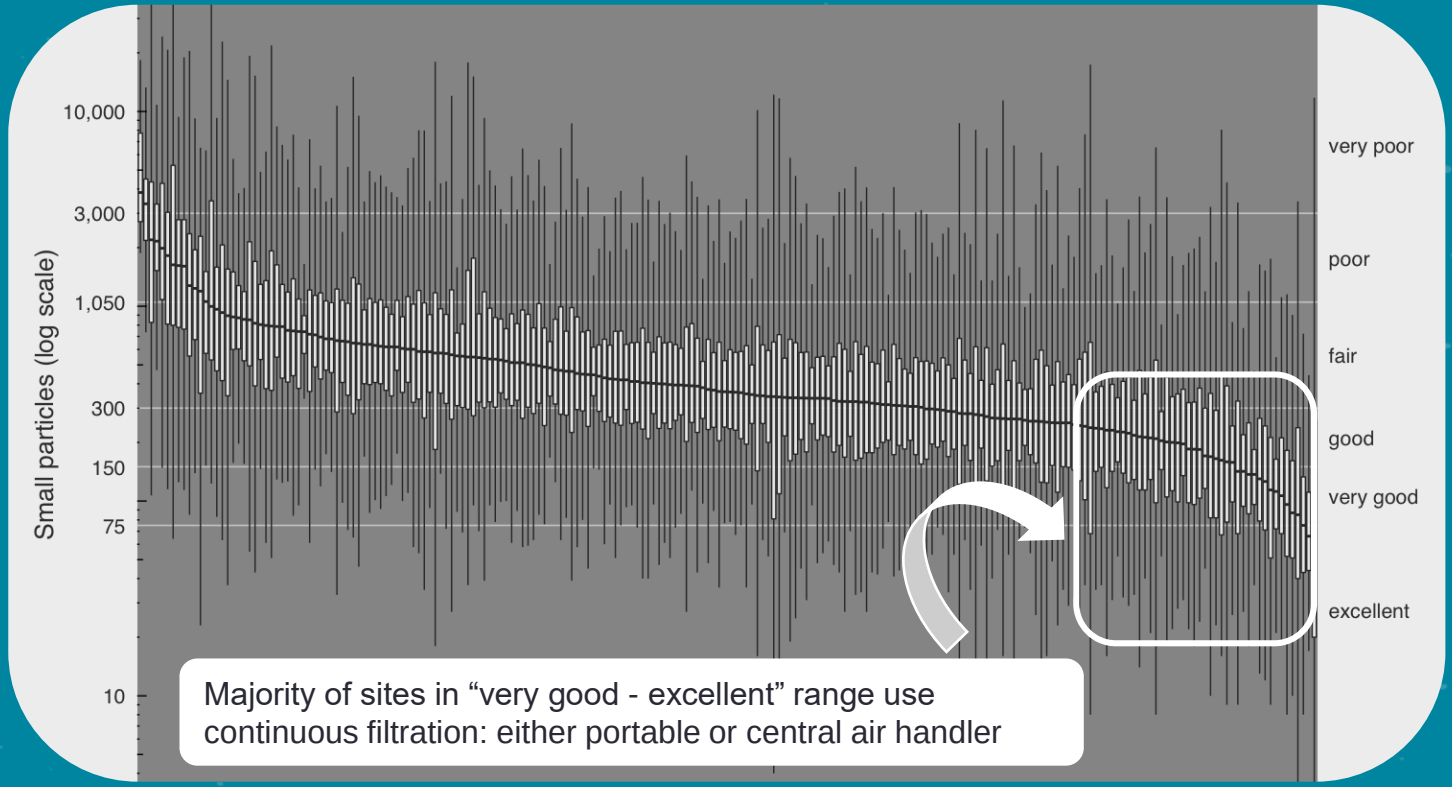
Clean it Up or Don't Disturb it

Many particle spikes from activity are resuspended – not generated

- Carpet
- Hard surface floor
- Couch - Upholstery
- Bedding
- Laundry
- Remodeling (attics, building cavities)

What was the original source?
Emissions from 50 years ago?
Residue from remodeling?
Particles from open windows?
Tracked in lead dust?

Indoor Particle Distribution:
All Sites



Majority of sites in “very good - excellent” range use continuous filtration: either portable or central air handler

More than 20 to 1 difference!
Median:
~70% Fair
~25% Good / Very Good

50% of observations are within each vertical box
Particles 0.5+ µm (Dylos small)
Dylos Corporation scale on right

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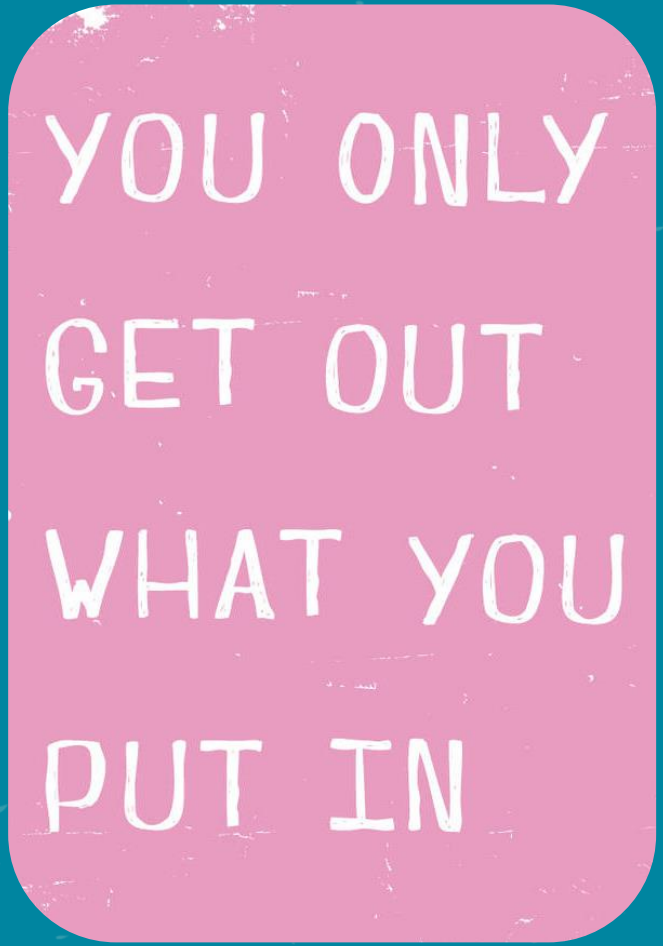
Filtration only works when it is ON!



Portable Air Cleaners (PAC) also referred to as Air Purifiers

- Designed to treat one room or zone
- Primarily reduce particles
- Some models offer added reduction of pollutants / odors

Performance: Filter Type

- **Particle Reduction:** (HEPA), *not HEPA-Like*
- **Reduction of Gases, Vapors, & Fumes:** Carbon? How much?
  - Avoid Others (Plasma Wave, Ionization, PCO)
  - NOTE: No standard for reduction of gases, vapors, & fumes, or certifying performance
  - Promises to “Kill”? Do not buy/use

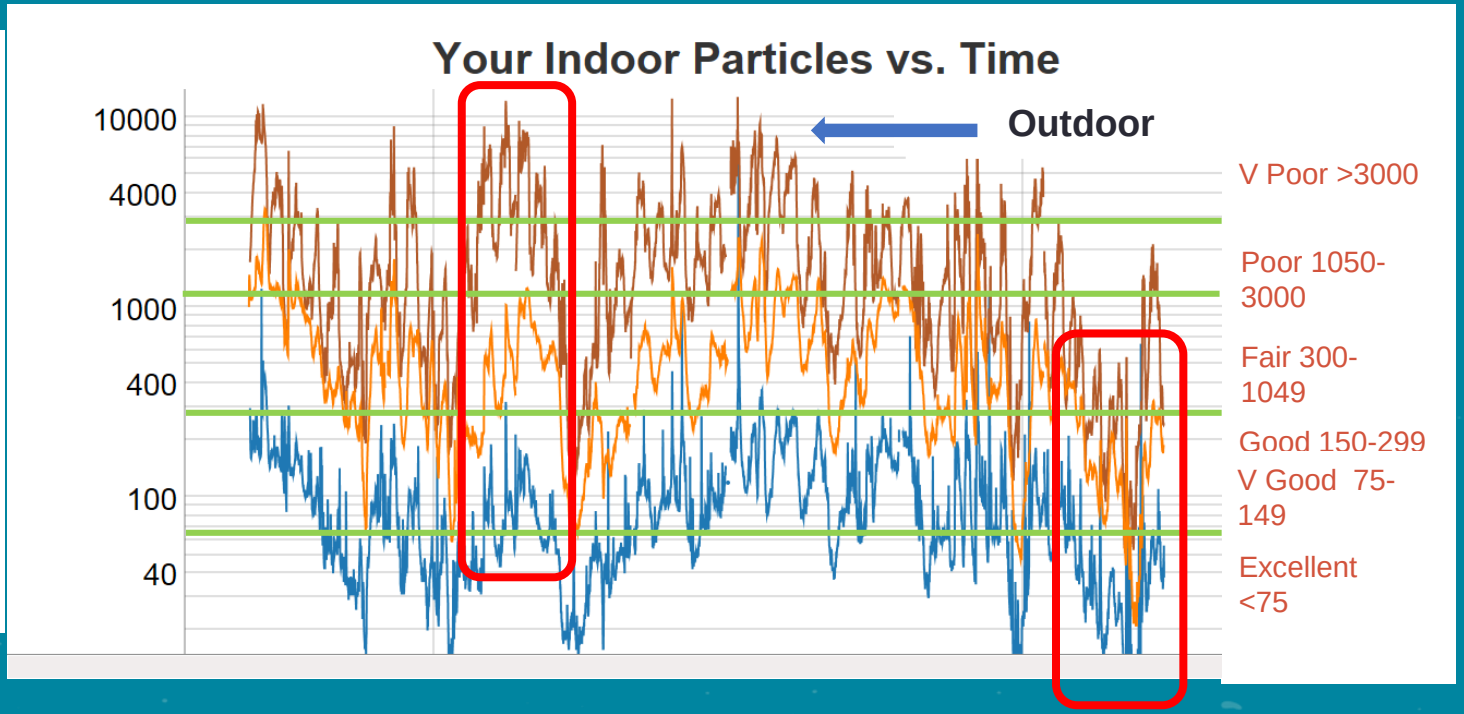
Impact of Portable Air Cleaner

http://rocis.org/rocis-data-explorer (j1t8)
0.5+ µm Particles by Time (15-min. avg.)

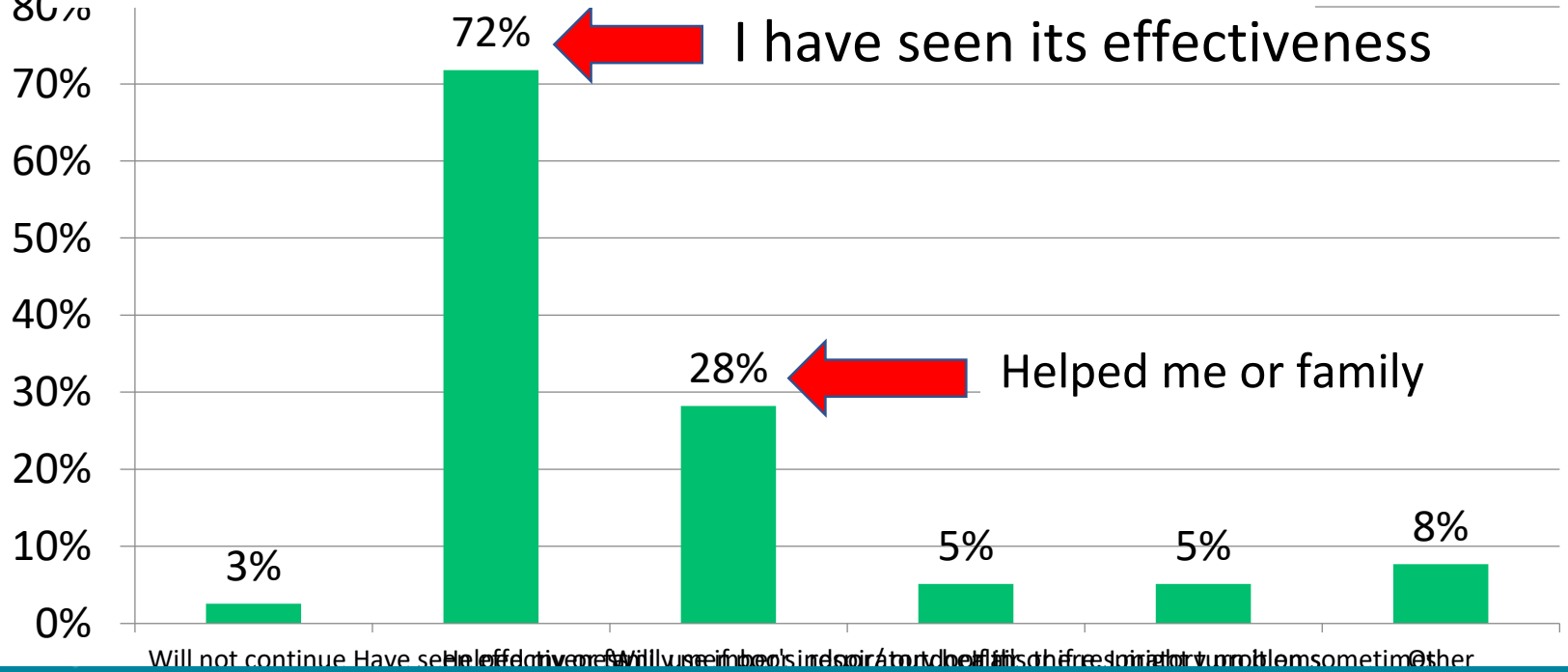
Brown: outdoors
Orange: untreated zone
Blue: treated zone with 24/7 air cleaner

Tight, single-family home

Though order of magnitude lower, Indoor (Blue/orange) tracks Outdoor (brown)



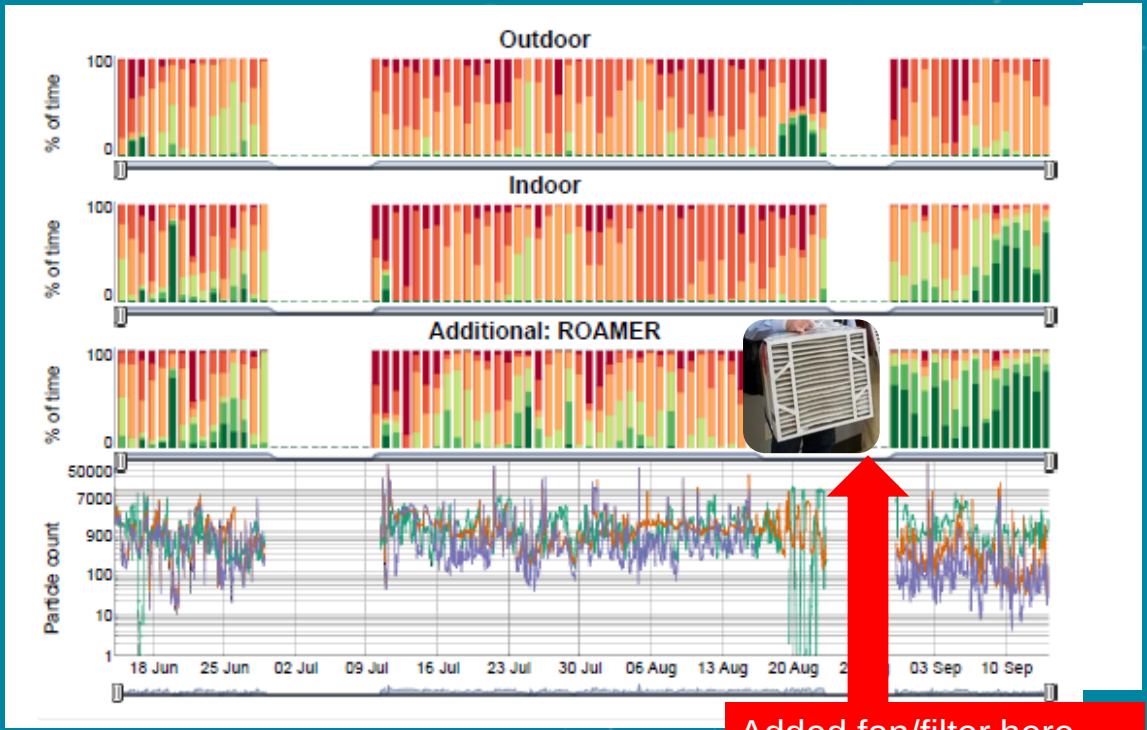
Why Continue to Use an Air Cleaner or Fan/Filter?



Fan/Filter Intervention: Low Cost, MERV 13

4” MERV 13 filter ($35) on 20” x 20” box fan (~$20)
Box fan in room or in window
UL-rated fan with overheat protection

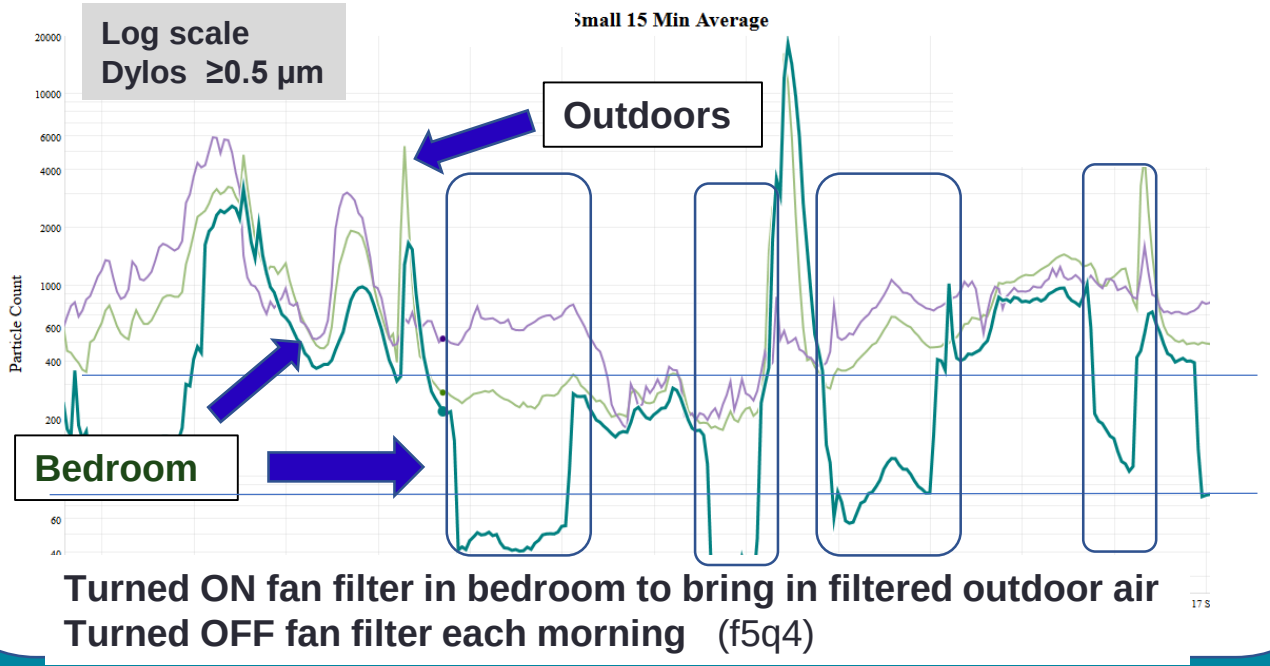
Indoor Fan/Filter 24/7 Impact



http://rocis.org/rocis-data-explorer (k4x3)

Fan Filter Intervention:
Bedroom Window at Night

Open window with/without box fan & filter on = Indoor tracks outdoor closely



Turned ON fan filter in bedroom to bring in filtered outdoor air
Turned OFF fan filter each morning (f5q4)

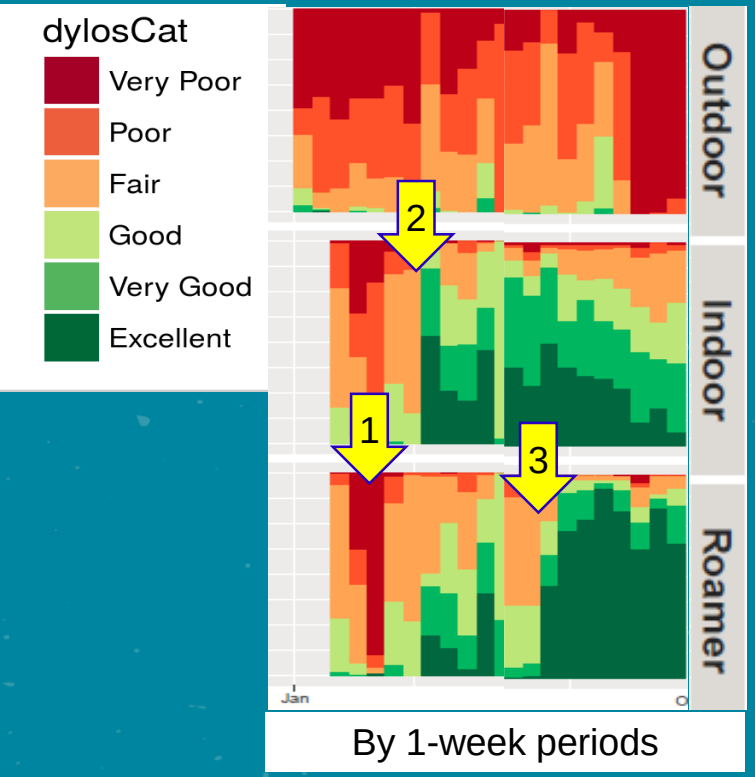
Fan/Filter Options
20” Box Fan w High MERV Filters

- Some use multiple filters (2 in V, or 4 in box)

https://www.treehugger.com/build-own-covid-19-air-filter-5081272

Image Credit: Comparetto Comfort Solutions

Behavior *Plus* Technical Intervention
Motivated Occupant



By 1-week periods

2-burner Induction Stove Top
(h9j2 example 2)

http://rocis.org/rocis-data-explorer


Fan/Filter


Induction Stove Top

Interventions:
1. Change use of humidifier
2. Add induction stove top & use fan filter (living room)
3. Add fan filter (bedroom)

High MERV Filter - Air Handler (Filter/AHU) Inquiry

Initial Question…

Is there an easy way to determine if I can use a high MERV filter with a longer air handler run-time without causing problems ($, equipment durability, performance, or GHG emissions)?

NO !!
Diagnostic Screen is Required

ROCIS 24/7 Air Handler Checklist

Big Issues with 24/7 High MERV Filter

Air handler (AHU) energy use can be high due to 500 to 1,500 watt-draw

- High cost of running air handler continuously
  (360 kWh to 1080 kWh/month = ~$500 to $1500/year[1])

Wrong blower speed

- Seldom set in field
- Often defaults to high speed, not low, in continuous mode
- Higher energy cost, less effective filtration

Ductwork issues introduce additional problems

- Static pressure too high (can lead to equipment failure)
- Duct leaks (energy waste & pressure-related problems)

[1] $0.12/kWh

Elements for AHU 24/7 Operation

- **ECM (electronically commutated motor) Blower**
  - Increase control to optimize (& lower) air flow
  - Drops electricity use, ***but only if static pressure*** is low/correct
- **4” Pleated MERV 13 filter – ideally also larger area**
  - Lower air flow thru filter increases reduction of smaller particles
  - 4” deep filter longer life without clogging
- **Good Duct System**
  - Minimal leaks to outside
  - Air flow & TESP within name plate specifications

NOT RECOMMENDED:

1” pleated MERV 11 or 13 filter (equivalent) without performance testing for TESP, air flow, & watt-draw

1st Air Handler Retrofit

Pre

Post

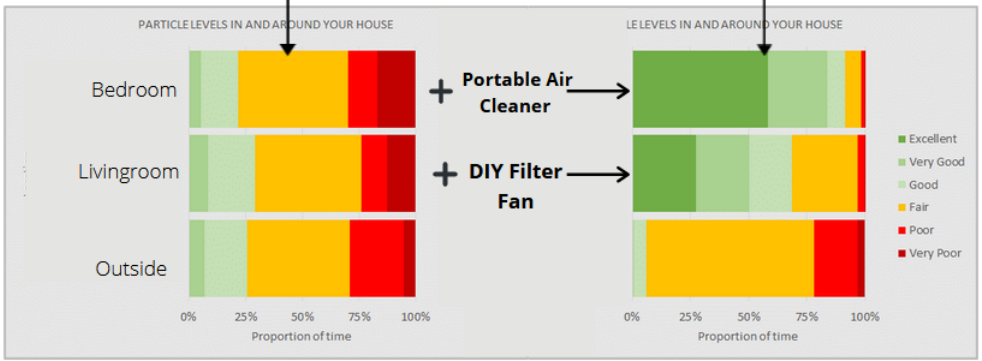
Replaced PSC motor w/ ECM motor

Labor & material cost: ~$1,000
24/7 monthly operating cost: ~$12.50

Results with Portable Air Cleaner & Fan/Filter

Week 1:
- Windows opened occasionally
- No portable air filter
- No filter fan
- Air quality indoors similar to outdoors

Week 2:
- Windows opened occasionally
- Portable air filter
- Filter fan
- Air quality indoors better than outdoors



"We noticed a marked difference with the use of both the fan filter and portable air cleaner. We observed our baseline particle counts were lower overall...We also observed that our particle counts lowered more quickly with both interventions after cooking, which was our biggest source of high indoor particle counts."

- Val, ROCIS Participant

Big Opportunity - HVAC Replacement

- *Downsize HVAC to reduce static pressure!!*
- Incorporate return drop modification & option for larger, deeper filter
- Set blower speeds for optimal performance
- Address duct system shortcomings

- To ponder…
  - Could potential filtration health & comfort benefits add impetus to getting HVAC systems designed & installed correctly?

Bottom Line: Air Handlers 24/7 w High MERV Filtration

- Can be very effective!
- Do not operate air handler 24/7 without confirming
  - Fan cost (electricity)
  - Minimal duct leakage to outside (big issue w/attic ducts)
  - Static pressure within operating range
  - NOTE: One-inch pleated filters can be very restrictive

In Conclusion

Integrated solutions are needed to enhance health, resilience, energy efficiency, comfort, & durability

Improve outdoor air quality!

Develop champions!

The most effective monitor is a motivated, knowledgeable occupant!

Schedule & Topics

75-minute Online Meetings
7 PM Mon. & Thurs., Repeated 10:30 AM Tues. & Fri.

Important Dates:

Sept 27/28	Intro to the LCMP Webinar
Sept 30	Confirm Your Interest
Oct 5	Kit Drop-off
Oct 8	Have all monitors set up
Nov 9	Kit Pick up

Meetings in orange are required

Meetings:

Oct 7 or 8	Virtual Cohort Kick-off
Oct 11 or 12	Check-in
Oct 14 or 15	Dylos Downloading
Oct 18 or 19	What are Good Numbers? IAQ Health Risks?
Oct 21 or 22	Online Resources
Oct 25 or 26	Behavioral Interventions
Oct 28 or 29	ROCIS Filtration Interventions
Nov 1 or 2	Health Impacts of Particles
Nov 4 or 5	Wrap-up Meeting

Thanks!

Thanks to Phil Johnson & The Heinz Endowments for support of the ROCIS initiative (Reducing Outdoor Contaminants in Indoor Spaces) and our 390 LCMP participants

This presentation: http://rocis.org/past-rocis-events

Upcoming Cohort (sign up for intro session)
http://ROCIS.org

Access to resources & research results

- LCMP http://rocis.org/rocis-low-cost-monitoring-project
- ROCIS Brief - Ducted Range Hood
http://rocis.org/kitchen-range-hoods
- Air Handler Inquiry http://rocis.org/air-handler-inquiry
- ROCIS Data http://rocis.org/rocis-data
- Clairton Air Filter Project
- http://rocis.org/clairton-air-filter-project

Stay Tuned!!

- Video Shorts - Telling the Story

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QUESTIONS??

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Upcoming Cohort (sign up for intro session)
7 PM Sept. 27, repeated 10:30 AM Sept. 28
http://ROCIS.org

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