INDOOR AIR QUALITY & HEALTH

Session 3 - Thursday, Oct. 22, 2020

2020 One Health One Planet™ Symposium
“One Health and the Air We Breathe”
Phipps Conservatory & Botanical Gardens Oct.19 - 23, 2020

Find this presentation here:
http://rocis.org/past-rocis-events
Outline

1. ROCIS, Why focus on particles?
2. Low Cost Monitoring Project
3. Reducing exposure

Frustration Alert! Lots of links & text
• Find this presentation here:
  • http://rocis.org/past-rocis-events
ROCIS *(Rock-us) or (Raucous)*
Reducing Outdoor Contaminants in Indoor Spaces
WWW.ROCIS.ORG
WHAT IS ROCIS?

Our MISSION

A Southwestern Pennsylvania initiative to reduce the impact of exterior pollution in indoor spaces.
Why??

Most of our exposure to outdoor pollution happens IN buildings

http://www.iaqscience.lbl.gov
Focus on Particles
Also referred to as Particulate Matter (PM)
Particles (PM)

PM$_{2.5}$: Particulate matter $<2.5$ µm in diameter
ROCIS LCMP Dylos: Particles $>0.5$ µm
(1/100 of human hair!)

Dylos 1700
Our work horse!
Health Concerns - Particles

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

Outdoor Plus Indoor!
ROCIS LCMP
Low Cost Monitoring Project

• Started 5 years ago
• Mostly homes, some work places
• 350 participants
ROCIS

Low Cost Monitoring Project (LCMP)

Objectives

1) Learn how low-cost air monitors empower occupants

2) Examine the impacts of outdoor on indoor air

3) Explore interventions to improve indoor air quality

4) Develop champions!!
Indoor Particle Distribution – All Sites

More than 20 to 1 difference!

Median: ~1/2 Fair; ~1/2 Good / Very Good

50% of observations are within each vertical box
Particles ≥ 0.5 μm
Dylos Corporation scale (on right)
Outdoor Particle Distribution – All Sites

Particles $\geq 0.5 \, \mu m$
Dylos Corporation scale on right

10 to 1 Difference
1/2 Poor; 1/2 Fair
LCMP Cohorts

Participants borrow monitoring equipment to measure:

- Particles (0.5+ µm and 2.5+ µm)
- Carbon dioxide (CO₂)
- Carbon monoxide (CO)
- Radon
- Temperature
- Relative humidity

During the course of the 3+ week cohort, participants:

- Learn from the ROCIS team & each other

*Participants receive weekly individualized feedback in response to their monitoring data, observations, & questions.*
NEXT VIRTUAL (FREE!) COHORT

Learn more about participating

https://ROCIS.org

Monday, 7 PM, Oct. 29, 2020
Tuesday, 10:30, Oct. 30 2020

Cohort Dates
Nov. 5 - Dec. 8, 2020
Reducing Exposure
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)
4 Options to Reduce Indoor Particles

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  - Portable air cleaners
  - Central air handler (furnace, AC, or ventilation)
Outdoor Data by Cohort - (70 mile spread) - Readings track

Log scale

We share the same air shed!
Rapid variations in outdoor particles – particularly worse at night
House with Windows Closed

PARTICLE LEVELS IN AND AROUND YOUR HOUSE

- **DINING RM**
- **BEDROOM**
- **LIVING RM**
- **OUTSIDE**

Legend:
- **Excellent**
- **Very Good**
- **Good**
- **Fair**
- **Poor**
- **Very Poor**

Proportion of time:
House with Wide Open Windows

PARTICLE LEVELS IN AND AROUND YOUR HOUSE

- Excellent
- Very Good
- Good
- Fair
- Poor
- Very Poor

DYLOS SMALL PARTICLES
- outside
- Inside living room
Should I Open My Windows??

- Purple Air Map - https://www.purpleair.com/map
- Smell Pittsburgh - https://smellpgh.org
- Create Lab VOC Monitor map - https://voc.createlab.org/?c=tVOC
4 Strategies to Reduce Indoor Particles

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• **Filter the air**
  • Portable air cleaners
  • Central air handler (furnace, AC, or ventilation)
Cooking Considerations!

Reduce emissions through

• Vented kitchen range hood

• Induction stove top unit - two burner portable option

• Cooking style (e.g. bake vs. frying bacon)

• Use lids

• Heat: Lower is better

• Cooking oil type vs. butter

• Add salt & pepper to cooking oil
Induction Cooktop or Portable Stove top

Benefits!

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

Online Kitchen Ventilation group:

https://www.buildingperformancecommunity.org/groups/kitchen-ventilation

Online closed group on Building Performance Community:

https://www.buildingperformancecommunity.org/groups/inexpensive-residential-particle-monitoring
Other Indoor-Generated Sources

*Here’s what we have seen:*

Tap water in ultra-sonic humidifier (should use distilled water)
Cleaning products (avoid scented & toxic!!)
Personal care products
Recreational combustion
  Cigarettes, vaping…
  Candles, incense, diffusers
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
  - Walk-off mats
  - Get rid of carpets, old upholstered furniture
- Filter air
  - Portable air cleaners
  - Central air handler (furnace, AC, or ventilation)
Number of CHILDREN LIVING THERE?

Large Particle Levels: Indoor

- More Kids
- Fewer Kids

167 sites // First Week Only
All Seasons // Time of Day: eating, cooking
Do you have PETS?
Large Particle Levels: Indoor

Dylos large

More Pets

Fewer Pets

135 homes // Full Monitoring Period
All Seasons // All Times of Day

Large particles 2.5+ μm (log scale)

no  yes
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?
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
  • Walk-off mats
  • Get rid of carpets, old upholstered furniture

• Filter the air
  • Portable air cleaners
  • DIY Fan/Filter
  • MERV 13 filter in central air handler (furnace, AC, or ventilation)
Indoor Particle Distribution – All Sites

More than 20 to 1 difference!
Median: ~1/2 Fair; ~1/2 Good / Very Good

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

50% of observations are within each vertical box
Particles 0.5+ μm (Dylos small)
Dylos Corporation scale (on right)
Filtration only Works When it is On!

FACTORS AFFECTING OPERATION

Maintenance
Cost of Filter Replacement
Energy Use /Energy Cost
Noise
Air Movement/Comfort –
  Comfort (summertime)
  Discomfort (wintertime)
Portable Air Cleaners
Also referred to as Air Purifiers
Portable Air Cleaners (or Air Purifiers)

- Designed to treat one room or zone
- True HEPA filter for best particle reduction
- Some models offer added reduction of pollutants / odors
- Some models have a variety of features (some useful, some not)
- Properly size (ideally oversized)
Why Continue to Use an Air Cleaner or Fan/Filter?

- 72% have seen effectiveness
- 28% helped my or family member’s health
- 3% will not continue
- 5% will use if poor indoor/outdoor air or if respiratory problems
- 5% if it's there, I might turn it on sometimes
- 8% other
Clairton Air Filter Distribution Program
Summer 2020

- 47 households served
- Goal: treat all regularly occupied spaces
- 153 portable air cleaners (3.25/home)
- Pre & post particle monitoring (~weeks)
- Weekly contact for feedback
- $870 - Average PAC cost per home
- Portable Air Cleaner Performance & Data here

http://rocis.org/clairton-air-filter-project
DIY Fan Filters
DIY 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

Log scale
Dylos ≥0.5 µm

Small 15 Min Average

Outdoors

Bedroom

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)


Image Credit: Comparetto Comfort Solutions
Air Handler/high MERV Inquiry
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

http://rocis.org/air-handler-inquiry
Big Issues with 24/7 High MERV Filter

Air handler (AHU) energy use & cost 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
CASE STUDY: Indoor Air Quality Interventions

Chris Guignon, evolveEA

Labor & material cost: ~$1,000
24/7 monthly operating cost: ~$12.50
Big Opportunity at 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?
FILTRATION RESOURCES

- EPA Guidelines - Air Cleaners & Air Filters in the Home
  https://www.epa.gov/indoor-air-quality-iaq/air-cleaners-and-air-filters-home-0
- ROCIS website - http://rocis.org/air-handler-inquiry
  http://rocis.org/clairton-air-filter-project

Digging Deeper

- IL Institute of Technology (Built Environment Research Group) (papers & presentations) http://built-envi.com/
- IAQ Scientific Findings Resource Data Bank
  https://iaqscience.lbl.gov/indoor-air-quality-iaq-scientific-findings
- ASHRAE Epidemic Task Force
- NAS HVAC Strategies for COVID-19 Webinar
- 2 - 3:30 PM (EDT), Wed. Oct. 28, 2020  Register here
SUMMARY
Behavior *Plus* Technical Intervention

**Motivated Occupant**

INTERVENTIONS

1) Change use of humidifier
2) Add induction stovetop & use fan/filter (living room)
3) Add fan/filter (bedroom)

[2-burner Induction Stovetop](http://rocis.org/rocis-data-explorer (h9j2) (example 2)]
Social Justice Concerns

Increased indoor particles are associated with

- Older homes
- Attached dwellings
- Substandard housing stock
- No air conditioning
- Higher occupancy
- Cooking (ethnic or cultural traditions – higher emissions)
- Unvented kitchen stoves
- Proximity to traffic & other point emission sources
4 Conclusions

1. Low cost monitors - reinforce behavior & investment

2. Less outdoor particle pollution - much less indoor levels

3. Occupants & building systems - significant impact on particle levels

4. Better outdoor air quality & housing stock/building systems - critical to reduce disparities & to improve health
Bottom Line!

**Integrated solutions** are needed to enhance health, resilience, energy efficiency, comfort, & durability (engagement, building tightness, source control, O&M)

*Improve outdoor air quality!*

*Develop champions!*

*The most effective low cost monitor is a motivated, knowledgeable occupant!*
Thanks to The Heinz Endowments for support of the ROCIS initiative (Reducing Outdoor Contaminants in Indoor Spaces) And 350+ LCMP participants
Questions & Comments Welcome!

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

Upcoming Cohort - sign up  http://ROCIS.org/

Access to resources & research results

• LCMP  http://rocis.org/rocis-low-cost-monitoring-project
• ROCIS Brief - Ducted Range Hood (Tom Phillips)
  • 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

Linda Wigington
Project Lead,  
ROCIS Initiative  
724-852-3085  
wigington1@outlook.com  
http://ROCIS.org/
INSIGHTS FROM ROCIS MONITORING DATA
Indoor Particle Levels
Tendency to Open Windows Compared to Outdoor Particle AQ

sleeping hours, summer season

Outdoor Air Quality
Bad=worst 33%
Good=best 33%

Linear Scale
Dylos ≥ 0.5
Indoor Particle Levels
Air Conditioning Type by Outdoor Particle AQ

all TOD, all seasons

Outdoor Air Quality
Bad=worst 33%
Good=best 33%

Linear Scale
Dylos ≥ 0.5

Central AC  Room AC  No AC
INSIGHTS / RESULTS FROM ROCIS INTERVENTIONS
Portable Air Cleaners
Also referred to as Air Purifiers
Did You Continue Using Your Air Cleaner or Fan/filter After ROCIS Monitoring?

ROCIS SURVEY 39 Responses

Yes: 90%
No: 10%
I no longer have an air cleaner in my home or workplace: 0%
Not applicable: I am still monitoring: 0%
Online Data Explorer
Indoor Counts Track Outdoors

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

V Poor >3000
Poor 1050-3000
Fair 300-1049
Good 150-299
V Good 75-149
Excellent <75

Blue: treated zone
Orange: untreated zone
Deep red: outdoors
Tight, single family home
Though order of magnitude lower; Indoor (Blue/orange) tracks Outdoor

Worst Outdoor
Best Outdoor
Indoor - treated
10/22/2020
One Health One Planet
Clairton Air Filter Project

Reductions – Very High Pre-Particles

Before and after PACs:

Homes

w/ >25,000 median week1 particles

CHANGE IN MEDIAN PARTICLES (>0.5 MICRONS) PER 0.01 CU. FT

- Median wk 1 Indoor
- Median wk 2 Indoor
Clairton Air Filter Project
Reductions: Low Pre-Particle Count

Before and after PACs:
homes w/ <300 median week1 particles

<table>
<thead>
<tr>
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<th>Median wk 1 Indoor</th>
<th>Median wk 2 Indoor</th>
</tr>
</thead>
<tbody>
<tr>
<td>QJO</td>
<td>-62%</td>
<td></td>
</tr>
<tr>
<td>QHB</td>
<td>-69%</td>
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<td>QJY</td>
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<tr>
<td>QLX</td>
<td>-55%</td>
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<tr>
<td>QKG</td>
<td>-81%</td>
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<tr>
<td>QMA</td>
<td>-24%</td>
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</table>

MEDIAN PARTICLES (>0.5 MICRONS) PER 0.01 CU. FT

CHANGE IN MEDIAN PARTICLES (>0.5 MICRONS) PER 0.01 CU. FT

- Median wk 1 Indoor
- Median wk 2 Indoor
Air Handler/high MERV Inquiry
Problems identified in 60 diagnostic inspections of SW PA air handlers

- Space Constraints: 17%
- HVAC Oversized: 27%
- High Static (Coil): 30%
- AC Oversized: 48%
- High Airflow: 52%
- High Static (Return): 67%
- High Static (Filter): 68%
- High TESP: 80%
Selected ROCIS Intervention Homes
Pre-Post Median Particle Count

Use above code (w2i9) to view data on ROCIS LMCP Data Explorer
http://rocis.org/rocis-data-explorer
Air Handler Interventions

Pre-Post Continuous Watt-Draw

Even lower post Watt-draws should be possible with a different ECM

Use these codes **(w2i9)** to view particle data on ROCIS LMCP Data Explorer

http://rocis.org/rocis-data-explorer
Case 2: Air Handler Retrofit 2.0

RESULTS:

In continuous mode:
- 4.27 CFM/watt
- 120 Watts
- Pressure drop across filter
  - Pre: 93 Pa, Post: 16 Pa
- Allowable TESP: 125 Pa
  (total system)

Larger return drop

2-part filter rack
- (20” x 25”)
- Horizontal
- (4” MERV 13 + 2” pre or post filter)

90 degree transition
- designed for better air flow (heel & throat);
- lower static

ECM replacement

Fan speed adjusted to optimize heating, cooling, & continuous performance.
Case 2 Pre & Post Particles
Air Handler Retrofit

PRE

<table>
<thead>
<tr>
<th>Location</th>
<th>ROAMER</th>
<th>INSIDE</th>
<th>OUTSIDE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outside</td>
<td>0%</td>
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<tr>
<td>Inside</td>
<td>25%</td>
<td>50%</td>
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<tr>
<td>Roamer</td>
<td>50%</td>
<td>75%</td>
<td>0%</td>
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</table>

POST

<table>
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<tr>
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<td>50%</td>
<td>75%</td>
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</table>

Week ending 5-24-2017 (windows open) vs. 7-31-2017, poorer outdoor counts

INTERVENTION:
ECM blower (lower air flow & energy cost on continuous setting)
New return (larger 20” x 25” MERV 13 filter & pre-filter)

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

**Air Handler 24/7 – MERV 13 Filter**

- Indoor tracks outdoor
- Indoor uniform – 2 locations
- Also – 2nd fl portable air cleaner

Continuous Mode: $12/month
Post: 110 watts; 500 CFM
(Pre-Post: 400 watt reduction)

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### Dylos small (0.5+ microns) (#/100 ft^3)

- Green – Outdoor
- Blue Living Room
- Yellow – 2nd Floor Hallway
Filter Bypass

…Relatively Common

Better the filter the greater the adverse impact!