USING CONSUMER IAQ MONITORS TO CREATE A HEALTHIER HOME

National Home Performance Conference

IAQ & Healthy Homes 10:30 - noon April 2, 2019





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Four Conclusions

- 1) Low-cost monitors can contribute to awareness, behavior change, use of technical interventions, & building capacity of people, communities, & organizations.
- 2) Outdoor particle counts have a significant impact on indoor levels.
- 3) Visualization tools influence how one interprets the data.
- Behavioral & technical interventions can substantially reduce indoor particle levels – *low-cost monitors can increase the likelihood of sustained operation.*

ROCIS (Rock-us) or (Raucous) Reducing Outdoor Contaminants in Indoor Spaces

WWW.ROCIS.ORG



WHAT IS ROCIS ? MISSION

NEONEONE

A Southwestern Pennsylvania initiative to reduce the impact of exterior pollution in indoor spaces. NHPC Conference 4-02-19 Chicago



NEONEONE



Most of our exposure to outdoor pollution happens in buildings¹



Canadian Human Activity Pattern Survey 2, 2010-11

Matz, C.J.; Stieb, D.M.; Davis, K.; Egyed, M.; Rose, A.; Chou, B.; Brion, O. Effects of Age, Season, Gender and Urban-Rural Status on Time-Activity: Canadian Human Activity Pattern Survey 2 (CHAPS 2). *Int. J. Environ. Res. Public Health* 2014, *11*, 2108-2124.

ROCIS LCMP LOW COST MONITORING PROJECT

http://rocis.org/rocis-low-cost-monitoring-project

Low Cost Monitoring Project (LCMP) Objectives

- 1) Learn how low-cost air monitors empower occupants
- 2) Examine the impacts of outdoor pollution on indoor air
- 3) Explore interventions to improve indoor air quality

Low Cost Monitoring Project (LCMP) Process

- Provide IAQ monitoring kit short-term loan for baseline, longer term for testing interventions
- > Tap participant's homes & workplaces
- >Invest in participants' experience & knowledge
- Provide protocols for reporting & interventions
- >Build baseline & develop/refine best practices
- > Develop champions!!

Cohorts meet for three, 2-hour face-to-face meetings



Low Cost Monitoring Kit

(3) Dylos Particle Counter DC1700 <u>http://www.dylosproducts.com/dc1700.html</u>
(2) AirThings Radon Monitor <u>https://airthings.com/us/</u>
(1-2) Carbon Monoxide (CO) Monitors
(Experts Model 2015) <u>http://coexperts.com/2015-2/</u>
(1) Carbon Dioxide (CO₂) TIM12 Datalogging Meter www.co2meter.com



Making the Invisible Visible

Dylos 1700 Optical Particle Counter: # Particles per 1/100 ft³, 1 min. resolution

2 size ranges of Particles:

> 0.5+ µm (Dylos "Total")

> 2.5+ µm (Dylos "Large")

Cost: \$300 - 400; 1 week max data storage

3 Dylos / Site

Outside, Inside (living area) Roamer (usually bedroom)

NOTE: Scale at right is from manufacturer; not health based

Dylos 1700 http://www.dylosproducts.com/dc1700.html



Air Quality Chart .5 um – Small Count Reading 3000 + = VERY POOR 1050-3000 = POOR 300-1050 = FAIR 150-300 = GOOD 75-150 = VERY GOOD 0-75 = EXCELLENT

Pittsburgh's Air Quality is Poor¹

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

>7th worst city & worst city east of the Rockies
 >Allegheny County (Pittsburgh) is 10th worst

…From Short-Term Particle Pollution (24-hour PM2.5) >10th worst city¹ & worst city east of the Rockies

1. Pittsburgh-New Castle-Weirton (PA-WV-OH)

SOURCE: American Lung Association State of the Air Report 2019 https://www.lung.org/assets/documents/healthy-air/state-of-the-air/sota-2019-full.pdf

NHPC Conference 4-02-19 Chicago



PM₁₀: Particulate matter less than 10 μm in diameter
 PM_{2.5}: Particulate matter less than 2.5 μm in diameter
 ROCIS LCMP Dylos: PM_{0.5}+: Particulate matter is *greater than* 0.5 μm in diameter (1/100 of human hair!)

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

>Health Concerns

- Fine (PM_{2.5}) & Ultra-Fine Particles (PM_{0.1}) can be vehicles to increase exposure of toxic contaminants such as SVOCs & metals
- Precautionary principle should apply avoid or minimize exposure

DATA VISUALIZATION

Opportunities & Challenge

Outdoor Impacts Indoors

Occupant Insights

Spikes dominate awareness

Biggest Impressions (Indoor Incidents)

- >Cooking
- Cleaning
- >Active occupants (e.g. children)
- Remodeling

Visualization Challenges Making Sense out of Data!

115 million data points -

...downloaded manually, 20K at a time!

Comparison to others

Impact of outside counts on inside

Comparison over time / Impact of interventions

• Did actions make a difference? How much?

Visualize Impact of Outdoor on Indoor, and Impact of Interactions ROCIS LCMP tools include:

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

> Outdoor Dylos Data Plot by Cohort (Weebly site)

LCMP Averager (Excel macro)

- Feedback to participant after each download
- http://rocis.org/rocis-averager

LCMP Data Explorer (R Shiny web app)

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

Indoor Particle Distribution – All Sites



Outdoor Particle Distribution – All Sites



Outdoor Data by Cohort -(70 mile spread) - Readings track

Log scale ROCIS Low Cost Monitoring Project



Most sites are Pittsburgh; Green line (Wbg) is 50 miles south Dylos particles (0.5+ μ m)

22

4 HOURS AGO

0 - -

Online Data Explorer Indoor Counts Track Outdoors



Blue: treated zone Orange: untreated zone Deep red: outdoors Tight, single family home

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

4 HOURS AGO

0 - -

What if Outdoor AQ was "Good" All the Time?



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

What if Outdoor AQ was "Poor" All the Time?



% of Time

Using online ROCIS Data Explorer http://rocis.org/rocis-data-explorer

PARTICLE DISTRIBUTION BY SITE VS

Household Characterization Survey Data (Pre)

Number of CHILDREN LIVING THERE?

Large Particle Levels: Indoor



Do you have PETS?

Large Particle Levels: Indoor



Is Your Home Detached?



What type of OVEN do you have?

Particle Levels: Indoor location



During what PERIOD WAS HOME BUILT?

Particle Levels: Indoor location



During what PERIOD WAS HOME BUILT?

Large Particle Levels: Indoor



INTERVENTION INSIGHTS

And the Role of Low Cost Monitors

Comparison of Early Vs. Late Particle Counts

First 10-day median compared to last 10-day median

1500·



Indoor Particle Levels

Comparing early vs. late in monitoring period



Outdoor Particle Levels

Comparing early vs. late in monitoring period


- 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)

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- Reduce resuspension
 - HEPA vacuum
 - Walk-off mats; clean hard-surface floors thoroughly
 - Get rid of carpets, old upholstered furniture
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Window Operation

- Single biggest factor affecting IAQ when outdoor counts are high
- In Pittsburgh, particle counts tend to be higher at night & early morning when windows are often open
- Poor air quality usually not perceptible (terrible AQ is)
- Most contentious!
- Balancing passive cooling, preferences, dilution of indoor pollutants, & ventilation
- Implications social justice, heat stress (no AC)

Windows Open vs. Closed (night)

(two different sites - same week; log scale)



Open Windows –

ROCIS Data Explorer Participant Example 4

- Click the link below to see ROCIS team member Don Fugler walk through an example of a participant's home data.
- Plug in the code m6i6 to the Data Explorer (link above) to further examine this participant's home.
 <u>http://rocis.org/rocis-data-explorer-participant-</u> example-4

Fan/Filter Intervention: Low Cost, MERV 13



Fan/Filter Intervention– Bedroom Window at Night

Open window with/without box fan and filter on:



Turned OFF fan filter each morning (f5q4)

- Reduce air exchange from outside
 - Close windows
 - Tighten home or building
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 - Use induction cook top & other good practices w/ cooking
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Behavior Plus Technical Intervention Motivated Occupant





2-burner Induction Stovetop

http://rocis.org/rocis-data-explorer (h9j2) (example 2)

INTERVENTIONS

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

- 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 Harder to do with kids & pets!
 - HEPA vacuum
 - Walk-off mats
 - Get rid of carpets, old upholstered furniture
- Filter air
 - Portable air cleaners
 - Central air handler (furnace, AC, or ventilation)

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 - HEPA vacuum
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• Filter air

- Portable air cleaners
- Central air handler (furnace, AC, or ventilation)

Indoor Particle Distribution – All Sites



Impact of Portable Air Cleaner

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



Your Indoor Particles vs. Time

Blue: treated zone Orange: untreated zone Red: outdoors Tight, single family home

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

Clean Zone: Portable Air Cleaner

ROCIS Data Explorer Participant Example 6

- Click the link below to see ROCIS team member Don Fugler walk through an example of a participant's home data.
- Plug in the code j1t8 to the Data Explorer (link above) to further examine this participants home. <u>http://rocis.org/rocis-data-explorer-participant-</u> <u>example-6</u>

Indoor Fan Filter 24/7 Impact



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

Added fan/filter here

Portable Air Cleaners Fan/filters

Match the load of contaminants – Volume (air exchange and pollutant)

Issues

- Inadequate run time
 - Role of feedback (low cost monitor)
 - Noise and wintertime discomfort
- Filter replacement
- Cost of air cleaner(s) (purchase \$, kWh, filters)





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- Filter air
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ROCIS Air Handler Inquiry

Purpose:

Explore feasibility of using air handler w/ high MERV filer to reduce particle counts

- >1-minute resolution particle counts for 3+ weeks (0.5+ microns, 2.5+ microns)
- >Gain experience w interventions & impact

Air Handler Intervention



16x25x1 MERV 12



20x25x4 MERV 13

CASE STUDY: Indoor Air Quality Interventions *Chris Guignon, evolveEA*

(by periods of 3 weeks)

Chris's Home 24/7 Air Handler w High MERV Filter

Our 1st ECM handler retrofit!

1) ECM change-out June 2016 Using existing 1" pleated filter

2) Early Sept. 2016 return drop modification w turning vanes & 4", 20"x 25", MERV 13 filter



Chris Guignon, evolveEA



Air Handler 24/7 – MERV 13 Filter

Indoor tracks outdoor Indoor uniform -2 locations Also -2^{nd} fl portable air cleaner

Continuous Mode: **\$12/month Post: 110 watts; 500 CFM**

Dylos small (0.5+ microns) (#/1/100 ft³)



Air Handler – 24/7 w Hi MERV Filter

ROCIS Data Explorer Participant Example 7

- Click the link below to see ROCIS team member Don Fugler walk through an example of a participant's home data.
- Plug in the code w2i9 to the Data Explorer (link above) to further examine this participants home. <u>http://rocis.org/rocis-data-explorer-participant-</u> <u>example-7</u>

Selected ROCIS Air Handler Intervention Homes Pre-Post Median Particle Count



(Case w2i9)

ROCIS Air Handler Inquiry – Biggest "Aha"

Most furnaces tested did not default to lower speed when thermostat was set to "fan on" or "circulation" mode, but rather highest speed.

In some cases, 1000 Watts

if 24 kWh/day = 8,650 kWh/yr. (\$1,038/yr.)

No easy way for homeowner to easily recognize energy & cost impact.

Monitoring can help to reinforce impact of air handler intervention (longer air handler run-time)

More Info on ROCIS Results

Tuesday session this afternoon)

3:30 - 5 PM

High MERV Filters in Central Air Handlers: Opportunities & Challenges

(Brent Stephens, Linda Wigington, Rhett Major)

And Then There is Radon

- AirThings Monitor
- Easy to use & interpret
- Pittsburgh 40% of blgs above 4.0 pCi
- Highest readings new homes w passive systems – easy retrofit
- Significant deployment opportunities!



https://airthings.com/us/



Intervention Summary

- These interventions can be effective; but household & HVAC screening is essential
- The tighter the house/building, the greater the impact of filtration...
- But, the tighter the building, the more critical it is to control indoor sources
- One option shift focus from building exposure to human exposure, e.g., air quality in bedrooms while people are sleeping



Low Cost Monitors

- Huge Potential
 - Making the invisible visible
 - Changing perception
 - Reinforcing behavior & interventions
 - Adoption & continued use
- Ideally within a framework of technical support & peers
- Not known: How much of LCMP impact is due to engagement, not just presence of low cost monitors

Low Cost Monitors - Cons

- False assurance
 - No problem Monitor says AQ is pretty good!
- Monitor limitations not understood
- Cost of monitor maintenance
- Long-term performance & accuracy

Four Conclusions

- 1) Low-Cost monitors can contribute to awareness, behavior change, use of technical interventions, & building capacity of people, communities, & organizations.
- 2) Outdoor particle counts have a significant impact on indoor levels.
- 3) Visualization tools influence how one interprets the data.
- Behavioral & technical interventions can substantially reduce indoor particle levels - Low-cost monitors – can increase likelihood of sustained operation.
Bottom Line!

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

Ideally, improve outdoor air quality!

Develop champions!

Thanks to Phil Johnson & The Heinz Endowments for supporting the ROCIS initiative (Reducing Outdoor Contaminants in Indoor Spaces) **and** Our 250+ Project Participants!

NHPC Conference 4-02-19 Chicago

The ROCIS Team



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RESOURCES

- Health Risks of Indoor Exposure to Particulate Matter -<u>http://www.nationalacademies.org/hmd/Activities/PublicHealth/Health-Risks-</u> <u>Indoor-Exposure-ParticulateMatter.aspx</u>
- IL Institute of Technology (Built Environment Research Group) (papers & presentations) <u>http://built-envi.com/</u>
- >IAQ Scientific Findings Resource Data bank -
- <u>https://iaqscience.lbl.gov/indoor-air-quality-iaq-scientific-findings</u>
- >IAQ Radio <u>https://www.iaqradio.com/</u>
- Smell Pittsburgh <u>https://smellpgh.org</u> (Now, also Smell Your City)
- >ROCIS website <u>http://ROCIS.org</u>
- > Purple Air Map <u>https://www.purpleair.com/gmap</u>
- > EPA Guidelines Air Cleaners & Air Filters in the Home
- <u>https://www.epa.gov/indoor-air-quality-iaq/air-cleaners-and-air-filters-home</u>

Questions?

http://ROCIS.org/

- White papers & presentations
- Access to resources & research results
 - LCMP <u>http://rocis.org/rocis-low-cost-monitoring-project</u>
 - ROCIS Brief Ducted Range Hood (Tom Phillips)
 - <u>http://rocis.org/kitchen-range-hoods</u>
 - Air Handler Inquiry <u>http://rocis.org/air-handler-inquiry</u>
 - ROCIS Data <u>http://rocis.org/rocis-data</u>

- Stay Tuned
 - ROCIS Brief Portable Air Cleaners
 - Video Shorts Telling the Story



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