ROCIS LOW COST MONITORING & INTERVENTIONS: INSIGHTS & IMPLICATIONS

Healthy Buildings Summit 2017: Research to Practice

Nov. 2-4, 2017; Seven Springs, PA

Linda Wigington
Team Leader, ROCIS Initiative
lwigington1@outlook.com
ROCIS (Rock-us) or (Raucous)
Reducing Outdoor Contaminants in Indoor Spaces
WHAT IS ROCIS??

**MISSION**

*Reduce* the impact of *exterior environmental pollution* in southwestern Pennsylvania to *improve healthy* & energy efficient *indoor environments* where we *live, work, & learn*.
Why??

Most of our exposure to outdoor pollution happens in buildings

Conclusions

• Outdoor particle counts have a significant impact on indoor levels

• Low cost monitors can contribute to awareness, behavior change, empowerment & use of technical interventions

• Individual actions & community-level initiatives have the potential to substantially reduce the exposure to particles

• Integrated solutions are needed to enhance health, resilience, energy efficiency, & durability of homes, work places, & schools
Research to Practice
&
Practice to Research

Challenge of Silos
ROCIS LCMP
Low Cost Monitoring Project

Objectives:
1. Understand How to Use Monitors to Empower Occupants/Build Capacity
2. Collect Baseline Data
3. Explore the Impact of Behavioral & Technical Interventions
FOCUS ON PARTICLES

Also referred to as Particulate Matter (PM)
People Most at Risk in the U.S. 
Year-Round Particle Pollution (Annual PM$_{2.5}$)

8$^{th}$ worst city – Pittsburgh$^1$

County level
13 worst – Allegheny County (Pittsburgh)
(12 worst counties are in California or Idaho)

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

Making the Invisible Visible

3 particle counters per home: outside, inside, & roamer

Left: Particle Count 0.5+ um; (Dylos total)
Right: Particle Count 2.5+ um; (Dylos large)
Particles per 1/100 Ft³

NOTE: Scale at right is from manufacturer; not a 3rd party

Dylos 1700
http://www.dylosproducts.com/dc1700.htm
Particles

PM$_{10}$: 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 greater than 0.5 µm in diameter (1/100 of human hair!)
ROCIS – Low Cost Monitoring Project
Not a Regulatory Focus

• Based on count, not mass; 1-min. resolution; 15-min avg.
• Household/bldg. level w/ multiple low-cost monitors
• Cohort of occupants – 3-4 week monitoring period
• Focus on indoor/outdoor comparison
• Proof of concept – exploration of interventions

Precautionary principle – lower the better

Fine & ultra-fine particles could be the vehicle to increase exposure of toxic contaminants such as SVOCs
In first two slides, particle data reflects all of the 0.5 um Dylos data for each site since monitoring began. In the last slide, data is limited to first 10 days compared to most recent 10 days in a subset of homes that showed the biggest change.
Indoor Median & Distribution
137 Participants (Dylos Total 0.5+ um)

More than 10 to 1 difference!
Median: 2/3 Fair; 1/3 Good

Log Scale
Homes – red bars
Workplaces – blue bars
Outdoor Median & Distribution
137 Participants (Dylos Total - 0.5+ um)

½ Poor; ½ Fair

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

Log Scale

Homes – red bars
Workplaces – blue bars
Comparison of Early Vs. Late Particle Counts
First 10 day median compared to last 10 days

Of these 86 sites
65 saw reduction in counts
47 more than 30% reduction
25 more than 50% reduction

Counts – 0.5+ um as measured by the Dylos meter
OUTDOOR IMPACTS INDOOR
Outdoor Data by Cohort - (70 mile spread) - Readings track

ROCIS Low Cost Monitoring Project

Cohort 15 Small 15 Min Average

Log scale

Equipment Error??
Your Indoor Particles vs. Time

Log Scale
Though order of magnitude lower; indoor tracks outdoor
Blue = roamer, sanctuary “clean” zone
What Could You Expect if…
Outdoor Air was Bad All the Time?
Good All the Time?

Dylos (small) ~0.5+

Using online ROCIS Data Explorer
INTERVENTION INSIGHTS

And the Role of Low Cost Monitors
Options to Reduce Particles

- Reduce air exchange from outside
  - Close windows
  - Tighten home or building
- Filter air
  - Portable
  - Central Air handler (furnace, AC, or ventilation)
- Reduce resuspension
- Reduce indoor sources
  - Vent kitchen stove!
  - Use induction cook top
Windows Open? Closed?

Dylos 'Small' Particle Levels

Windows closed here
Fan Filter – Bedroom Window at Night
Impact of open window with/without box fan & filter

Windows open? – inside (green) tracks outdoors (purple line)

Log scale
Dylos total

Outdoors

Bedroom (green)

Red arrow – turned on fan filter in bedroom to bring in filtered outdoor air
Blue arrow – turned off fan filter each morning
Low-Cost Fan/Filter (MERV 13)

- 4” MERV 13 filter ($35) on 20” x 20” box fan (~$20)
- Place within room or in window
- Outstanding issues – filter emissions
- UL-rated fans do have overheat protection
Portable Air Cleaners
Fan/filters

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

ISSUES
• Inadequate run time
• Role of feedback (low cost monitor)
• Noise & wintertime discomfort
• Filter maintenance
• Cost of air cleaner(s)
Impact of Portable Air Cleaner

Your Indoor Particles vs. Time

Sanctuary Zone – Blue (550 sq ft.) Up to 2 air cleaners on – blower setting varies in response to Dylos readings
Log Scale

Outdoor: 422 Roamer
High MERV Filter - Air Handler (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, or performance)?
High MERV Filter - Air Handler (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, or performance)?

No!
NOTE: Hi MERV Filter - Air Handler Inquiry

Context for this work

*SW Pennsylvania typical housing stock*

- Basements
- Mostly gas heat; central AC (oversized)
- Sheet metal ducts in basement
- Supplies & returns to each room

Implications different w/ attic or crawlspace ducts & homes with central returns
High MERV Filter - Air Handler Inquiry

- Developed protocol to screen & verify
- Over 35 air handler systems tested to date
- Adjustment made at time of initial visit – blower speed
- Evaluate opportunity for MERV 13, 24/7 operation

- **Very good reductions in particles when operated 24/7!**
- Minimal impact if air handler operated in “Auto” mode
- Targeted operation (operating at night during highest house occupancy) shows promise

Best performance – w/ air cleaner in bedroom w 24/7 whole house filtration.
High MERV Filter - Air Handler Inquiry

But…Big Issues –

- **Air handler (AHU) energy use** can be high (500 to 1,500 watts)
- High cost of running air handler continuously (@500 to 1,500 watts: $54 - $130/month\(^1\))

- **Ductwork issues** introduce additional problems
  - Leaks, with pressurization or depressurization
  - Air flow
  - Static pressure too high

**Wrong blower speed**: seldom set in field; defaults to high, not low in continuous mode
Elements for 24/7 Operation of AHU

ECM (electronically commutated motor) Blower
Increase control to optimize air flow
Drops electricity use, *but only if static pressure* is low

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 for 24/7:*
1” pleated MERV 11 or 13 filter (equivalent) without performance testing for TESP, air flow, & watt-draw
**Air Handler Inquiry - Intervention**

- **Modified return drop** to reduce static pressure & accommodate bigger filter
- **4” MERV 13 filter** (plus 1 or more specialty filters) all in horizontal location
- **Adjust blower speed** for continuous/longer operation
- **Consider ECM replacement**
Pre & Post – Air Handler Retrofit

Week ending 5-24-2017 vs. 7-31-2017

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

Cost – labor & materials $1,000
Another One – 24/7 High MERV Filtration

PARTICLE LEVELS IN AND AROUND YOUR HOUSE

Roamer2 - Small
Roamer1 - Small
Indoor - Small
Outdoor - Small

0% 25% 50% 75% 100%
Proportion of time

Excellent
Very Good
Good
Fair
Poor
Very Poor

dylosCat

Very Poor
Poor
Fair
Good
Very Good
Excellent
Night-time Air Handler Use

Lower exposure during periods of greatest occupancy
Key Questions - Issues
Window &/or Filtration Operation

- Ambient *air quality varies greatly* over short periods
- How bad is bad? Whose criteria is basis for action? (.5 um Vs. 2.5 um low cost particle monitor)
- How to alert folks re ambient air quality?
- How to provide *feedback* – automatic building control?

- Opportunities for *reductions other than particles*

- *Huge opportunity for new construction / renovation / replacement* (lower cost than upgrading existing installation)
Insight to Date re Interventions?

Proof of concept; can be effective, screening essential

Tighter the house, the greater the impact of filtration

But, tighter the building, the more critical it is to control indoor sources – Comprehensive strategy is needed

Significant potential in homes – address air quality in bedrooms while people are sleeping

Shift focus from building exposure to human exposure?
Conclusions

• Outdoor particle counts have a significant impact on indoor levels

• Low cost monitors can contribute to awareness, behavior change, empowerment, & use of technical interventions

• Individual actions & community-level initiatives have the potential to substantially reduce the exposure to particles

• Integrated solutions are needed to enhance health, resilience, energy efficiency, & durability of homes, work places, & schools
Thanks to Phil Johnson & The Heinz Endowments for support of the ROCIS initiative (Reducing Outdoor Contaminants in Indoor Spaces)

And our 150+ Low Cost Monitoring Project Participants!
The ROCIS Team

Don Fugler
LCMP research
Ottawa, Canada

Kacy McGill
LCMP Coordinator
Pittsburgh, PA

Rhett Major
Air Handler Inquiry
North Huntingdon, PA

Norm Anderson
Advisor
Winthrop, ME

Bill Turner, P.E.
Consultant
Harrison, ME

Yujie Xu
Data
Pittsburgh, PA

Rob Busher
Air Quality Fellow
Pittsburgh, PA

Greg Fanslow
LCMP Data Analysis
Burlington, VT

Tom Phillips
Range Hood Brief
Davis, CA

Linda Wigington
Team Leader
Waynesburg, PA
Questions?

- White papers
- Access to resources & research results
- Stay Tuned

ROCIS Brief - Range Hood Venting (Tom Phillips)
ROCIS Brief - Portable Air Cleaners
Video Shorts - Telling the Story

http://ROCIS.org/

Linda Wigington
Project Lead, ROCIS Initiative
724-852-3085
lwigington1@outlook.com
DESCRIPTION: ROCIS Low Cost Particle Monitoring & Interventions: Insights & Implications

For 2 years, ROCIS (http://rocis.org/) has engaged over 150 professionals and homeowners in monitoring their homes (and a few workplaces) in southwestern PA. Emphasis has been on monitoring particles (0.5+ microns) inside and outside to better understand the impact of outdoor air pollution on IAQ. While typical participation was for a 3-week period, 25+ sites have tested interventions and monitored for longer periods. Explore what we have learned in an effort to understand the 10 to 1 difference in median particle counts from one site to another.
ROCIS LCMP Online Tool Demo

- https://bluetree.shinyapps.io/lcmpDemo/
- https://bluetree.shinyapps.io/stackbarexplorer/
- b8z3
- q4y9
Resources: Filtration & Air Cleaners

Available from:
U.S. EPA's web site
http://www.epa.gov/iaq/pubs/residair.html

Residential Air Cleaners
Resources: Low Cost Monitoring

- EPA’s Air Sensor Toolbox for Citizen Scientists
  https://www.epa.gov/air-sensor-toolbox

- Data interpretation guidelines
- Education & outreach
- Low cost sensor performance information
TOPICS

- Building Ventilation
- Indoor Dampness
- Indoor Volatile Organic Compounds
- Human Performance and Productivity
- Benefits of Improving Indoor Environmental Quality
- Air Cleaning Effects on Health and Perceived Air Quality
- Climate Change, Indoor Environmental Quality, & Health

https://iaqscience.lbl.gov/
Reducing Outdoor Contaminants in Indoor Spaces (ROCIS) Website

http://ROCIS.org/

- White papers
- Access to resources & research results

- Stay Tuned

ROCIS Brief - Range Hood Venting (Tom Phillips)
ROCIS Brief - Portable Air Cleaners
Video Shorts - Telling the Story
Low Cost Monitoring Kit

(3) Dylos **Particle** Counter DC1700
(1) Speck **Particle** Counter (optional)
(2) Corentium **Radon** [https://airthings.com/us/](https://airthings.com/us/)
(2) **CO$_2$** TIM12 Datalogging Meter [www.co2meter.com](http://www.co2meter.com)

Our cost - ~ $1,850 - $2,000/kit
Quantity discounts, some donated equipment
No cost to participants
Two Examples

When Outside Better - Inside Better

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

Date (by periods of 1 days)
Stacked Bar - Outdoor Impacts Indoor

Online ROCIS LCMP Stacked Bar
Window Operation

• Single biggest factor affecting IAQ when outdoor counts are high

• 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)
Portable Air Cleaners – Fan/Filters

dylosCat

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

[Graph showing air quality data for different periods and locations]
Purchased Air Cleaner or DIY Fan/Filter

DIY Fan/filter (with $30 4” filter) often drops particles faster – *but only addresses particles*

**Initial cost**
- Portable Air Cleaners – $200 - $800
- Fan/Filter – $50

**Operational cost (for both)**
- Electricity
- Cost of replacement filters
# MERV Filter Rating – Particle Size

<table>
<thead>
<tr>
<th>MERV</th>
<th>Min. particle size</th>
<th>Typical controlled contaminant</th>
</tr>
</thead>
<tbody>
<tr>
<td>1–4</td>
<td>&gt; 10.0 μm</td>
<td>Pollen, dust mites, cockroach debris, sanding dust, spray paint dust, textile fibers, carpet fibers</td>
</tr>
<tr>
<td>5–8[^1]</td>
<td>10.0–3.0 μm</td>
<td>Mold, spores, dust mite debris, cat and dog dander, hair spray, fabric protector, dusting aids, pudding mix</td>
</tr>
<tr>
<td>9–12</td>
<td>3.0–1.0 μm</td>
<td>Legionella, Humidifier dust, Lead dust, Milled flour, Auto emission particulates, Nebulizer droplets</td>
</tr>
<tr>
<td>13–16</td>
<td>1.0–0.3 μm</td>
<td>Bacteria, droplet nuclei (sneeze), cooking oil, most smoke and insecticide dust, most face powder, most paint pigments</td>
</tr>
</tbody>
</table>

24/7 Air Handler w High MERV Filter

Our 1st air ECM handler retrofit!

ECM change-out

In June 2016 using existing 1” pleated filter

The return drop modification with larger, fatter MERV 13 filter was early Sept. 2016

CTG

(by periods of 3 weeks)
24/7 Air Handler MERV 13 Filter

Already had electronic air cleaner in place.

At diagnostic visit adjusted settings.

Now running 24/7 (lower speed; lower cost)
Mitigation Strategies: Deposition - Removal Treatment…

Better cleaning & reducing track-in dust
Carpets
Hard surfaces – *mopping vs. cleaning!*

Consider reservoirs
*building upgrades
*may disturb*

Lots of anecdotal information; LCMP have not attempted to quantify
Attention to Cooking
Portable Induction Stove Top

Portable, double-burner induction stove top unit ~$275.
(Single burner, lower quality units <$100)

Care when cooking
Cover the pan!
Implications – Low Cost Monitoring

Aha – particle monitors make the invisible visible –

“Wow! Look what happens when we fry bacon!, or burn the toast”

“Air quality in the region is worse than I thought”

Often difficult to interpret raw indoor readings

Monitors can reinforce behavior change

Monitors can inform occupants to take an action
Stay Tuned

- Easier/reliable systems to track behavior & house conditions (apps)
- More analysis (macro & case study)
- Open source data
- Draft guidance documents - interventions
- Tell the story
- Hopefully - exploration of integrated solutions – e.g. ventilation options to address filtration & dehumidification

- [www.ROCIS.org](http://www.ROCIS.org)