Protecting Homes, Schools, and Commercial Buildings From Outdoor Pollutants

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Creating Healthy Places: Protecting Indoor Spaces from Outdoor Pollution

December 4-5, 2014 Pittsburgh, PA

Reducing Outdoor Contaminants in Indoor Spaces (ROCIS)

What's the problem?

- Indoor air pollution in buildings is usually blamed on indoor pollutant sources
- Outdoor air is the "clean" air used for ventilation
  - It flushes contaminants out of buildings
- What if the outdoor air carries a high pollutant load?
  - How do we deal with that?

Why is this an issue now?

- There are traditional outdoor pollutant sources, which vary over time and by location
  - e.g. traffic-related pollutants, wild fires, wood stoves, power plant emissions, radon
  - More research has shown that much of our exposure and our body's dose of outdoor PM occurs in buildings
- There are new and growing outdoor pollutant risks
  - Fracking, fuel transport, refining
  - Freight transport
  - Climate change impacts such as heat waves, wildfires, mold, pollen, outdoor air pollution, and flooding

Fracking Operation at Marcellus Shale Well

Source: Wikipedia, 2014. http://en.wikipedia.org/wiki/Hydraulic_fracturing_in_the_United_States

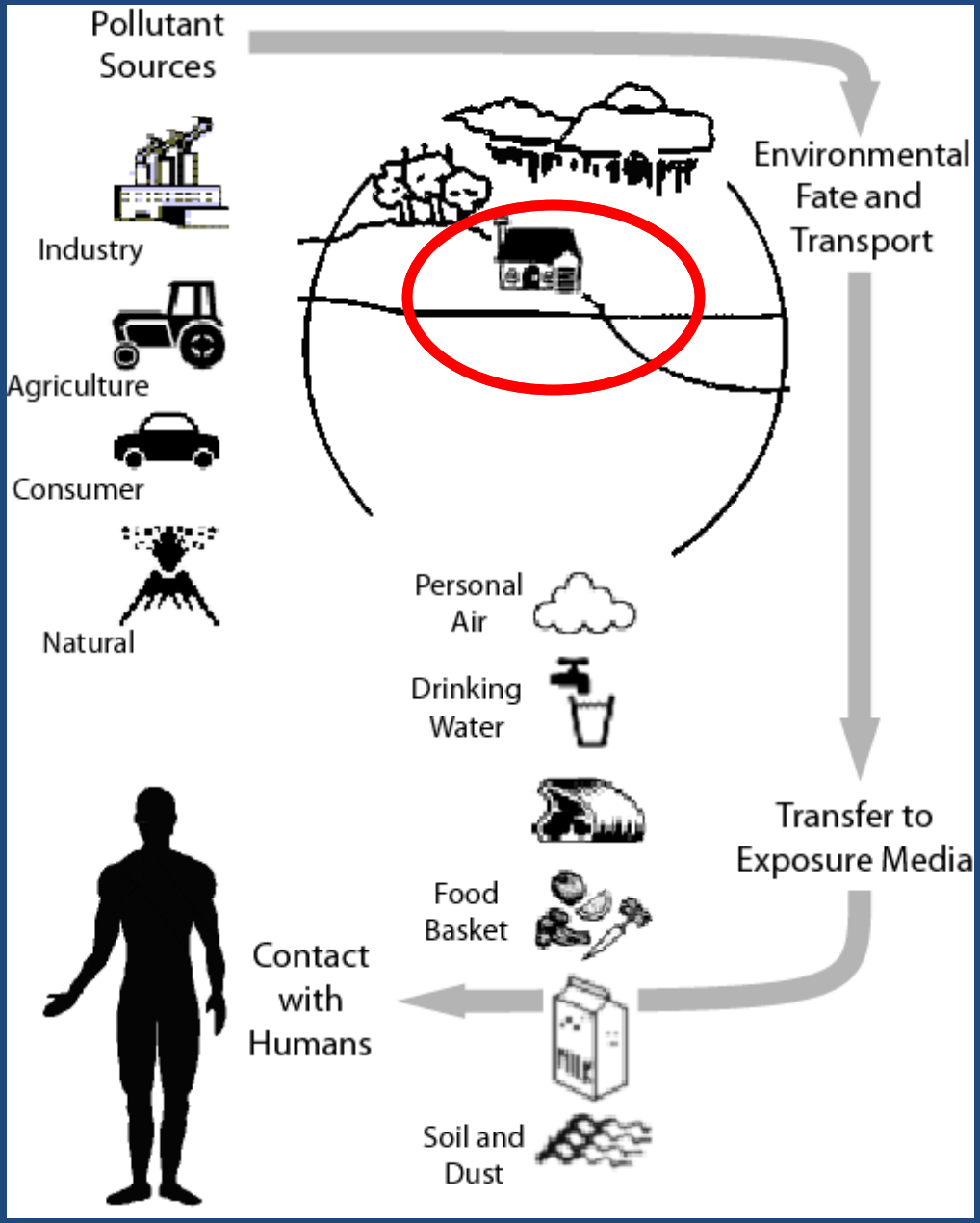
Pollutants of concern

- Mostly airborne pollutants
  - Some come in with track-in dust or in water
- Most cause respiratory problems, but also risks of fatal poisoning, cardiovascular effects, cancer, neurological effects, allergy symptoms, etc.
- Full list of pollutants available in White Papers

Pollutants of concern

- Respirable particles, aka PM_{10}, $PM_{2.5}$, ultrafines (UFP) from combustion, soil, biological decay, chemical reactions
- Heavy metals (lead, arsenic, mercury, etc.)
- Volatile organic compounds (VOC)
- Semi-volatile organic compounds (SVOC)
- Odors
- Explosive gases (e.g. methane)
- Ozone and oxides of nitrogen (usually traffic-related smog)
- Radioactive gases (e.g. radon)

Environmental Pollution: Fate, Transport, Exposure, and Dose



Source: Modified from ATDSR,
Public Health Assessment Guidance Manual (2005 Update.
http://www.atsdr.cdc.gov/hac/PHAManual/ch6.html.

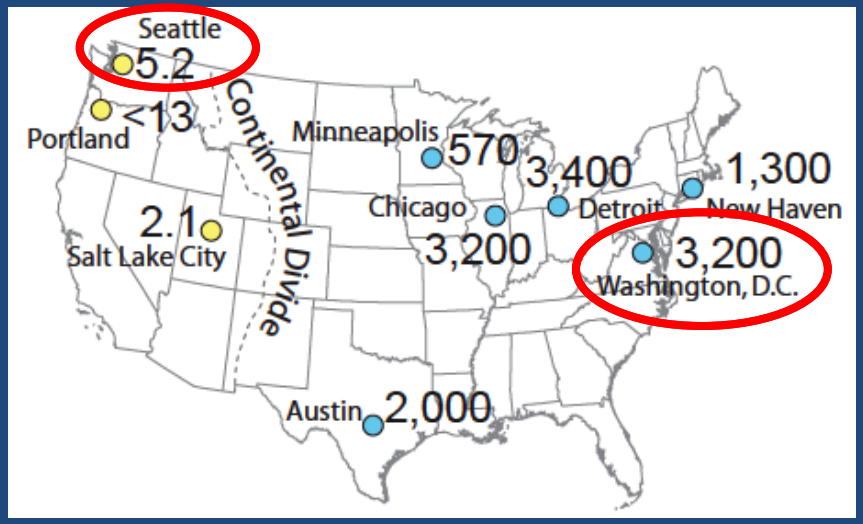
Can you tell when you have a problem with outdoor pollutants?

- Visual and odor inspections of building exterior and local area to locate sources
- Daily diary of symptoms, local activities
- Mapping with online tools and consultation with state and local officials
- Measurement can be helpful but sometimes difficult
  - Some pollutants (like CO) have consumer-level detection devices available
  - More affordable and portable devices are in development
  - Some pollutants require expensive test equipment and trained personnel

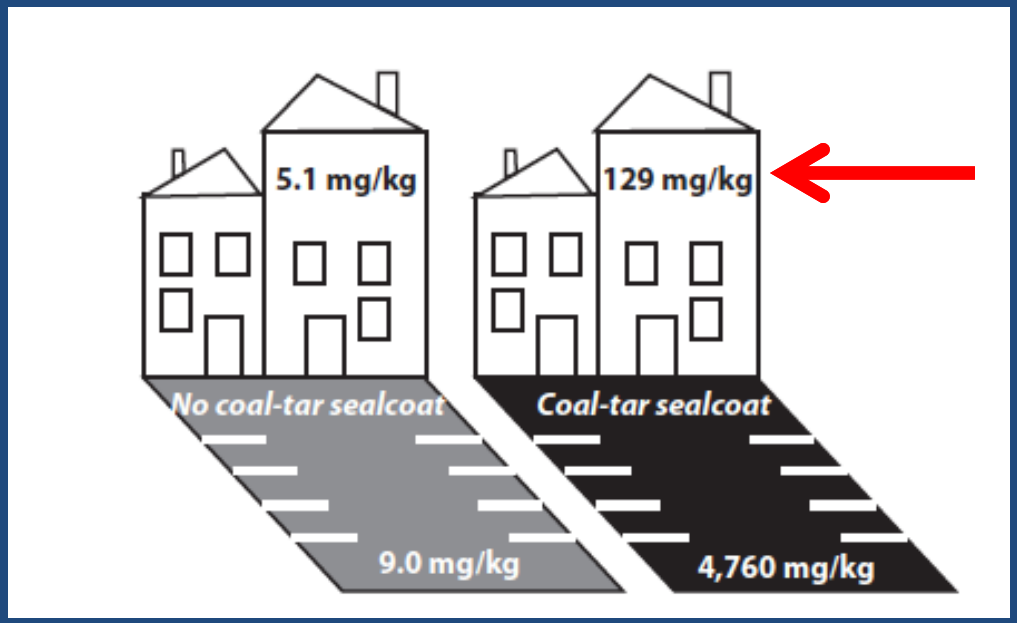
How do pollutants get into buildings?

- Mechanical ventilation systems with air intakes
- Unintentional air infiltration (air leakage)
  - Through building envelope and air ducts
  - Through adjacent spaces (garages, crawl spaces, apartments, attics, etc.)
- Intentional air infiltration by open windows & doors
- Soil gases through foundation
- Track-in dust (humans, pets)
- Water systems (mostly volatile pollutants)

Track-in Source:
PAHs from Coal-Tar Pavement Sealant



Concentrations of 12 PAHs in dust from parking lots with coal-tar based sealant (mg/kg)



Higher PAH levels in parking lot and apartment dust when parking lot has coal-tar based sealant

Direct contact on outdoor play surfaces

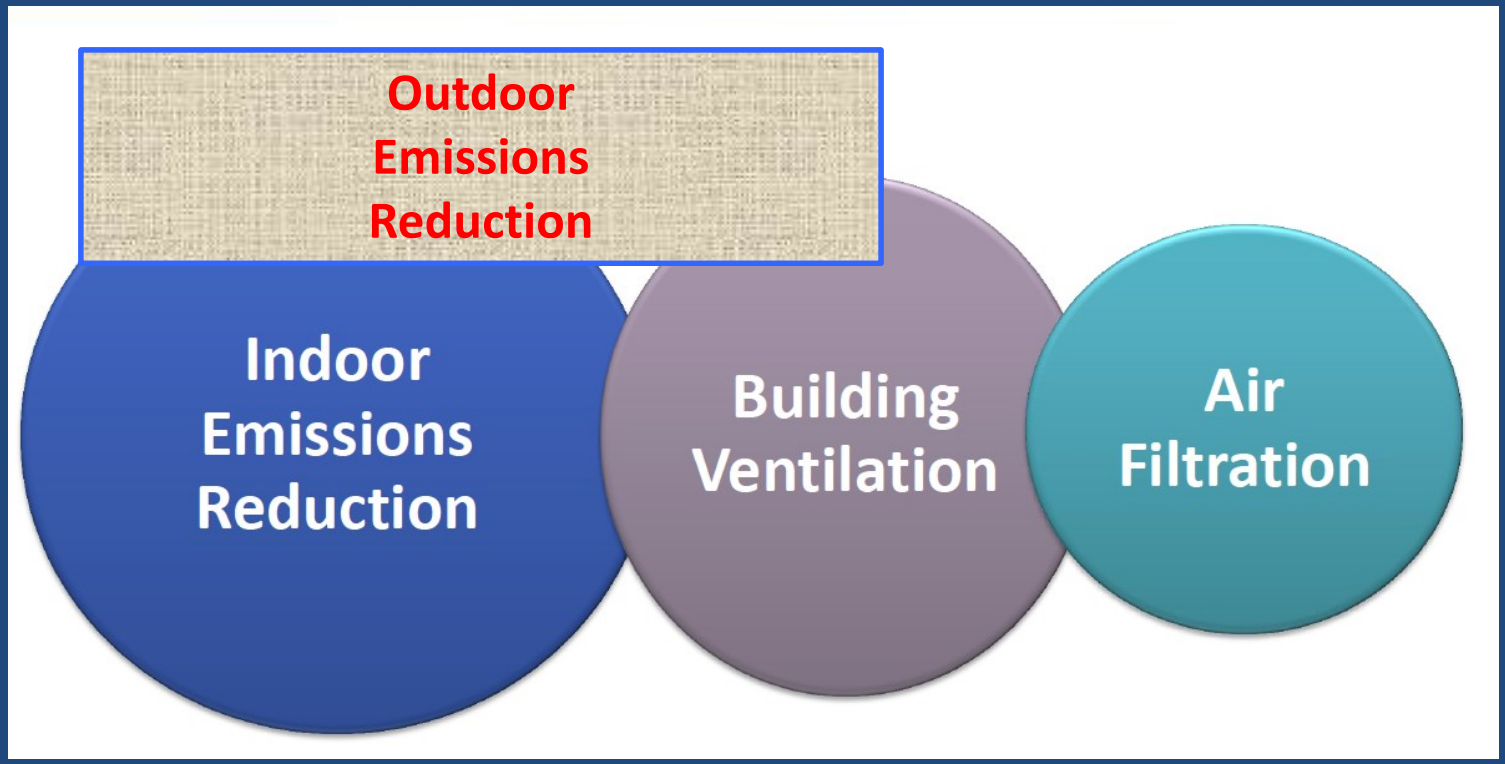
USGS, 2011. Coal-Tar-Based Pavement Sealcoat, Polycyclic Aromatic Hydrocarbons (PAHs), and Environmental Health. Fact Sheet 2011–3010. http://pubs.usgs.gov/fs/2011/3010/pdf/fs2011-3010.pdf.

Stopping pollutant entry

- Those are the entry points
- How do we prevent that entry or mitigate it?

Effectiveness of Mitigation Strategies: *IEQ Perspective*

More Effective and Reliable



More Energy and Maintenance

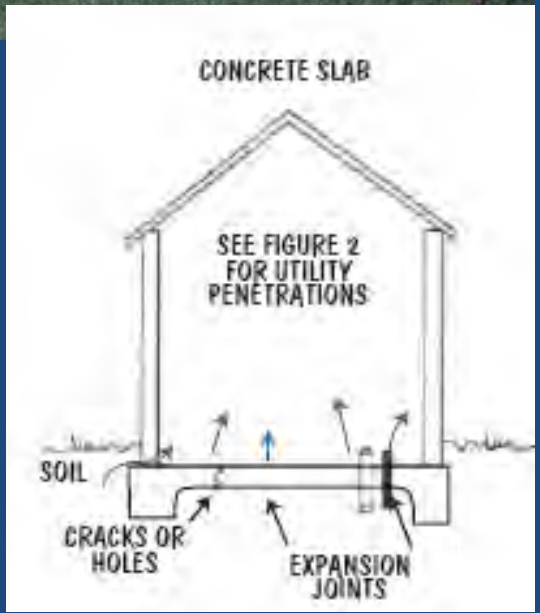
Mitigation Strategies:
Source Control and Ventilation

- Source reduction or minimization
  - Building setback
  - Air intake location and sanitation

- Air sealing
  - Building to outside
  - Building and crawlspace to soil
  - Building to garage & other spaces

Mitigation Strategies:
Source Control and Ventilation (contd.)

- Timing of ventilation
- Building pressurization & filtration
- Soil gas exclusion



Mitigation Strategies: *Removal Treatment*

- Filtering incoming air
  - Filtering recirculating or room air reduces pollutants too
- Better cleaning and reducing track-in dust
- Reducing water-borne pollutants

Comparison of Mitigation Strategies: *Source Control and Ventilation*

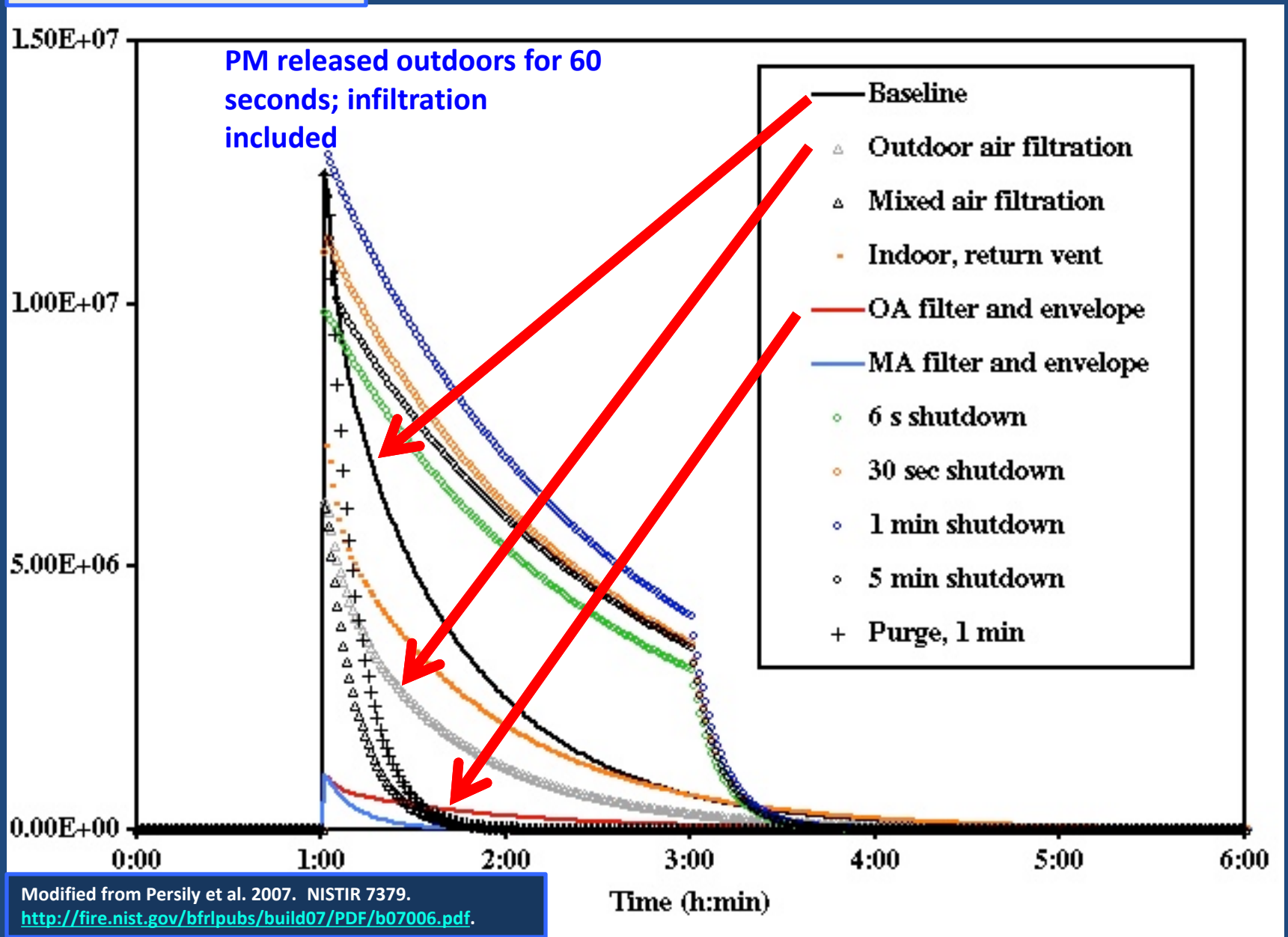
Mitigation strategy	Potential effectiveness	Cost *	Degree of occupant interaction required	Maturity of technology (readily available?)
Setback of building	High	Varies	Low	High
Air intake location	High	Varies	Low	High
Air sealing building and HVAC	High	Varies	Low	High
Timing of ventilation	High	Low	High	Low
Building pressurization and supply air filtration	High	Medium	Medium	Low
Soil gas exclusion	High	Medium	Low	High

* Initial cost can vary, depending on the building. Energy savings can make some strategies cost-effective, depending on the building and climate.

Comparison of Mitigation Strategies: *Removal Treatment*

Mitigation strategy	Potential effectiveness	Cost	Degree of occupant interaction required	Maturity of technology (readily available?)
Filtration of outdoor air and/or indoor air	Medium (high at portable filter; medium in rest of building)	Medium	High (requires inspection, replacement, need to accept noise)	High (for particle reduction)
Cleaning and reducing track-in	Medium	Low	High	High
Water treatment for gaseous pollutants	Medium to high	High	Medium	High

Modeled PM Exposure: *2-Story Office Building*

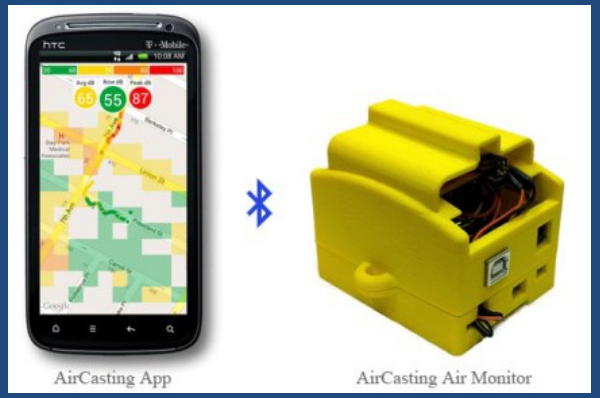


Modified from Persily et al. 2007. NISTIR 7379.
http://fire.nist.gov/bfrlpubs/build07/PDF/b07006.pdf.

Emerging Technology

- Low-cost, portable sensors
  - Personal, micro-environment, and mobile monitoring
  - Networked, web-based
- Sensor packages
  - Pollutants, temperature, RH
  - Location, traffic, noise, and meteorology
- Community-based Citizen Science is growing

*CAir Clip sensors: NO_2 / O_3 , H_2S, NH_3 **

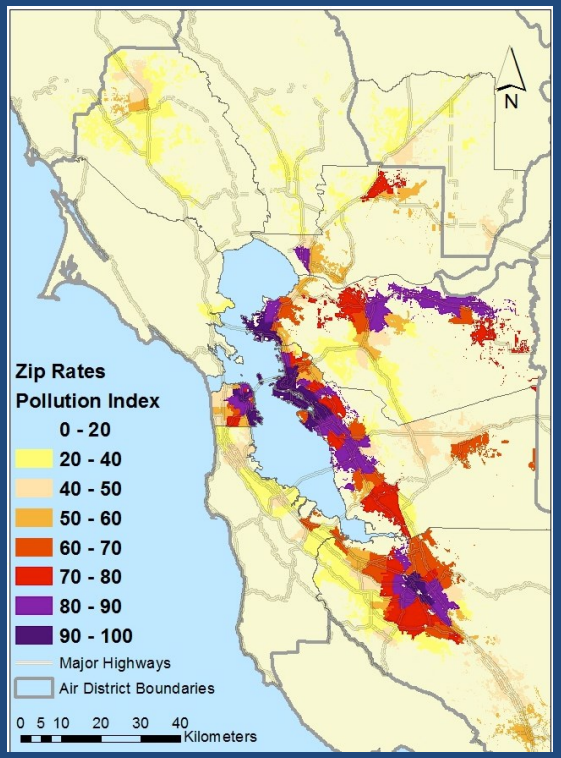


*Citizen Science monitor and app **

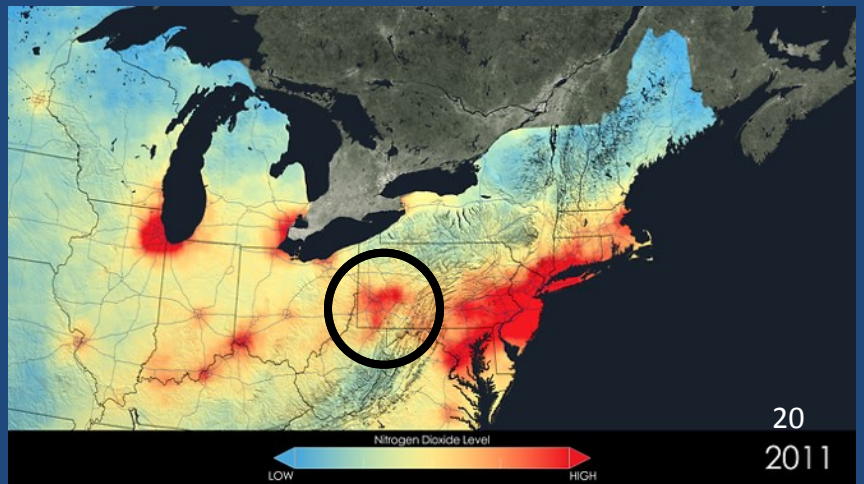
* EPA, 2014. Citizen Science Opportunities for Monitoring Air Quality. http://www.epa.gov/research/priorities/docs/citizen-science-fact-sheet.pdf.

Emerging Technology (contd.)

- Leak detectors, passive monitors, fence line monitors, urban networks
- Mapping local air quality and vulnerable populations
- Satellite measurements of air pollution



Vulnerability to cumulative pollution impacts, San Francisco Bay Area AQMD, 2014



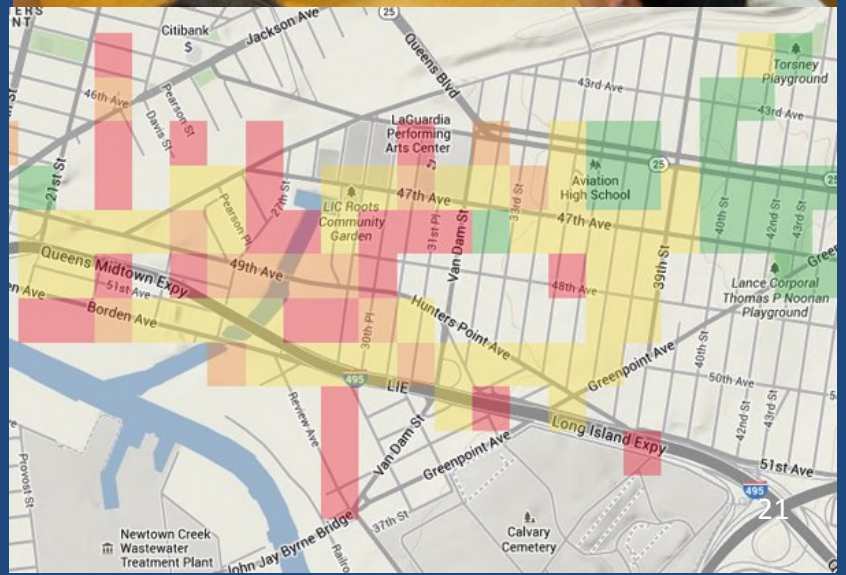
NASA. NO_2 image, 2011

Top image:
http://www.baaqmd.gov/~/media/Files/Planning%20and%20Research/CARE%20Program/Documents/ImpactCommunities_2_Methodology.ashx?la=en

High School Students Build PM Monitors: Queens, NY

- Open source design
  - PM, noise, temperature, & humidity
  - Help from local colleges and historian
  - Parts cost < $120

- Monitored and mapped PM, etc.
  - AirCasting web-based platform
  - Identified hot spots (tentative)



Source: Newtown Creek Alliance, 2014.
http://www.newtowncreekalliance.org/community-health/aircasting/

Conclusions

- Several mitigation strategies are available
  - Depending on the building, pollutant sources, and pathways
  - A combination of strategies often works best
  - Data on the effects on indoor pollution are sparse, especially long-term
- To be successful, any equipment or procedure requires:
  - Quality assurance
  - Training
  - Maintenance
  - Persistence, durability

Conclusions (contd.)

- Monitoring of pollutants and air pressures *may* be needed
  - If required for regulatory compliance
  - Inspection and mapping will identify many outdoor sources and paths
  - Assess mitigation effectiveness, and “do no harm” from mitigation
  - Track indoor and outdoor conditions
  - Liability from monitoring is not an issue if proactive actions are taken and best practices are followed
- Further R&D needed (see White Papers and references)

Recommendations: Short- and Long-Term Strategies

- Implement and improve best practices
  - Commission HVAC and filtration systems
  - Include outdoor mitigation measures
  - Focus on vulnerable populations
- Build the evidence base
  - Research and Demonstration; case studies
  - Share data and lessons learned
- Build a better toolbox
- Stress awareness and training at all levels
- Take a seat at the table in health, energy, and planning decisions

Many Thanks to the Team

- Linda Wigington
- Norman Anderson
- Karyn Butts
- Phil Johnson
- Reviewers

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BONUS SLIDES

Revisions to Commercial White Paper

- Executive Summary added
- Summary, Recommendations, and Information appendix expanded
- Mitigation Strategies
  - Added more case studies
  - Added cost-effectiveness results
  - Expanded houseplant discussion
- Methods of pollutant detection
  - Added community-based examples
  - Added IAQ sensor test study links
  - Added PA and mapping examples
  - Expanded liability discussion

When Is Air Sealing of a Commercial Building Worthwhile ?

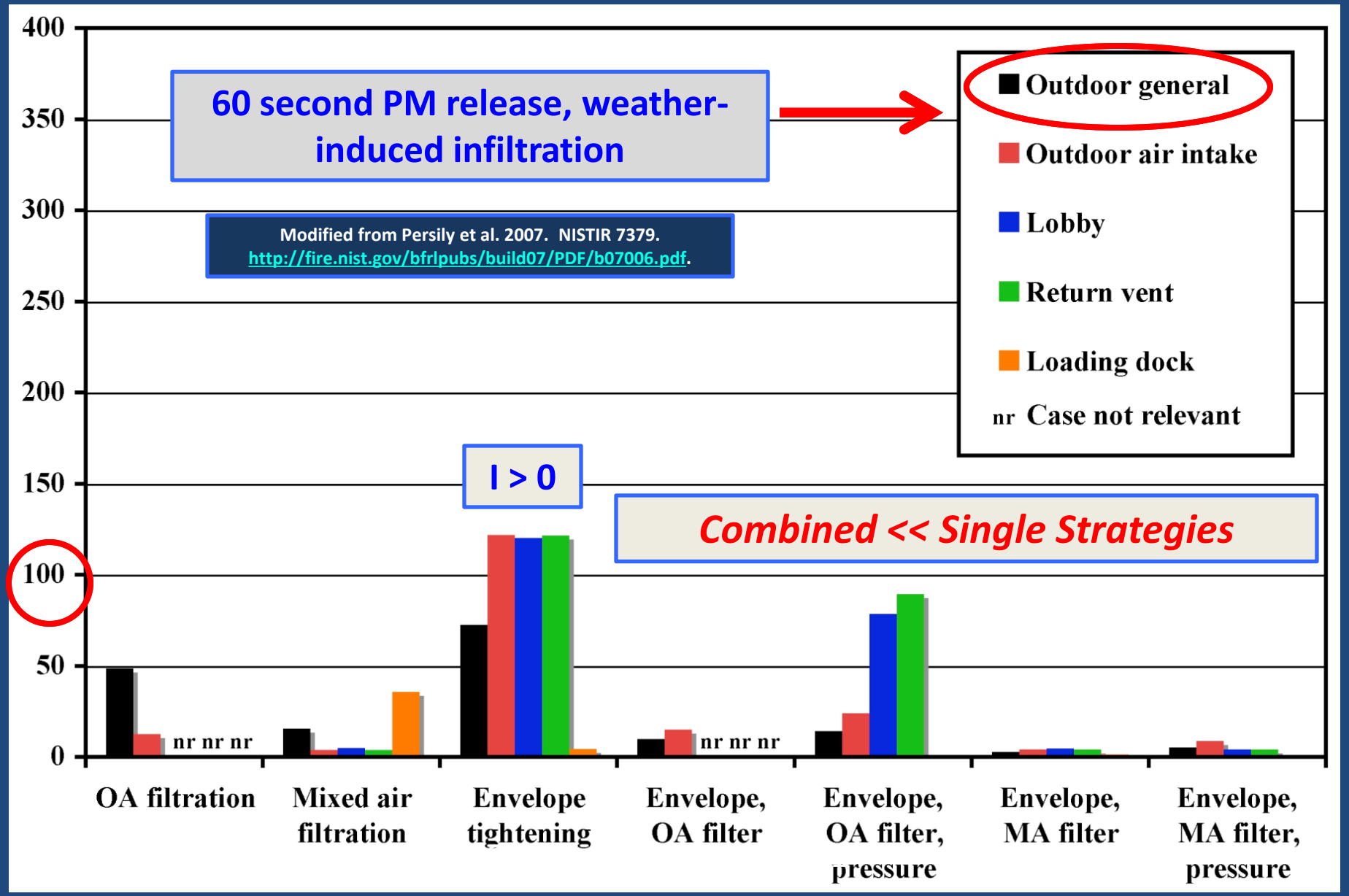
- You can see out the envelope gaps & leak is accessible
- Taller (5+ stories) in open terrain
- Reported problem that is likely to be caused by air leakage
- You live in portion of US that hasn't had to worry about infiltration

Other Opportunities

- Older/leaky dampers (cost?)
- Building pressure control

Source: Bohac, D., 2014. Webinar: Energy Saving From Sealing Large Buildings. Energy Design *Conference* & Expo, Duluth, MN, February 25. http://www.slideshare.net/mnceeInEx/bohac-lrg-bldg-air-sealing-energy-design-conf-v2

Modeled PM Exposure:
2-Story Office Building

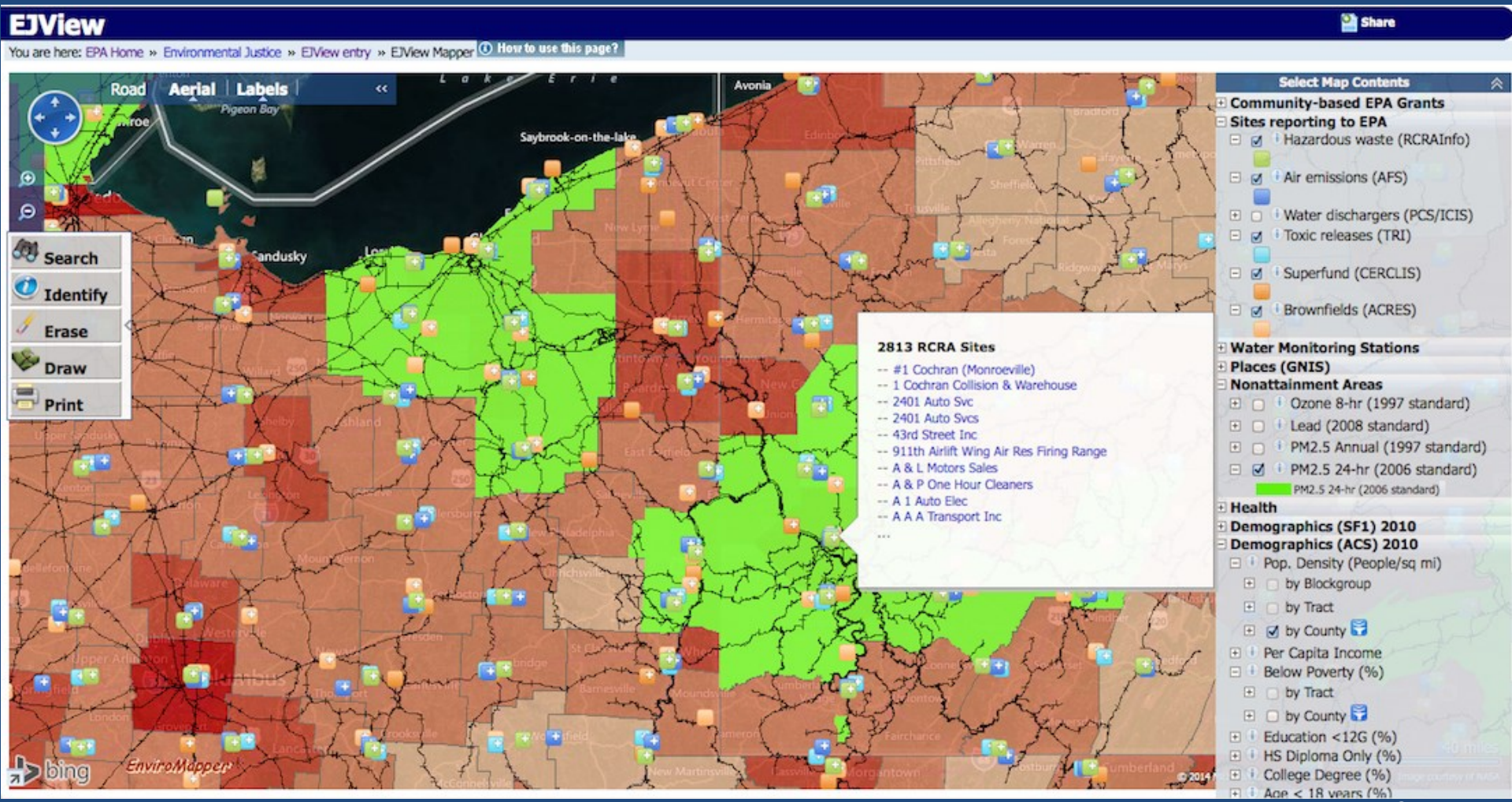


Pollution, Population, and Health Risk Mapping:
EJ View by EPA, Pittsburgh Region

Flags = air emission and waste sites

Brown = Population Density

Green = PM2.5 hourly, non-attainment



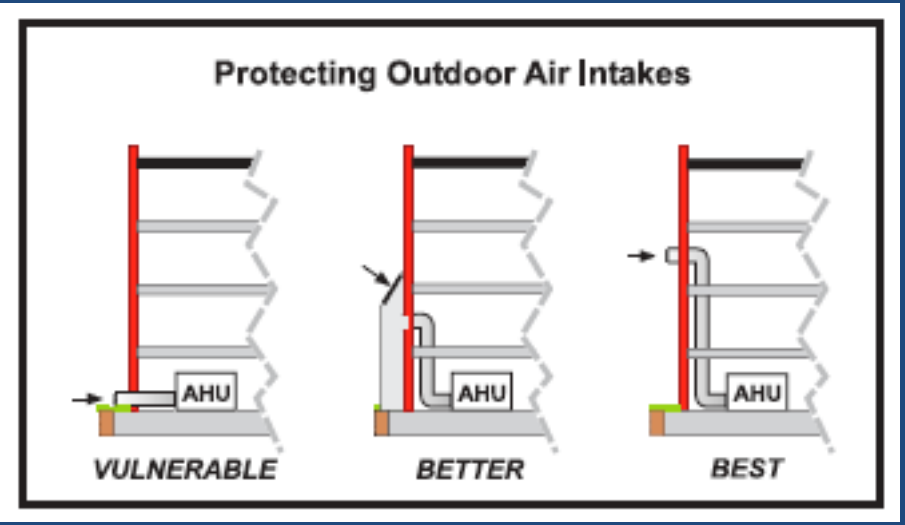
Source: EPA, 2014. EJ View, Allegheny Co., PA.
http://epamap14.epa.gov/ejmap/ejmap.aspx?wherestr=Allegheny%20County%2CPA

What are other sources and pollutant pathways, *especially in Schools and Commercial Buildings ?*

- Nearby outdoor sources
  - Idling motor vehicles
  - Roads and parking
  - Tobacco smoke
  - Ag pesticide spray
- Stack effect is stronger in taller buildings
- More penetrations in the envelope
  - Elevator shafts
  - Utility connections
  - Loading docks

Pollutant sources and pathways (cont.)

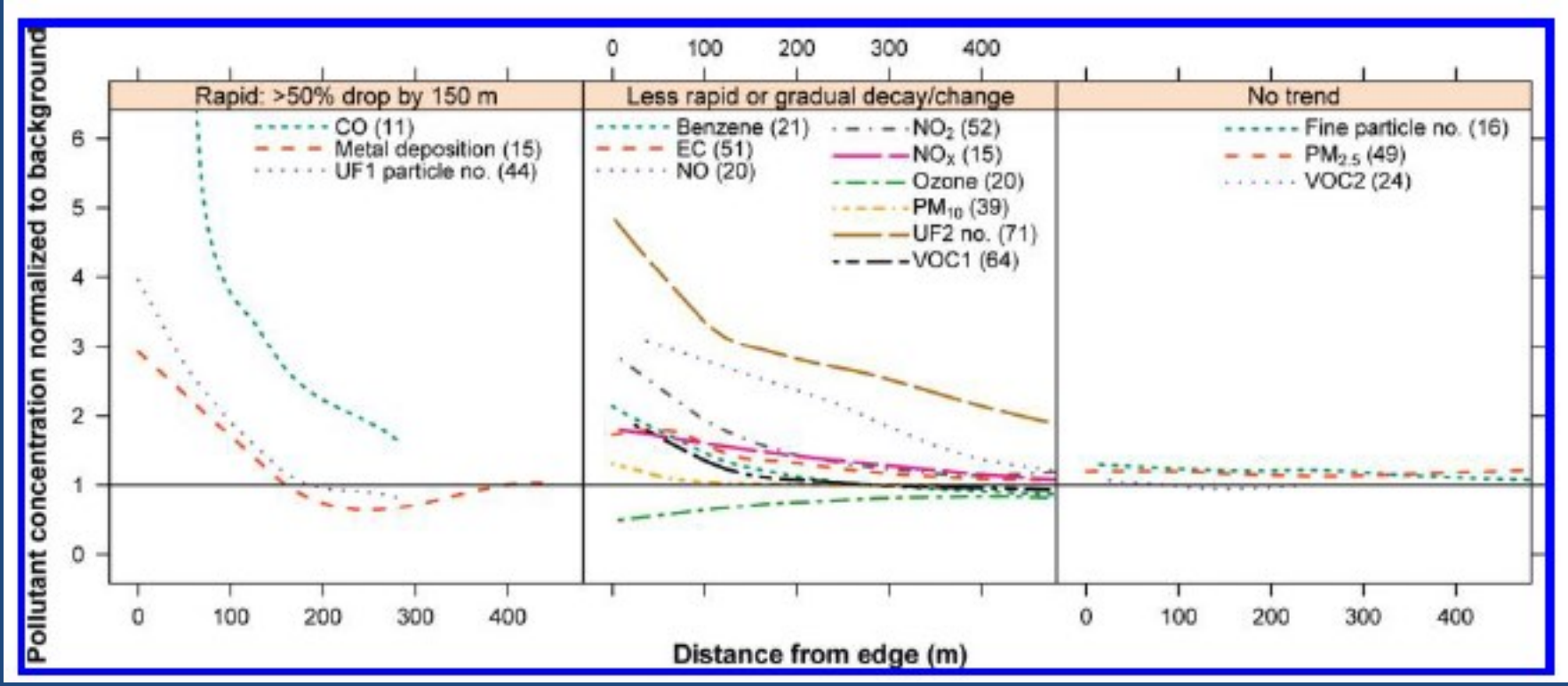
- Air intake location
  - Cooling towers (Legionella)
  - Exhaust vents and flues
  - Height from ground
  - Security issues



HVAC Air intake Options for improved security (NIOSH, 2002)

- Air intake contamination
  - Insects, bird feces, debris, moisture
- Adjacent businesses, apartments
- Sewer lines
  - Sewer gas
  - Chlorinated VOCs

Outdoor Air Pollution Near Roads



- **Meta-analysis: normalized results from several short-term studies (n)**
- **3 groups of decay rates:**
  1) several pollutants decayed rapidly within 100-150 m of road
  2) some more gradually
  3) some not at all (fine PM number, $PM_{2.5}$)
- **Range of distances to reach background level: 161 - 910 m**

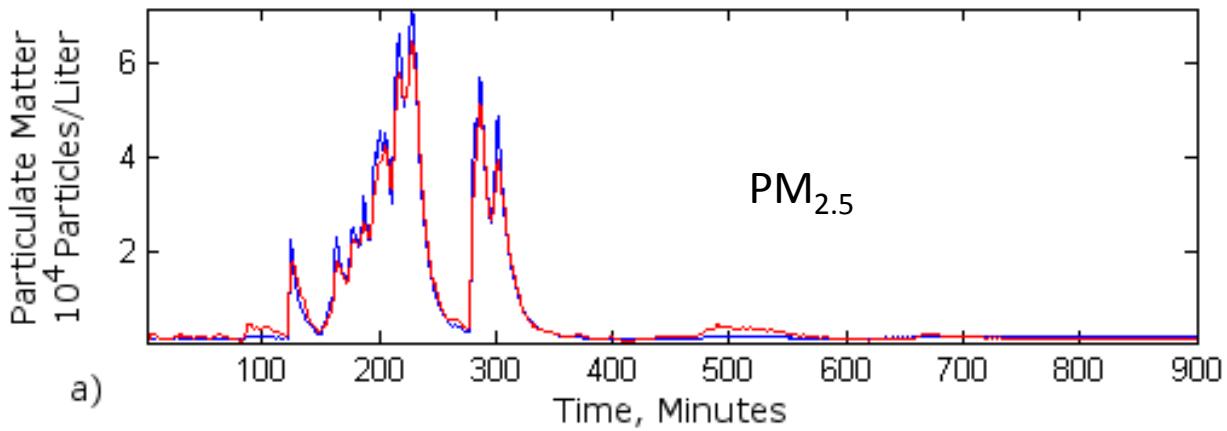
Karner et al., 2010. Environ. Sci. Technol. 2010, 44, 5334–5344. DOI: 10.1021/es100008x.

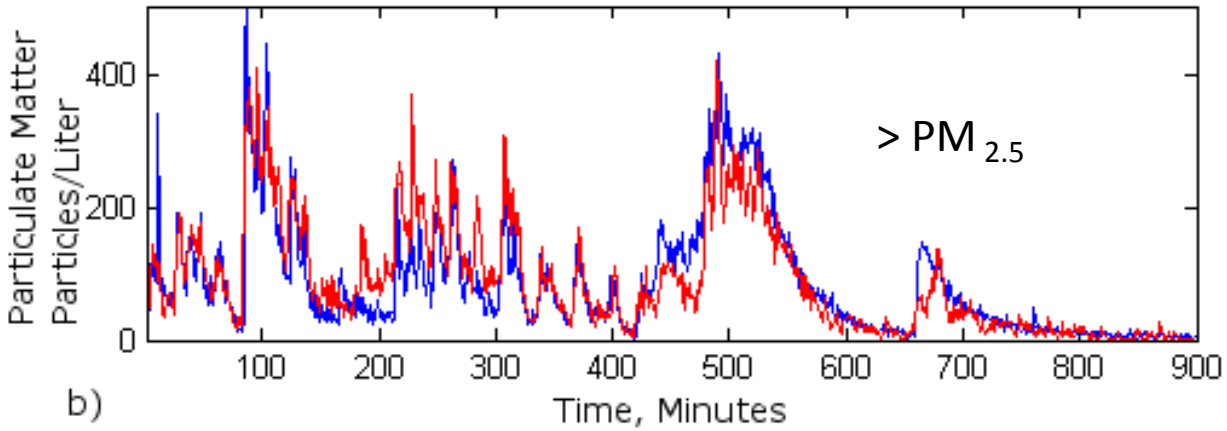
20+ Citizen Observatories (COs) in the EU

- 8 COs for outdoor air quality in cities
- Up to 10 COs for indoor air quality in schools
- 4 COs for personal comfort in public spaces
- 9 cities: Barcelona, Belgrade, Edinburgh, Haifa, Ljubljana, Oslo, Ostrava, Vienna and Vitoria

Source: Citi-Sense, EU Projects, 2014.
http://www.citi-sense.eu/Portals/106/Documents/Dissemination%20material/CITI-SENSE_information_update_7.pdf

Indoor PM Counter vs. Commercial PM Counter





IHAQ Particle Counter

Commercial Particle Counter

Source: Hall et al., 2012. http://coen.boisestate.edu/ece/in-home-air-quality-monitor/.