Air Monitoring: Are Current Strategies Protecting Health?

Marilyn V. Howarth, MD, FACOEM

Adjunct Associate Professor of Emergency Medicine and Systems Pharmacology and Translational Therapeutics

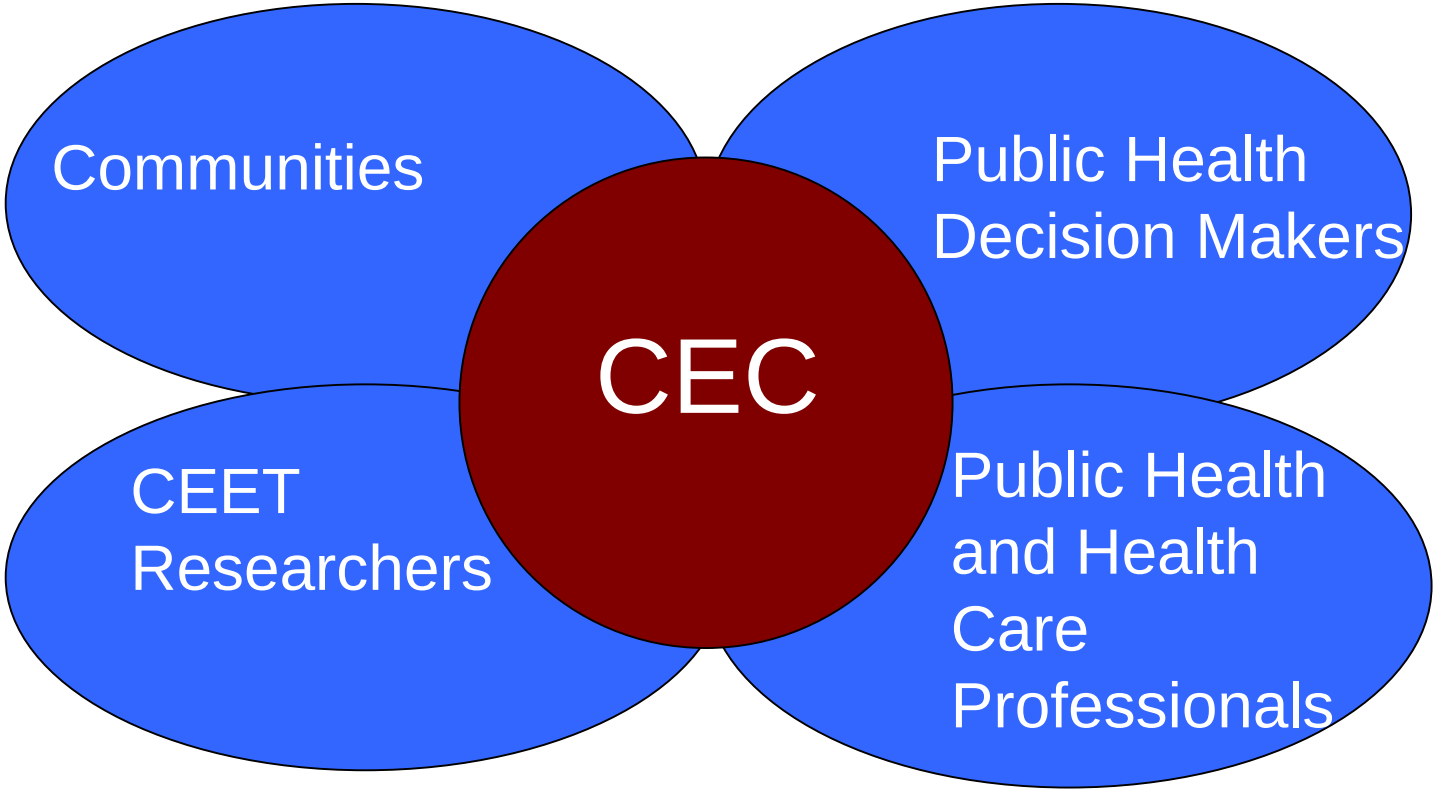
Director, Community Engagement Core

23 Environmental Health Core Centers Nationwide

Baylor College of Medicine
Columbia University Health Sciences
Emory University
Harvard University
Icahn SOM- Mount Sinai
Massachusetts Institute of Technology
New York University School of Medicine
North Carolina State U.
Rutgers University EOHSI
Texas A&M
U. of Arizona
U. Of California, Davis
U. Of Chicago
U. of Cincinnati
U. of Iowa
U. Of Kentucky
U. of Michigan at Ann Arbor
U. of North Carolina Chapel Hill
U. of Pennsylvania
U. of Rochester
U. of Southern California
U. Of Washington
Wayne State U.

UPENN only Center in EPA Region 3

Community Engagement Core (CEC) Promotes Relationships and Facilitates Action Among Stakeholders

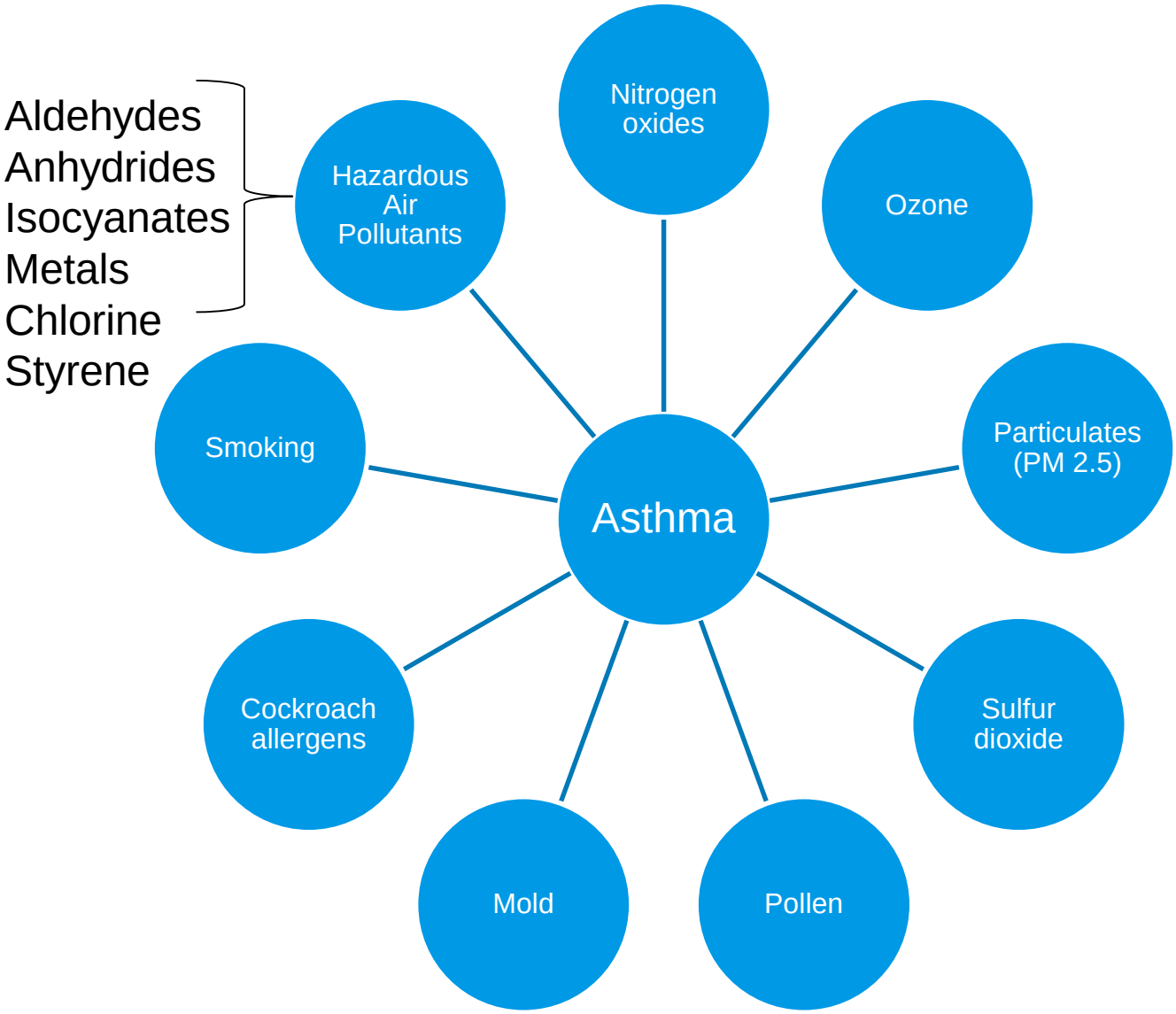


Health Effects from Environmental Exposures

- Asthma
- Lung Disease
- Cardiovascular Disease
- Autism
- Breast Cancer
- Cancer
- Lupus
- Parkinson's Disease
- Neurologic Disorders
- Reproductive Impacts

Cumulative Effects of Wind and Water

Cumulative Effects of Environmental Exposure



Case Study

- **Andre is a 6 year old boy who lives in Philadelphia. He has asthma and allergies to dogs and pollen. Andre caught a cold from a friend at school. He had a cough when he visited another friend who had a dog. He had some wheezing and his parents gave him his inhaler. He felt better and went to school. Then, there was an orange air quality day and he went out for recess.**

Asthma in Children

- **Between 1980 and 2018 the prevalence of asthmatic children in the USA increased from 2.3 million to 6.1 million**

US 8%

PA 10%
CT 13%
NY 9%

MA 16%
DC 11%

Pittsburgh 22%
Philadelphia 23%

Asthma and Air Pollution

- **Air pollution has been associated with:**

- **Increased bronchial hyper-responsiveness**
- **Increased airway inflammation**
- **Decreased lung function**
- **Increased hospital admissions and ER visits**
- **Priming of the airways to allergic responses**

- **(Molfino, Lancet, 1991; Peden, AJRCCM, 1995; Patel & Miller Curr Opin Peds 2009;21:235-242)**

Inhaled Particulates

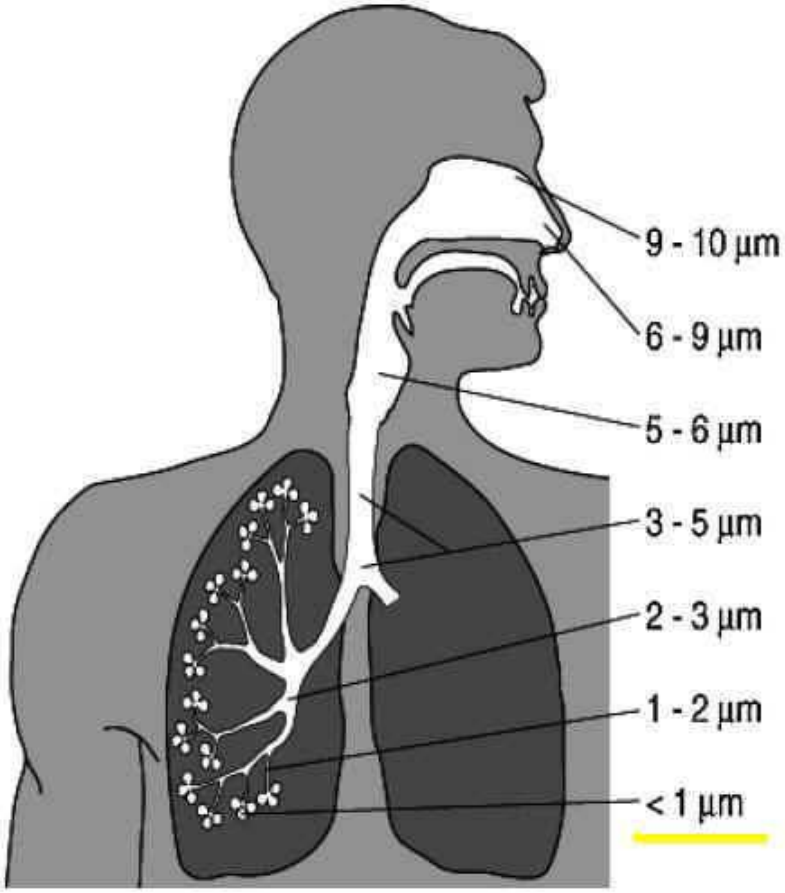


Figure 2 Particle deposition in respiratory system

Alveoli with capillaries

Health Effects of Fine and Ultrafine Particles

Fine PM was associated with increased mortality risk due to lung cancer, pulmonary disease and cardiovascular disease: ischemic heart disease, dysrhythmias, heart failure, and cardiac arrest .

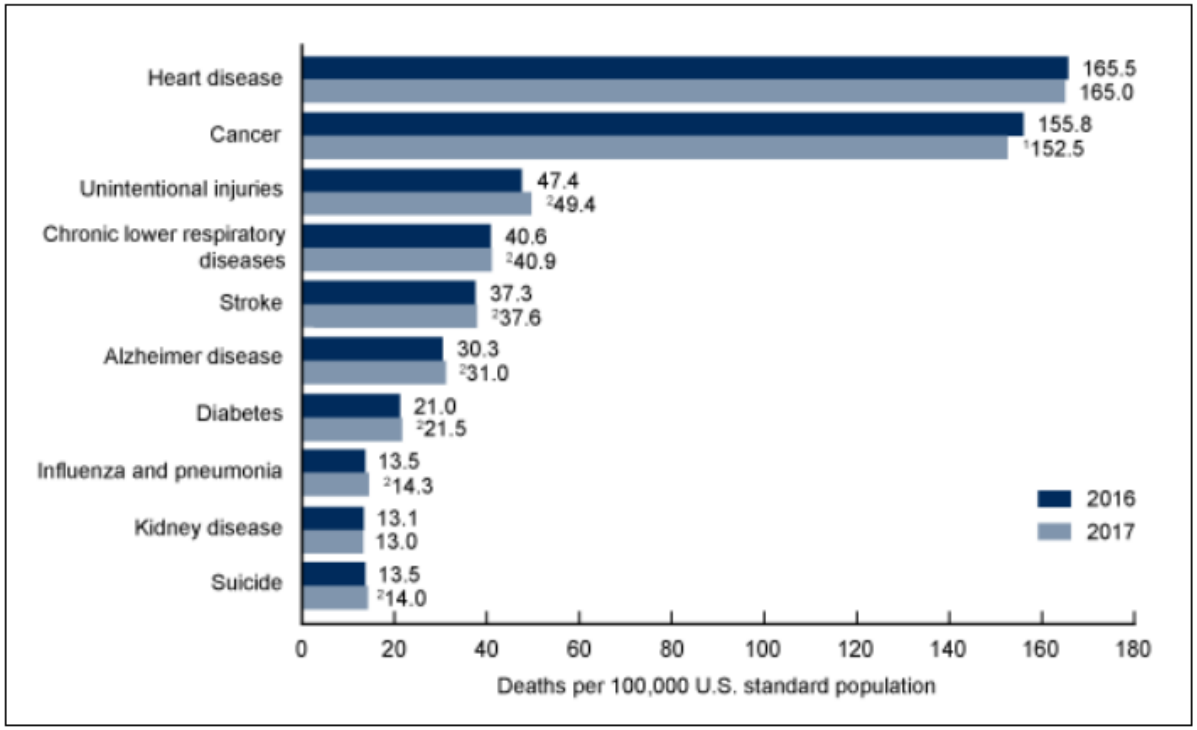
Increased mortality from cardiac/ respiratory problems in populations exposed to fine particulates such as in diesel exhaust

- Each 10-μg/m^3 elevation in $PM_{2.5}$ associated with
  - 4% increased risk of all-cause mortality
  - 6% increased risk of cardiopulmonary mortality
  - 8% increased risk of lung cancer mortality

Ref: Dockery et al, 1993,Pope et al 2002, 2004, Bruske-Holfield et al, 2005

Heart Disease is the leading cause of death in US

Figure 4. Age-adjusted death rates for the 10 leading causes of death: United States, 2016 and 2017



National Center for Health Statistics,
CDC Mortality in the US 2017

Air Pollution and cognitive function

- **Chronic air pollution exposure decreases cognitive function**

- **Chronic air pollution exposure may increase risk for developing Alzheimer's and other dementia**

Environ Health Perspect. 2016 Mar; 124(3): 306–312.
Published online 2015 Jul 31. doi: 10.1289/ehp.1408322
Research

PMCID: PMC4786976

Traffic-Related Air Pollution and Dementia Incidence in Northern Sweden: A Longitudinal Study

Anna Oudin,[1] Bertil Forsberg,[1,†] Annelie Nordin Adolfsson,[2] Nina Lind,[3] Lars Modig,[1] Maria Nordin,[3] Steven Nordin,[3] Rolf Adolfsson,[2] and Lars-Göran Nilsson[4,5]

Author information ► Article notes ► Copyright and License information ►

Are current standards for particulates protective of human health?

Estimated Number of Avoided $PM_{2.5}$ Health Impacts per year

December 14, 2012 EPA revised PM 2.5 standard from 15ug/m^3 to 12 ug/m^3

Health Impact	12 ug/m3	11 ug/m3
Non-Fatal Heart Attacks	52	170
Hospital Admissions Respiratory	110	380
Hospital Admissions Cardiovascular	140	480
Emergency Dept visits for Asthma	230	810
Asthma Exacerbations in Children	40,000	120,000

Integrated Science Assessment for Particulate 2009

September 2019

Policy Assessment for the Review of the National Ambient Air Quality Standards for Particulate Matter, External Review Draft

- **"…potential alternative annual standards with levels from 11.0 down to 9.0 µg/m^3 could reduce PM2.5-associated mortality broadly across the U.S., including in most of the 47 urban study areas evaluated. In such locations, estimated risk reductions range from about 7 to 9% for a level of 11.0 µg/m^3 , 14 to 18% for a level of 10.0 µg/m3 , and 21 to 27% for a level of 9.0 µg/m3."**

EPA/600/R-19/188
December 2019
www.epa.gov/isa

Integrated Science Assessment for Particulate Matter

December 2019

- **"evidence from US studies examining short-term PM2.5 exposure and mortality indicate a linear relationship at concentrations as low as 5ug/m3 with cutpoint analyses providing no evidence of a threshold"**

What Impact on Health do the Hazardous Air Pollutants Have?

The 188 HAPS

1. Acetaldehyde A C P
2. Acetamide P
3. Acetonitrile
4. Acetophenone P
5. 2-acetylaminofluorene
6. Acrolein A C P
7. Acrylamide P
8. Acrylic acid P
9. Acrylonitril P
10. Alkyl chloride P
11. 4-aminobiphenyl C
12. Aniline C P
13. o-Anisidine
14. Antimony compounds P
15. Arsenic compounds P
16. Asbestos P
17. Benzene A C P
18. Benzidine
19. Benzotrichloride
20. Benzyl chloride P
21. Beryllium compounds
22. Biphenyl P
23. Bis(2-ethylhexyl) phthalate (DEHP)
24. Bis(chloromethyl)ether P
25. Bromoform
26. 1,3-butadiene C
27. Cadmium compounds A C P
28. Calcium cyanamide P
29. Caprolactam A
30. Captan P
31. Carbaryl A P
32. Carbon disulfide P
33. Carbon tetrachloride P
34. Carbonyl sulfide C
35. Catechol C
36. Chloramben P
37. Chlordane P
38. Chlorine A P
39. Chloroacetic acid P
40. 2-chloroacetophenone
41. Chlorobenzene P
42. Chlorobenzilate P
43. Chloroform P
44. Chloromethyl methyl ether A
45. Chloroprene
46. Chromium compounds A C P
47. Cobalt compounds A P
48. Coke oven emissions A
49. Cresols/Cresylic acid C P
50. o-Cresol C P
51. m-Cresol C P
52. p-Cresol C P
53. Cumene P
54. Cyanide Compounds P
55. 2,4-D, salts and esters P
56. DDE P
57. Diazomethane A
58. Dibenzofurans
59. 1,2-dibromo-3-chloropropane A
60. Dibutylphthalate A
61. 1,4-dichlorobenzene
62. 3,3-dichlorobenzidene
63. Dichloroethyl ether P
64. 1,3-dichloropropene P
65. Dichlorvos P
66. Diethanolamine A P
67. N,N-diethyl aniline
68. Diethyl sulfate P
69. 3,3-dimethoxybenzidine
70. Dimethyl aminoazobenzene
71. Dimethyl carbamoyl chloride
72. 1,1-dimethyl hydrazine
73. Dimethyl phthalate P
74. Dimethyl sulfate A
75. 4,6-dinitro-o-cresol, and salts P
76. 2,4-dinitrophenol P
77. 2,4-dinitrotoluene
78. 1,4-dioxane P
79. 1,2-diphenylhydrazine
80. Epichlorohydrin P
81. 1,2-epoxybutane
82. Ethyl acrylate P
83. Ethyl benzene P
84. Ethyl carbamate
85. Ethyl chloride P
86. Ethylene dibromide P
87. Ethylene dichloride P
88. Ethylene glycol P
89. Ethylene imine A
90. Ethylene oxide A
91. Ethylene thiourea P
92. Ethylidene dichloride
93. Formaldehyde A C P
94. Glycol ethers P
95. Heptachlor P
96. Hexachlorobenzene P

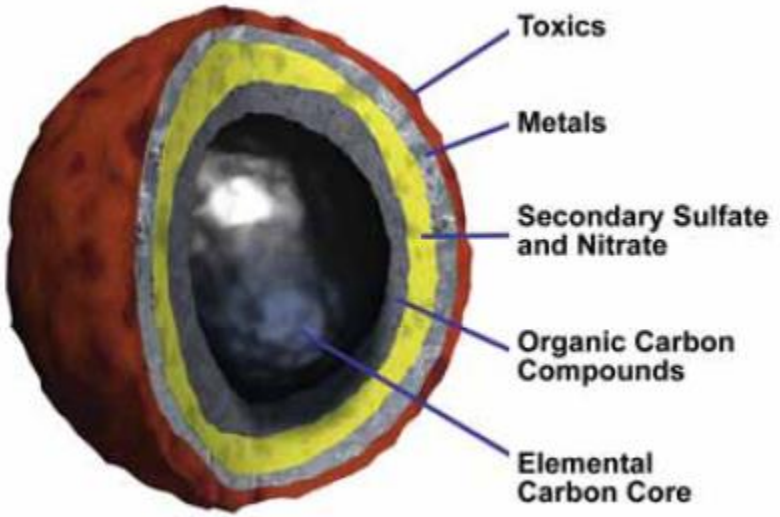
= 32/33 NATA HAPs (33 = diesel PM); A = Leikauf list of asthma HAPs; C = In cigarette smoke; P = Pesticide active ingredient (PAN)

The 188 HAPS *continued*

97. Hexachlorobutadiene
98. Hexachlorocyclopentadiene P
99. Hexachloroethane P
100. Hexamethylene-1,6-diisocyanate
101. Hexamethylphosphoramide
102. Hexane
103. Hydrazine A C P
104. Hydrochloric acid A
105. Hydrogen fluoride A
106. Hydrogen sulfide A P
107. Hydroquinone C P
108. Isophorone P
109. Lead compounds P
110. Lindane P
111. Maleic anhydride P
112. Manganese compounds A P
113. Mercury compounds A P
114. Methanol P
115. Methoxychlor P
116. Methyl bromide P
117. Methyl chloride C P
118. Methyl chloroform
119. Methyl ethyl ketone P
120. Methyl hydrazine
121. Methyl iodide P
122. Methyl isobutyl ketone P
123. Methyl isocyanate A P
124. Methyl methacrylate A
125. Methyl tert butyl ether
126. 4,4-methylene bis P
127. Methylene chloride P
128. Methylene diphenyl diisocyanate P
129. 4,4-methylenedianiline
130. Mineral fibers, fine
131. Naphthalene P
132. Nickel compounds A C P
133. Nitrobenzene P
134. 4-nitrobiphenyl
135. 4-nitrophenol
136. 2-nitropropane
137. N-nitroso-n-methylurea
138. N-nitrosodimethylamine C
139. N-nitrosomorpholine
140. Parathion P
141. Pentachloronitrobenzene
142. Pentachlorophenol P
143. Phenol C
144. p-phenylenediamine
145. Phosgene A
146. Phosphine A P
147. Phosphorus P
148. Phthalic anhydride P
149. Polychlorinated biphenyls
150. Polycyclic organic matter C
151. 1,3-propane sultone
152. beta-propiolactone
153. Propionaldehyde C P
154. Propoxur (Baygon) P
155. Propylene dichloride
156. Propylene oxide P
157. 1,2-propylenimine
158. Quinoline C P
159. Quinone P
160. Radionuclides C
161. Selenium compounds P
162. Styrene A C
163. Styrene oxide
164. 2,3,7,8-tetrachlorodibenzo-p-dioxin A C
165. 1,1,2,2-tetrachloroethane P
166. Tetrachloroethylene (perc) P
167. Titanium tetrachloride
168. Toluene C P
169. 2,4-toluene diamine
170. 2,4-toluene diisocyanate A P
171. o-toluidine C
172. Toxaphene P
173. 1,2,4-trichlorobenzene P
174. 1,1,2-trichloroethane
175. Trichloroethylene
176. 2,4,5-trichlorophenol A P
177. 2,4,6-trichlorophenol A P
178. Triethylamine P
179. Trifluralin P
180. 2,2,4-trimethylpentane
181. Vinyl acetate P
182. Vinyl bromide
183. Vinyl chloride P
184. Vinylidene chloride
185. Xylenes (isomers and mixture)
186. o-xylenes
187. m-xylenes
188. p-xylenes

■ = *32/33 NATA HAPs (33 = diesel PM); A = Leikauf list of asthma HAPs; C = In cigarette smoke; P = Pesticide active ingredient (PAN)*

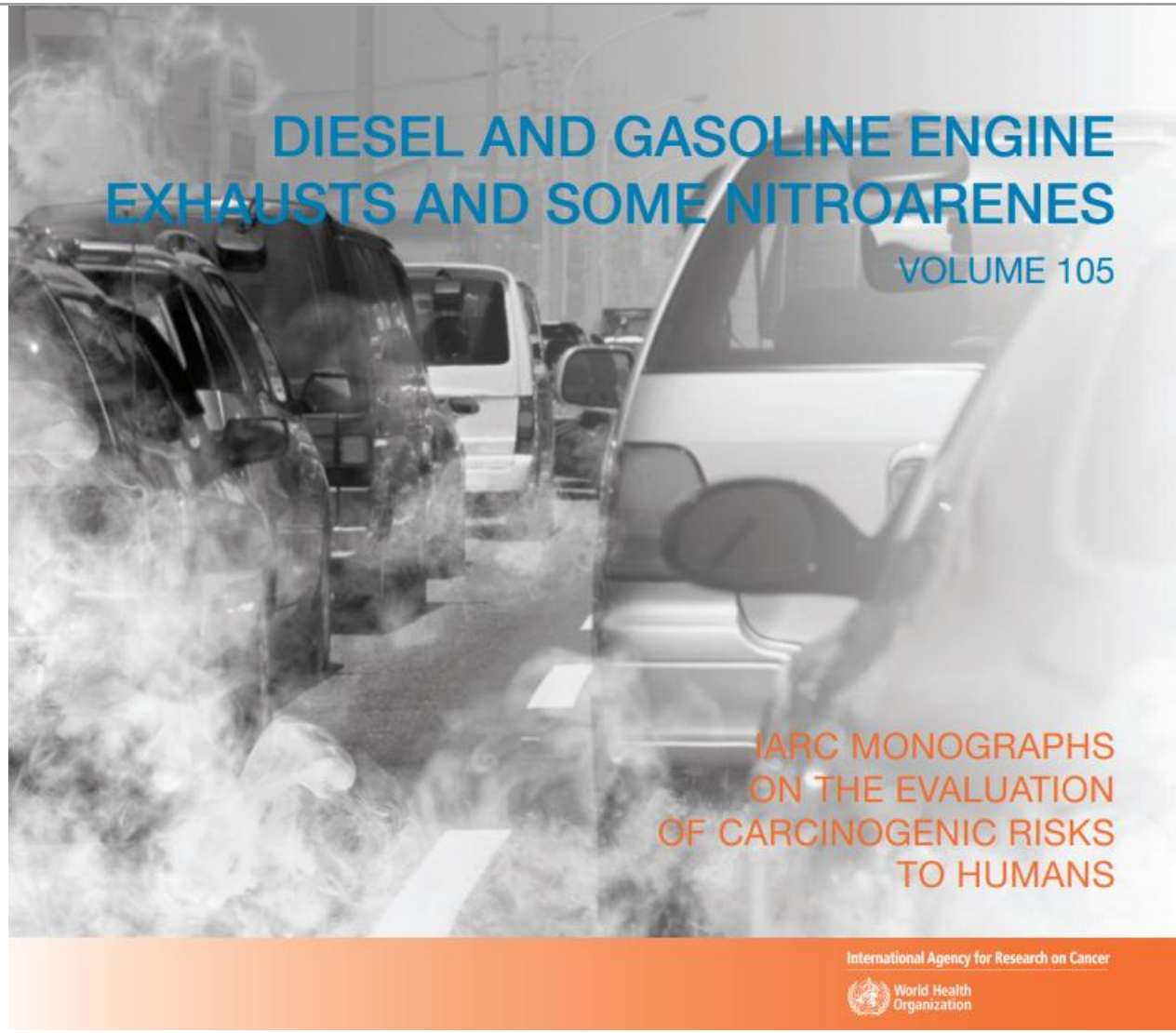
Composition of Diesel Exhaust



- **Particulate phase**
  - Mostly elemental carbon (soot)
    - 20% to 40% adsorbed organic compounds
  - Sulfates, nitrates, metals, other trace elements
  - The most toxicologically relevant adsorbed **compounds:**
    - **PAHs** - **Nitro-PAHs** - **Oxidized PAH derivatives**
  - 92% of mass is in particles smaller than 1 micron

International Agency for Research on Cancer

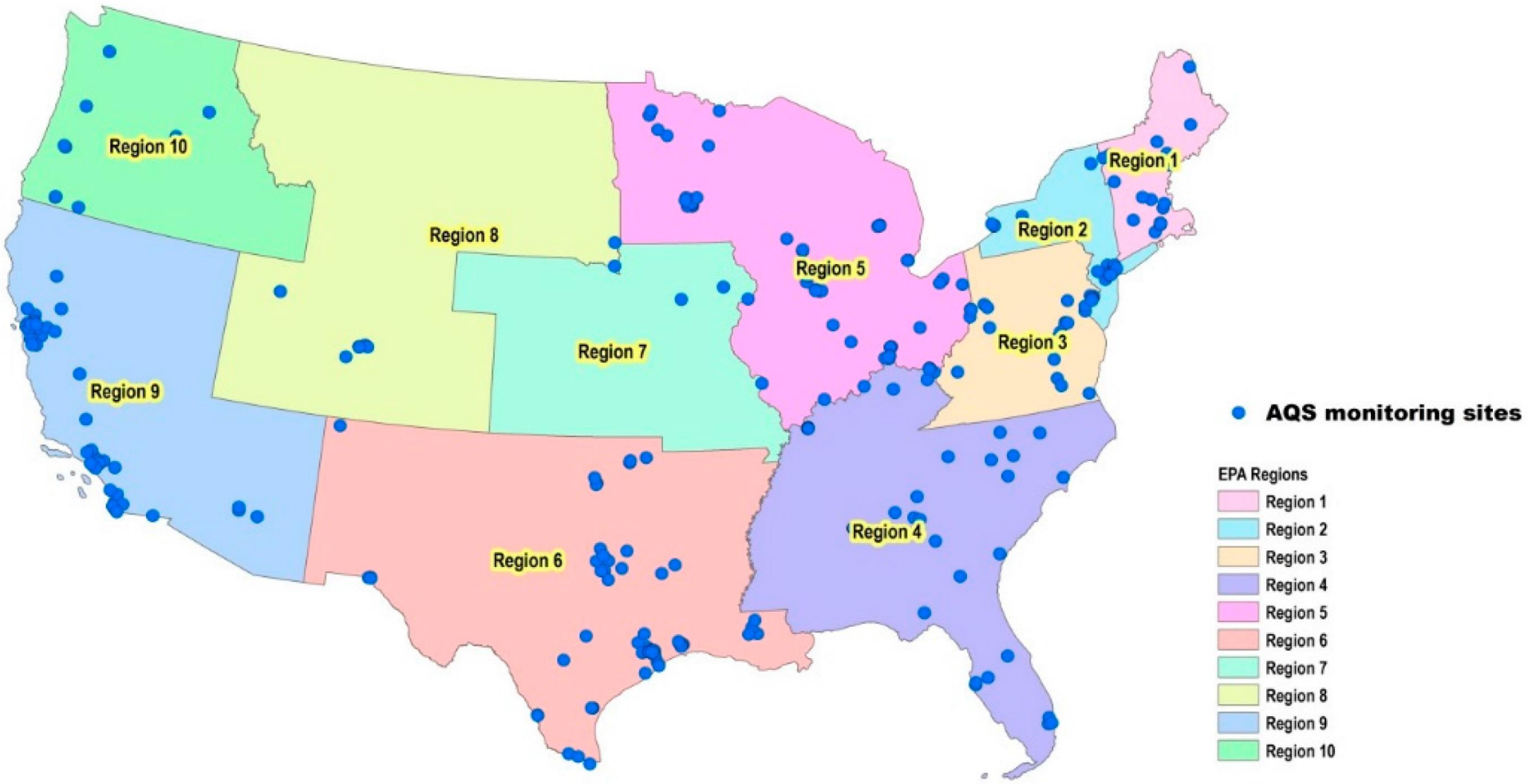
- 2012
- Group 1 Carcinogen
- Definite cause of Lung Cancer
- Probable cause of Bladder Cancer



International Agency for Research on Cancer

- 2013
- Polyaromatic hydrocarbons formed during combustion
- Present in particulate and gaseous states
- Several PAHs Group 1 Carcinogens

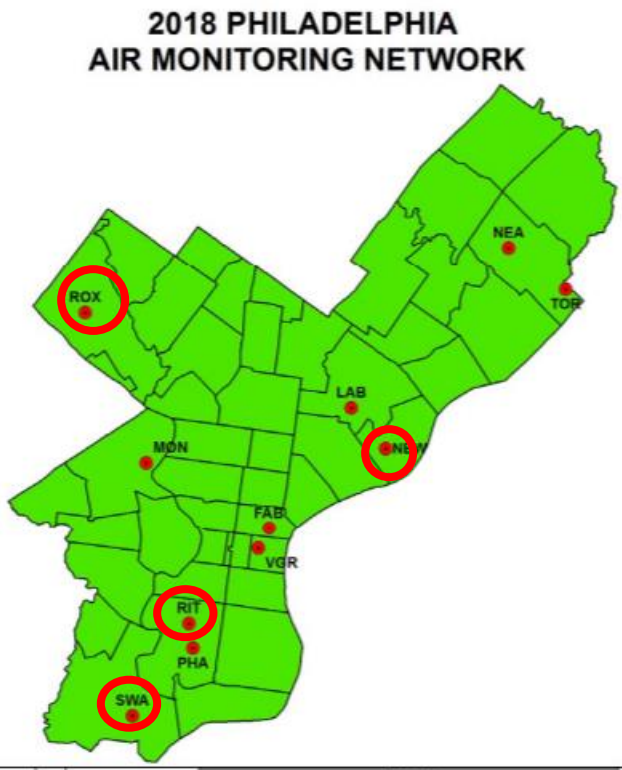
HAP monitoring by EPA region



Xue and Jia, A Model-to-Monitor Evaluation of 2011 NATA, Toxics, 2019, 7(1) 13

Exposure Assessment HAPs in Communities

- **Very few EPA air monitors**
- **Many communities with no monitoring at all**



			Parameter																					
AQS Site Code	AMS Site	Address	CO	SO_2	Ozone	NO_2	NOy/NO	PM_{10}	$PM_{2.5}$	Speciated $PM_{2.5}$	PM Coarse	Black Carbon / Ultrafine PM	Carbonyls	PAMS VOC	BaP	TSP Metals (Be, Cr, Mn, Ni, As, Cd, Pb)	Toxics TO15	MET	Comm. Air Toxics OPEN PATH		AMS Site
421010004	LAB	1501 E. Lycoming St			X																		LAB
421010014	ROX	Eva & Dearnley Sts											X				X						ROX
421010024	NEA	Grant Ave & Ashton Rd			X																		NEA
421010048	NEW	2561 Lewis St	X	X	X	X	X	X	X	X	X	X		X	X			X	X				NEW
421010055	RIT	24th & Ritner Sts		X					X	X				X			X	X					RIT
421010057	FAB	3rd & Spring Garden Sts							X														FAB
421010063	SWA	8200 Enterprise Ave												X				X					SWA
421010075	TOR	4901 Grant Ave & James St	X			X			X										X				TOR
421010076	MON	I-76 & Montgomery Drive	X			X			X				X			X			X				MON
	PHA	3100 Penrose Ferry Rd																			X		PHA
	VGR	6th & Arch Sts			X				X										X				VGR

Philadelphia Air Monitoring Network

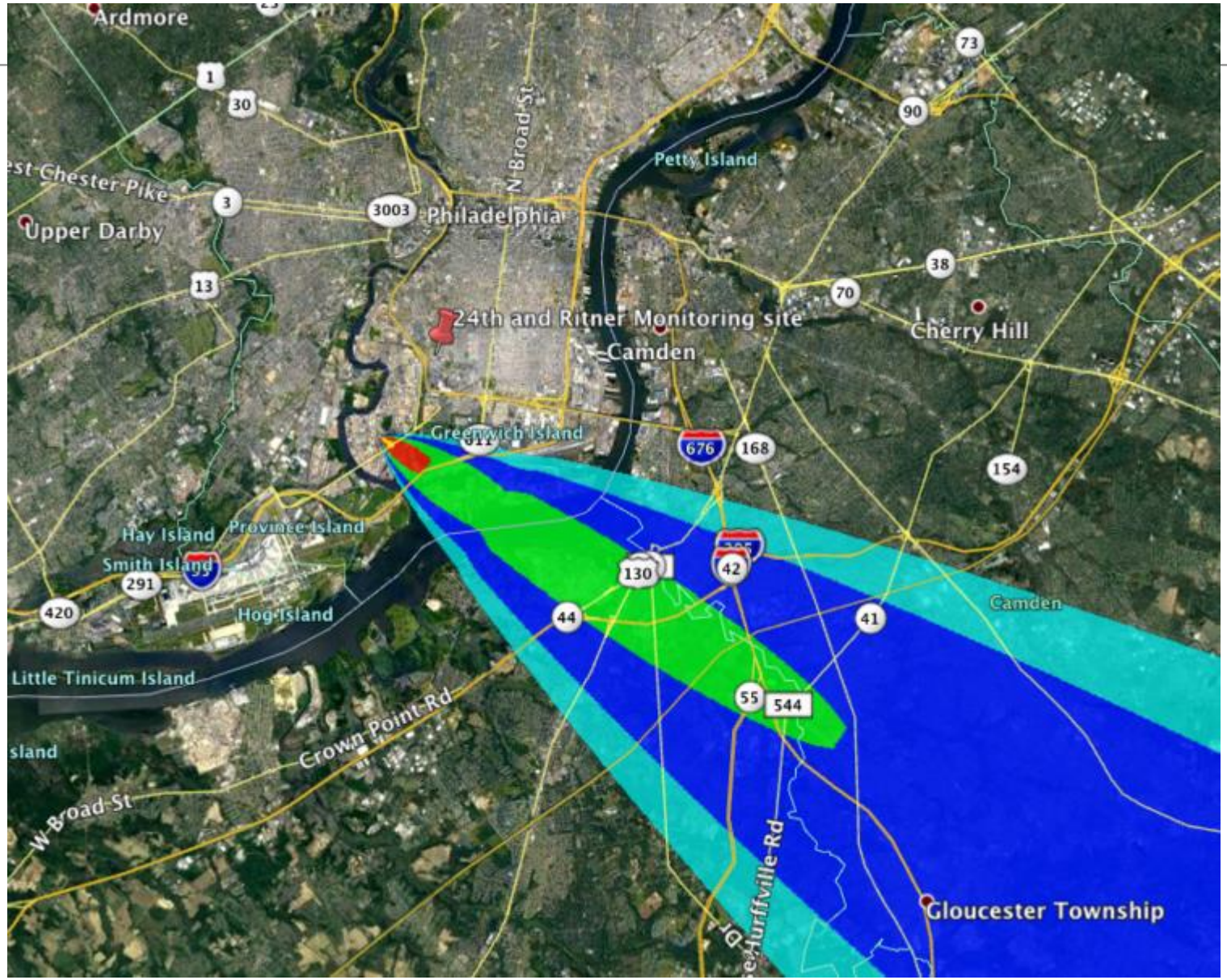
Pollutants detected in local air monitors

Hazardous Air Pollutant	IARC Cancer Classification	Primary Cancer Type/Site
Benzene	1	Leukemia
Vinyl chloride	**1**	Liver
1,3-Butadiene	1	Leukemia, Lymphoma
Trichloroethylene	**1**	Kidney, Lymphoma, Liver
Ethylene dibromide	1	Lung
Tetrachloroethylene	2A	Liver & Kidney
Ethylene dichloride	2B	Liver
trans-1,3-Dichloropropene	2B	Liver
Dichloromethane	2B	Liver & Lung
Carbon tetrachloride	2B	Liver
Chloroform	2B	Liver & Kidney

Philadelphia

Multiple sources in close proximity to people

PES explosion and fire: June 21, 2019

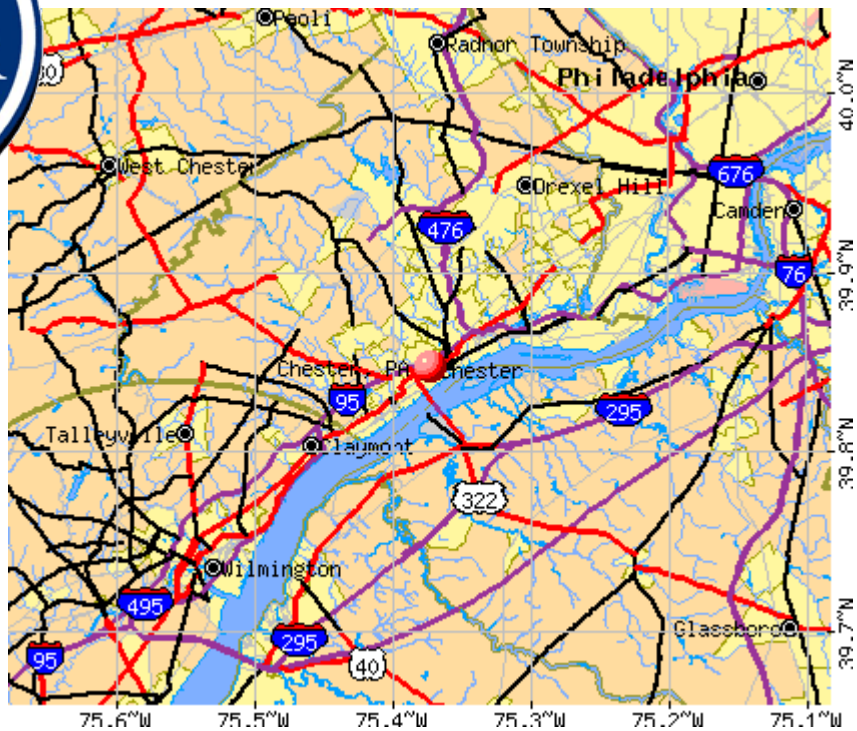


Massive fire:
Not recorded
on existing
monitors

Graphic created by Dr. Peter DeCarlo

Current Monitoring Approach Underestimates Exposure

- **Monitors are sparsely distributed**
- **Have not been shown to be helpful in emergency situations to assess risk to communities**
- **Considering that current standards on particulates are outdated (too high) and there are no standards for HAPS, monitoring in neighborhoods to identify hot spots is important**



34,000 residents
Median household income: $28,000 compared with $55,000 in PA
Median home value $69,000 compared with $170,000 in PA
Races in Chester 71% Black
17% unemployment

Permitted and unpermitted industry

- **Environmental Injustice**

CEET Relationship with Chester

- **Community Engagement Core- Founding member of Chester Environmental Partnership**
- **Scientific and Health Technical Advisors**

- **Members**
- **Delaware Valley Regional Planning Commission**
- **Drexel Academy of Natural Sciences**
- **PA DEP**
- **Multiple industries in Chester**
- **EPA Region 3**
- **University of Pennsylvania**
- **Widener University**
- **Swarthmore College**
- **Chester Crozer Hospital**
- **Chester City Government**
- **Sierra Club**
- **Chester Residents**
- **Penn Future**
- **Penn Environment**
- **Clean Air Council**
- **Delaware Riverkeeper**

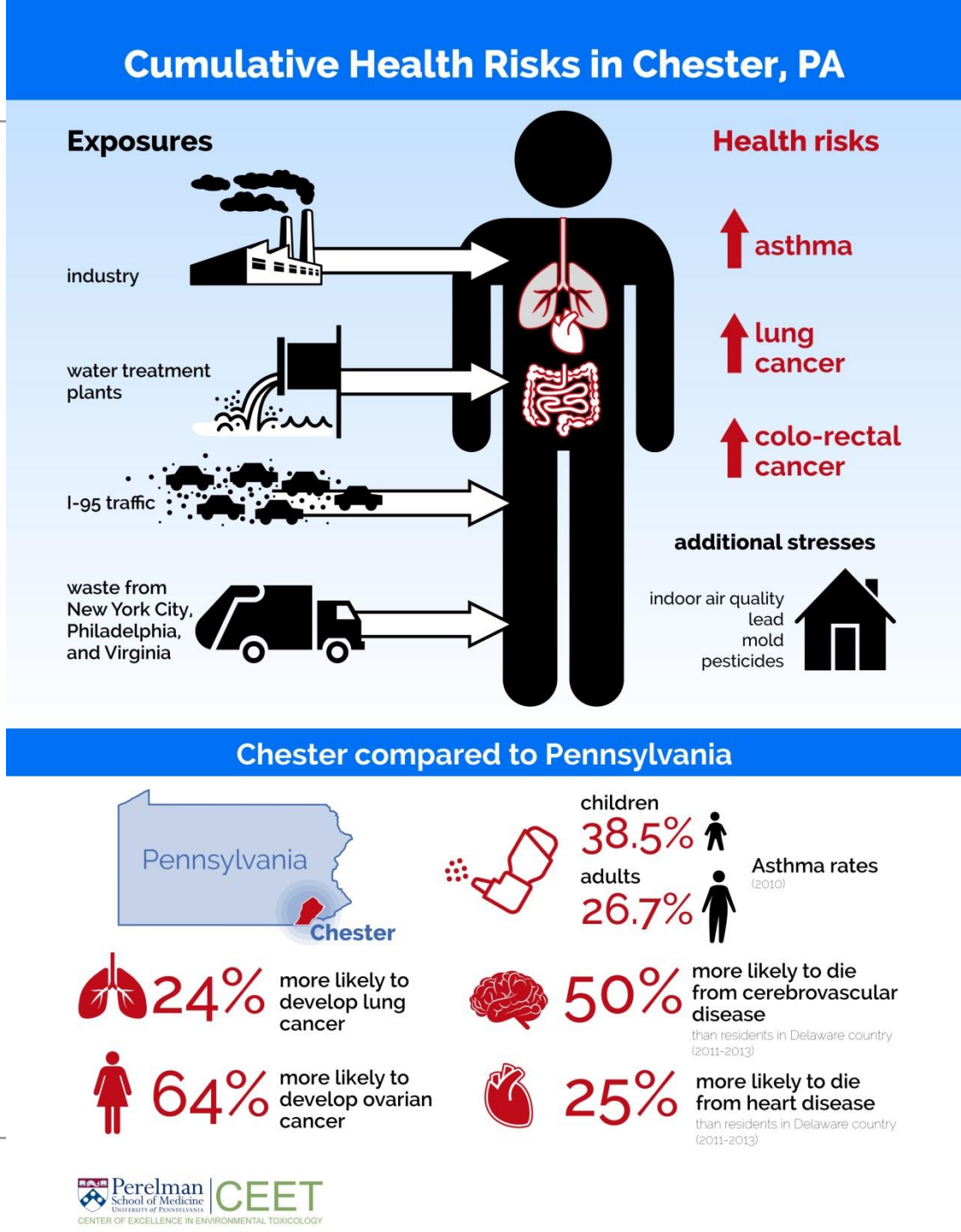
To improve and sustain the quality of life, cleaner and healthier environment for the residents of Chester and the Commonwealth, while attracting positive economic development, sustainable growth, economic opportunities for the residents of Chester and reducing emission and negative environmental exposures to the citizens through collaborative partnerships.

CEP Solutions
Protecting People and the Environment

Chester Environmental Partnership

Infographic designed to call attention to Cumulative Risks in Chester and their health impacts

Based on PA DOH data 2012



Perelman School of Medicine
University of Pennsylvania

Chester birth weight disparities (2012-2016)

		Chester City (n=2,767)		Delaware county (n=33,057)	
Birth weight category		**n**	**%**	**n**	**%**
< 1,500 g	Very low birth weight	**85**	**3.1**	**10,233**	**1.5**
< 2,500g	Low birth weight	**362**	**13.1**	**56,934**	**8.1**

https://www.health.pa.gov/topics/HealthStatistics/VitalStatistics/BirthStatistics/Documents/Birth_BirthWt_MCD_2012_2016.pdf

Association of Air Pollution and Poor Birth Outcomes

- **Air pollution**
  - **Higher levels of CO, NO_2, PM ➡ lower birth weights**
  - **Third trimester exposure with preterm birth**
  - **Racial disparities in exposure, proximity to traffic and industry**

Andrews et al. Am J Ind Med. 1994; Stieb et al. Envir Res. 2012; Pratt et al. Int J Environ Res Public Health. 2015; Liu,Y et al. BMC Public Health, 2019

Prematurity and Low Infant Birth Weight

- **Introduction of EZ PASS led to 10.8% reduction of prematurity and 11.8% reduction of low birth weight within 2 km of the toll plaza**
- **Decreased CO and NO_x**

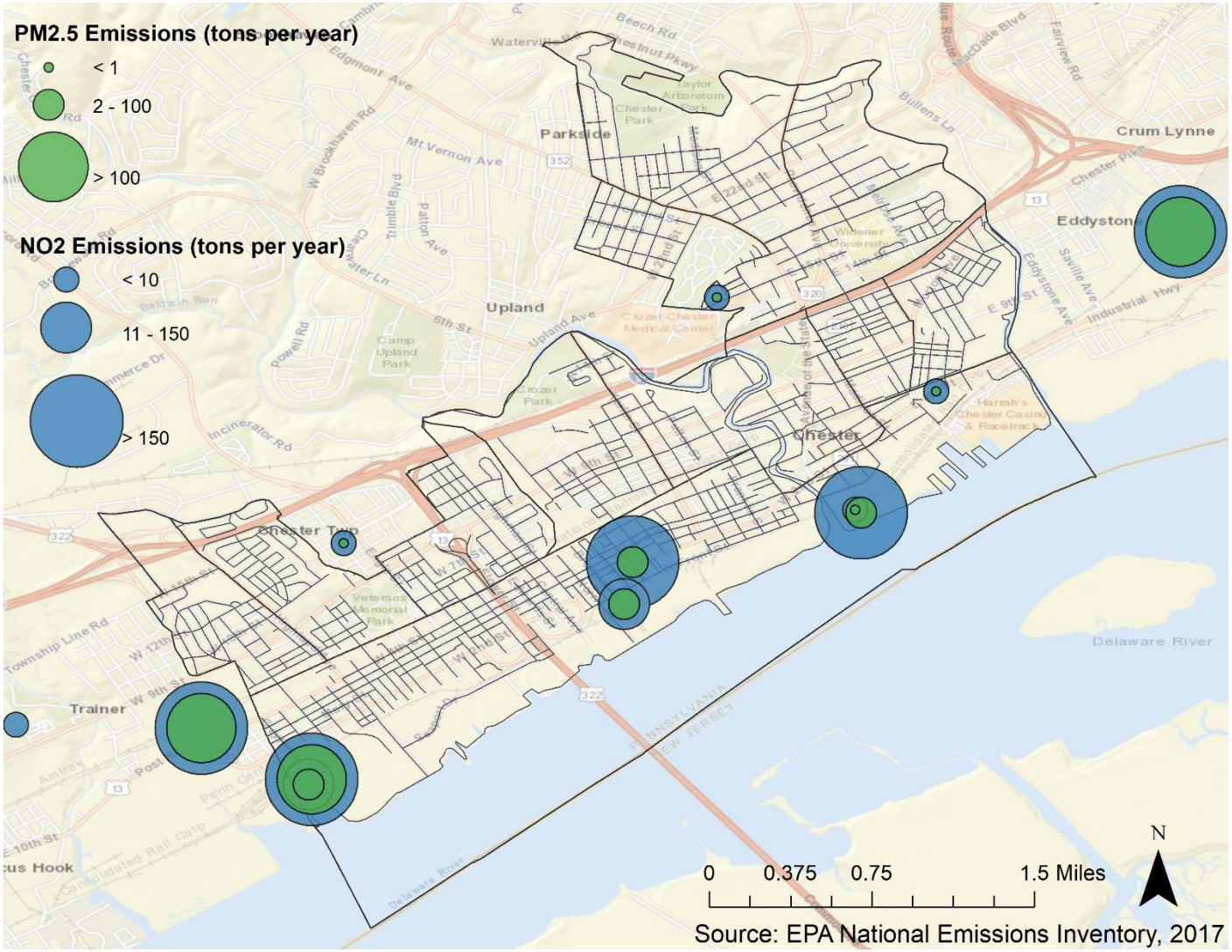
American Economic Journal: Applied Economics 3 (January 2011): 65–90
http://www.aeaweb.org/articles.php?doi=10.1257/app.3.1.65

Traffic Congestion and Infant Health: Evidence from E-ZPass†

By JANET CURRIE AND REED WALKER*

We exploit the introduction of electronic toll collection, (E-ZPass), which greatly reduced both traffic congestion and vehicle emissions near highway toll plazas. We show that the introduction of E-ZPass reduced prematurity and low birth weight among mothers within 2 kilometers (km) of a toll plaza by 10.8 percent and 11.8 percent, respectively, relative to mothers 2–10 km from a toll plaza. There were no immediate changes in the characteristics of mothers or in housing prices near toll plazas that could explain these changes. The results are robust to many changes in specification and suggest that traffic congestion contributes significantly to poor health among infants. (*JEL* I12, J13, Q51, Q53, R41)

PM 2.5 and NO_2 Emissions from Point Sources in Chester, PA



Chester Healthy Infant Research-to-Action Program (CHIRP)

George L. Gerton, PhD

Marilyn V. Howarth, MD

Heather Burris, MD

Mary Regina Boland, PhD

Perelman School of Medicine
University of Pennsylvania

CEET

CENTER OF EXCELLENCE IN ENVIRONMENTAL TOXICOLOGY

Pilot Study: CHIRP

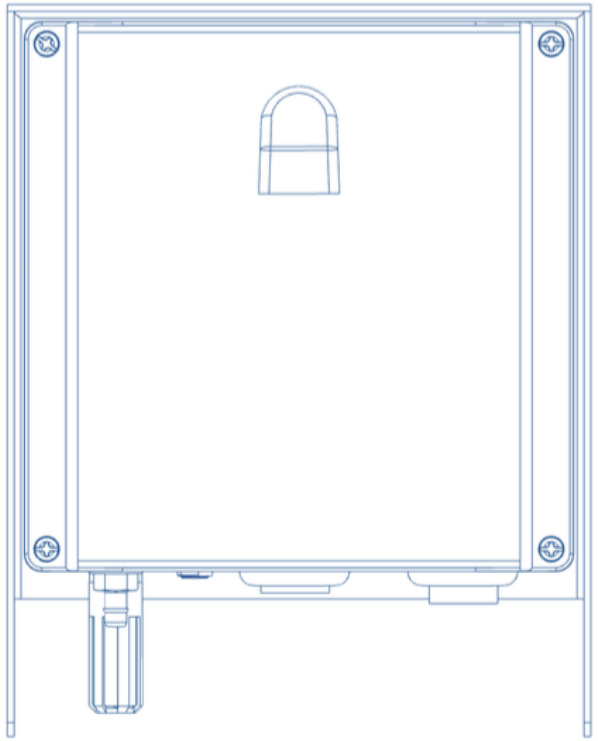
- **Overall hypothesis: Poor environmental conditions (air quality, heavy metal exposure, noise, and/or violence) negatively impact fetal growth.**
  - **AIM 1. Measure air quality in residential areas where mothers are predicted to live.**
    - *Question: Do residential neighborhoods closer to sources of air pollution (incinerators, sewage treatment facilities, paper products plants, highway, etc.) have high levels of air pollutants?*
  - **AIM 2. Perform spatial analysis of publicly available toxic release data and compare to the data gathered in this study.**
    - *Question: Are there "hot spots" of air pollution in different regions of Chester?*

Selection of Monitor: Aeroqual AQY-1

- **Air pollution compounds to measure:**
  - PM2.5 (industry, traffic, heating)
  - Ozone (secondary pollutant)
  - Nitrogen dioxide (traffic and urban heating)
- **Reviewed available literature and available devices**
- **Carefully considered testing performed by Air Quality Sensor Performance Evaluation Center (AQ-SPEC) program of the South Coast Air Quality Management District.**
- **Quality and price: Aeroqual AQY-1**

AQY 1

aeroqual



O_3 Ozone

$PM_{2.5}$ Particulate Matter $PM_{2.5}$

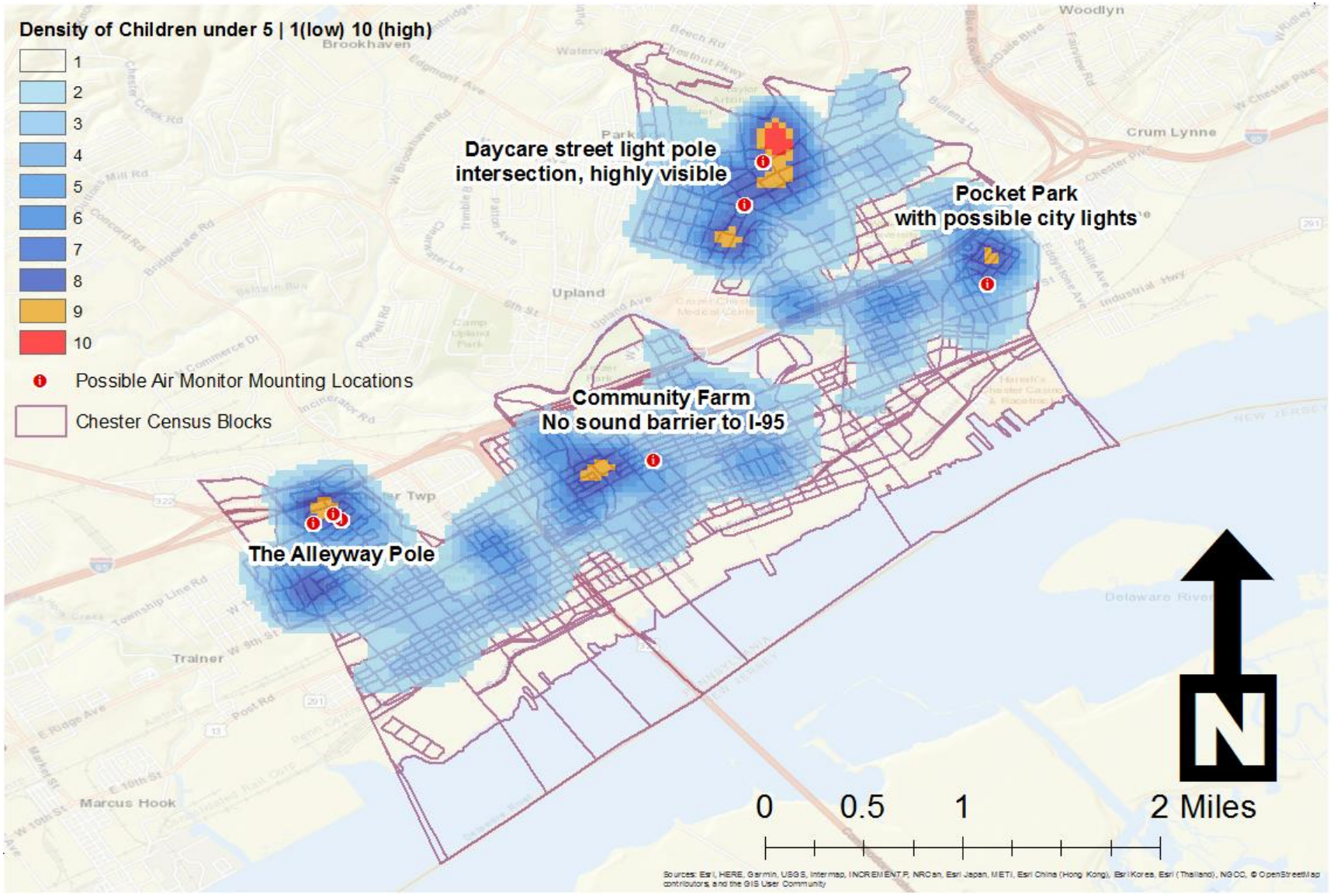
NO_2 Nitrogen Dioxide

Temperature Humidity & Dew Point

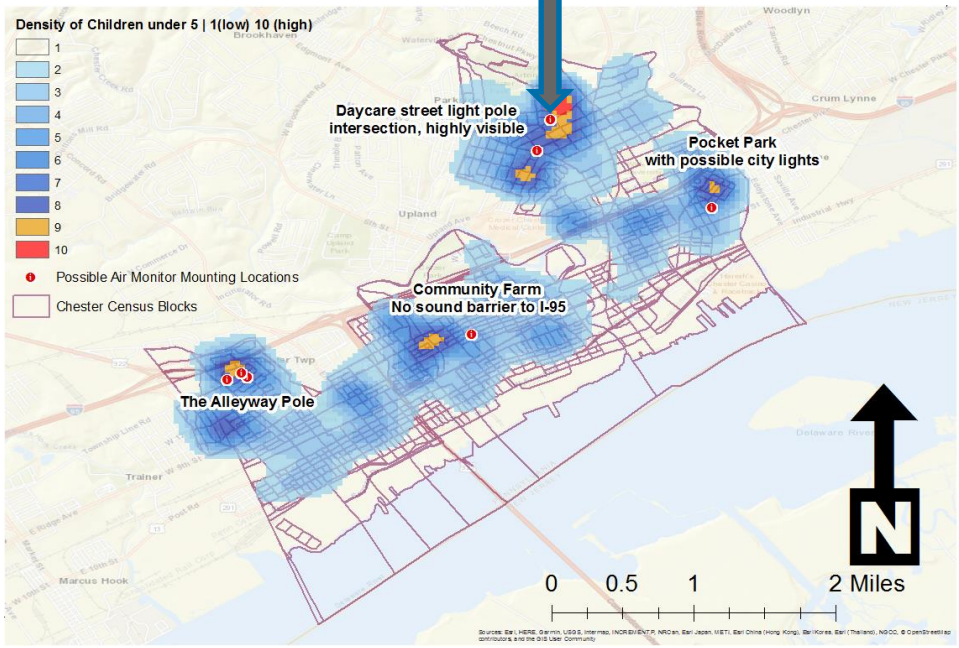
Steps to Project Initiation

- Support of the Chester Environmental Partnership
- Approval of project by Chester City Council
- Gain approval of Chester City engineers for sites chosen
- Approval from the Chester Housing Authority
- Learn and troubleshoot the equipment
- Community-based assistant for battery charging/replacement
- Install and activate monitors

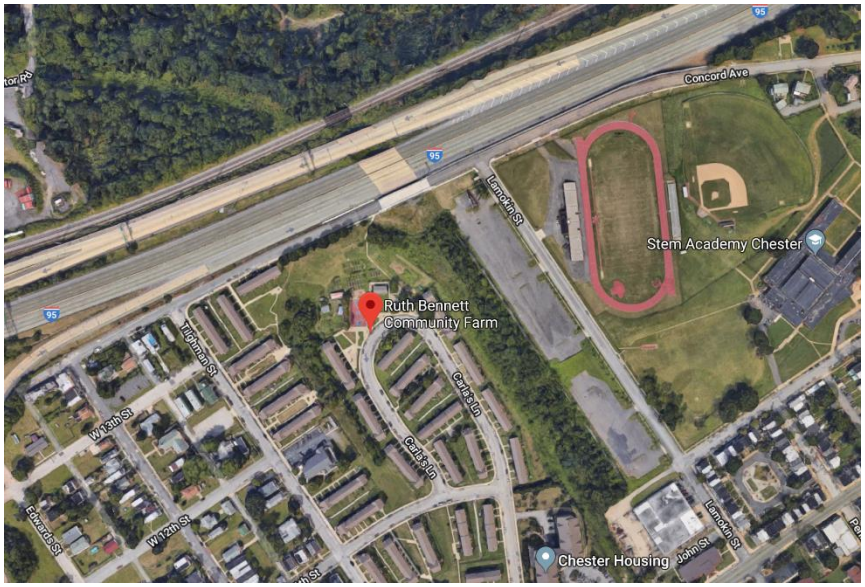
Locations for Air Monitor Placement



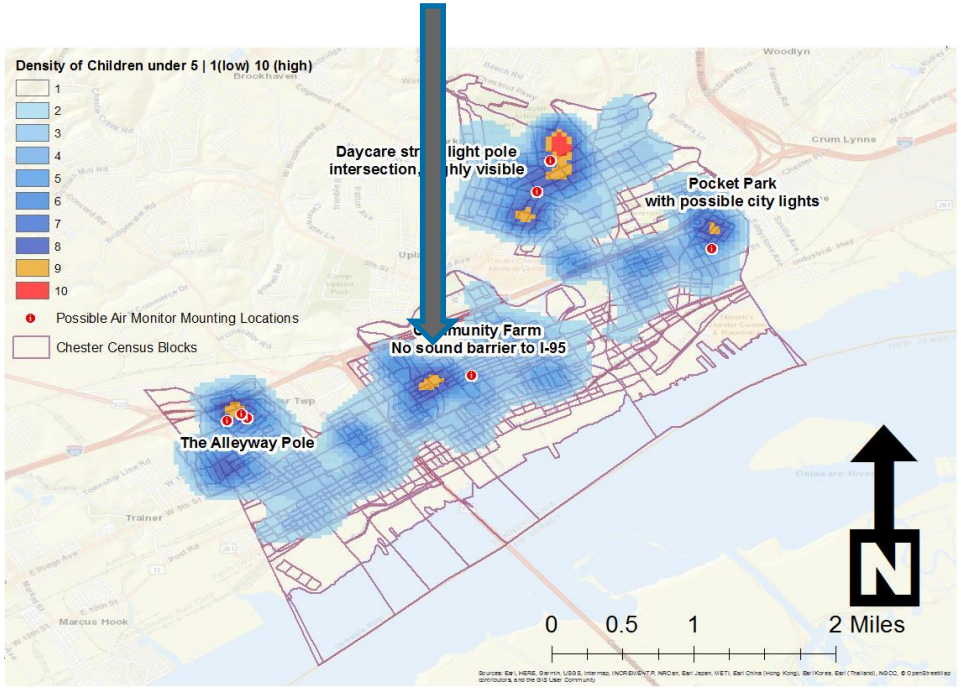
Street Light
Edgemont ave and W 22nd street



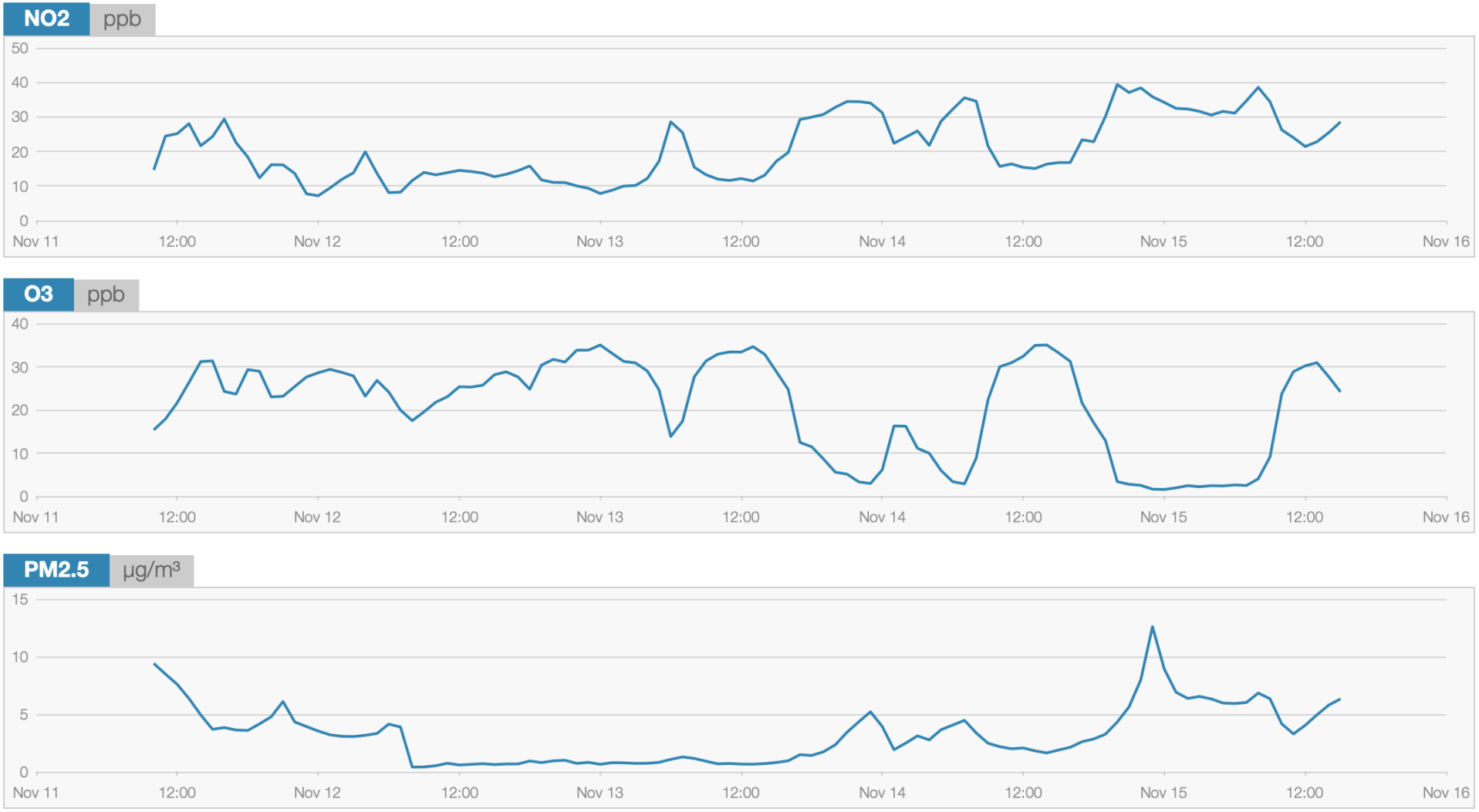
Chester Housing Authority



Ruth Bennett Community Farm



Sample Data (November 11-15, 2020)



Analysis and Future Directions

- **Collect data every 30 seconds and average at 1 hour intervals**
- **Plot data over time to analyze the running values over a long-term period (weekly and monthly)**
- **Determine the variability in levels of air pollution for sites**
  - Time of day
  - Season
  - Impact of weather
- **Use handheld monitor to measure the levels of VOCs and SO2 at our stationary sites as well as other locations.**
- **Accumulate knowledge to inform our hypotheses for our subsequent NIEHS grant proposal.**
- **Future: heavy metal exposure, noise, violence, etc.**

Thank you to Collaborators

Penn/CEET

- Thomas Mckeon
- Adrian Wood
- Jessica Murray
- Peter DeCarlo

Community

- Chester Environmental Partnership
- Foundation for Delaware County
- City of Chester
- Chester Housing Authority
- Darren Alston

https://www.facebook.com/CECatCEET

@UPennCEET_CEC