EPA United States Environmental Protection Agency

Exposure Science Application and Opportunities at the U.S. EPA

Tim Buckley
Senior Science Advisor for Exposure Characterization and Modeling
Center for Computational Toxicology and Exposure (CCTE)

February 23, 2021

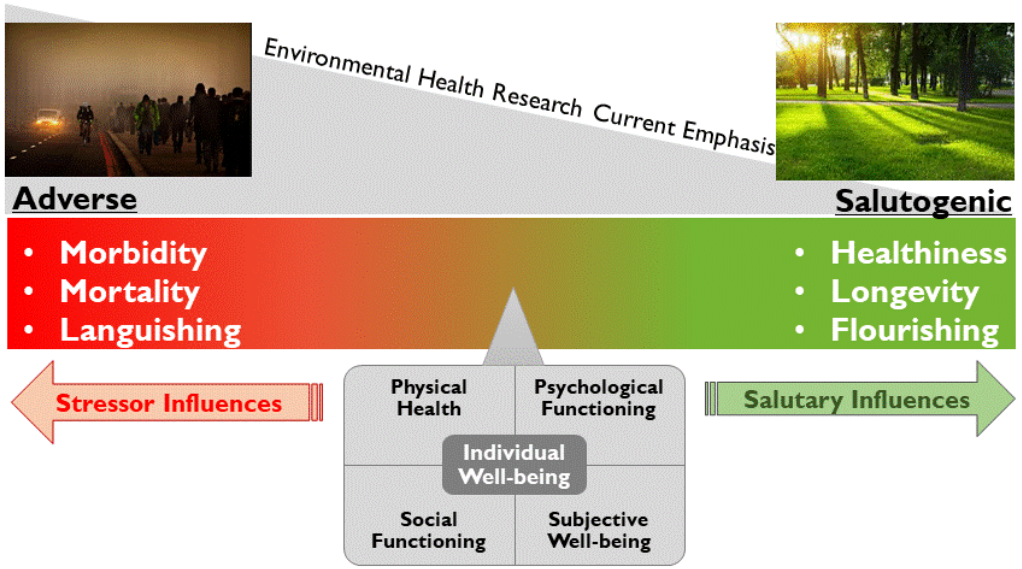
Discussion with Duke MHS students

The views expressed in this presentation are those of the author and do not necessarily reflect the views or policies of the US EPA.

Office of Research and Development
Chemical Safety for Sustainability Research Program

Outline

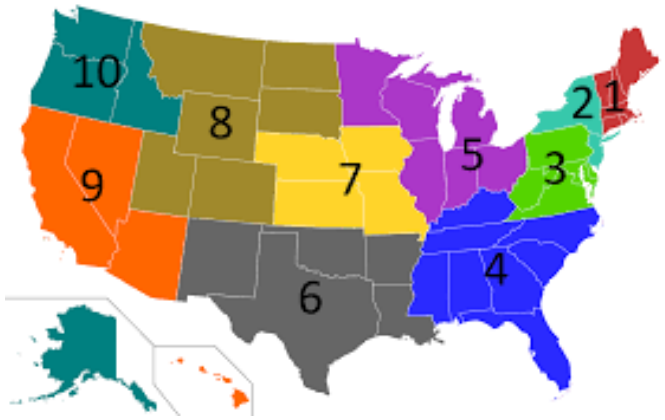
- Organizational Context
- EPA Impact / Success
- Public Health Context
- Research Examples
- Summary
- Joining EPA
- Q & A



Source: Silva et al., ES&T 2018

EPA Organizational Overview

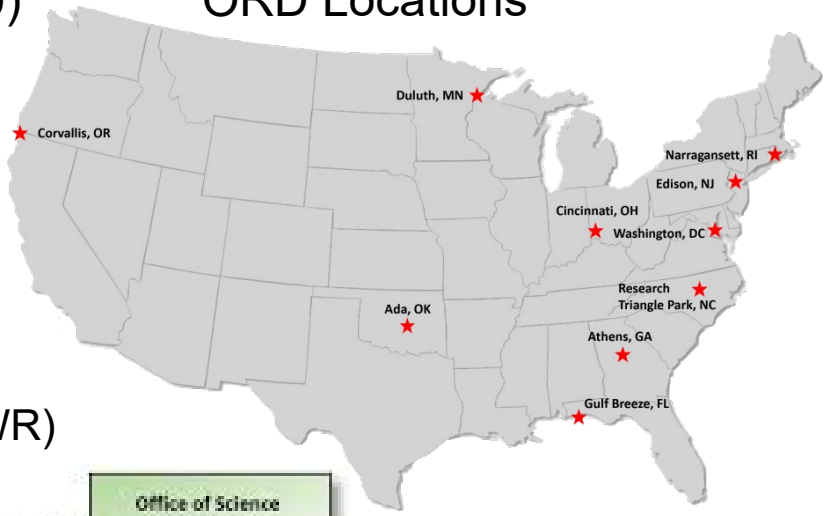
- Federal Staff of ~14,000; FY20 Budget of ~$9 Billion
- Program Offices
  - Office of Air and Radiation (OAR)
  - Office of Chemical Safety and Pollution Prevention (OCSPP)
  - Office of Enforcement and Compliance Assurance (OECA)
  - Office of General Counsel (OGC)
  - Office of International and Tribal Affairs (OITA)
  - Office of Land and Emergency Management (OLEM)
  - Office of Water (OW)
- Office of Research & Development (ORD)
- Regional Offices (n=10)



Office of Research & Development

- Federal Staff of ~1500 (~200 new hires FY20)
- FY21 Budget: ~$524.5 M (+$4.4 FY20)
- Research Programs
  - Air and Energy (A&E)
  - Chemical Safety for Sustainability (CSS)
  - Health and Environmental Risk Assessment (HERA)
  - Homeland Security (HSR)
  - Safe and Sustainable Water Resources (SSWR)
  - Sustainable and Healthy Communities (SHC)

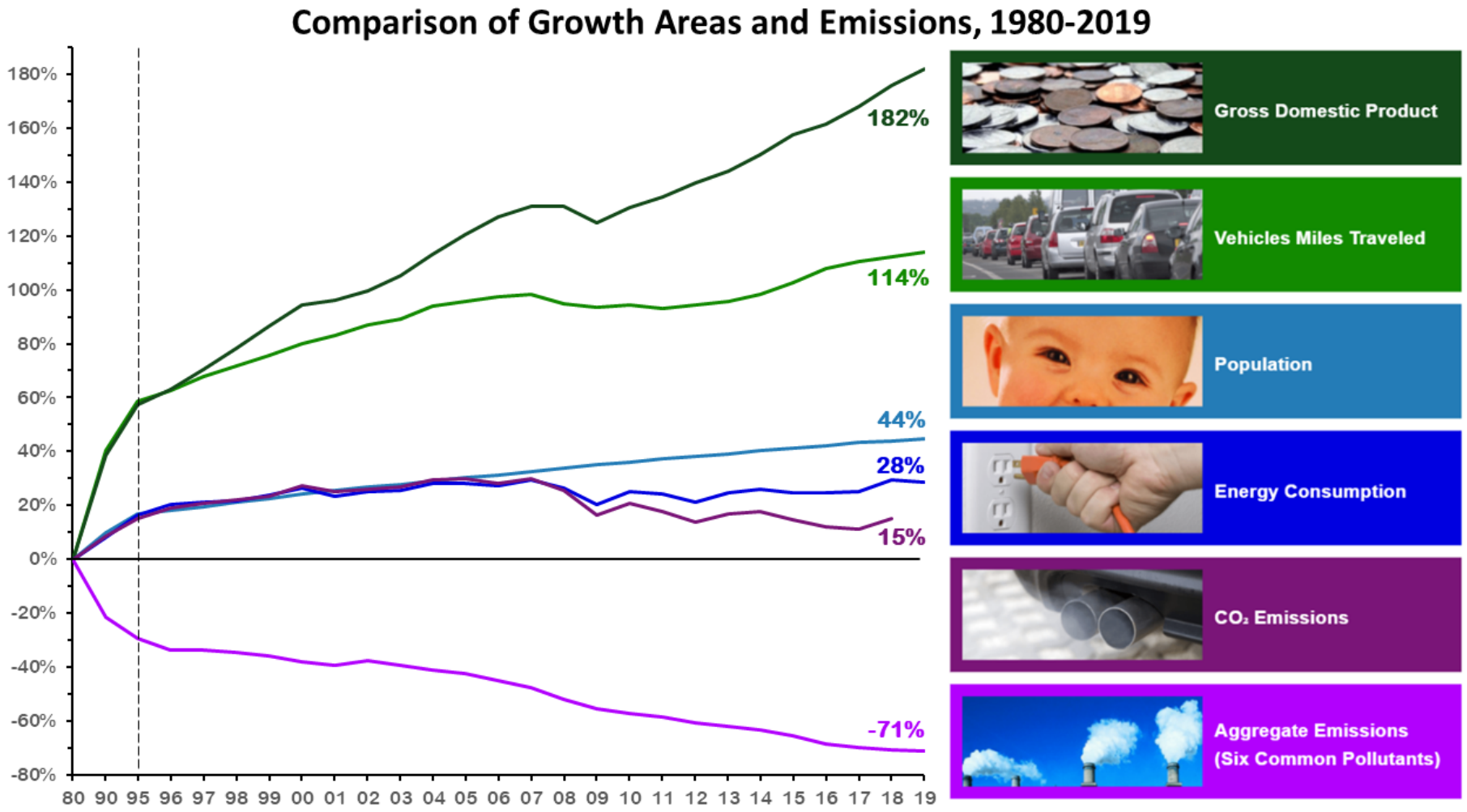
ORD Locations



Regulatory Context

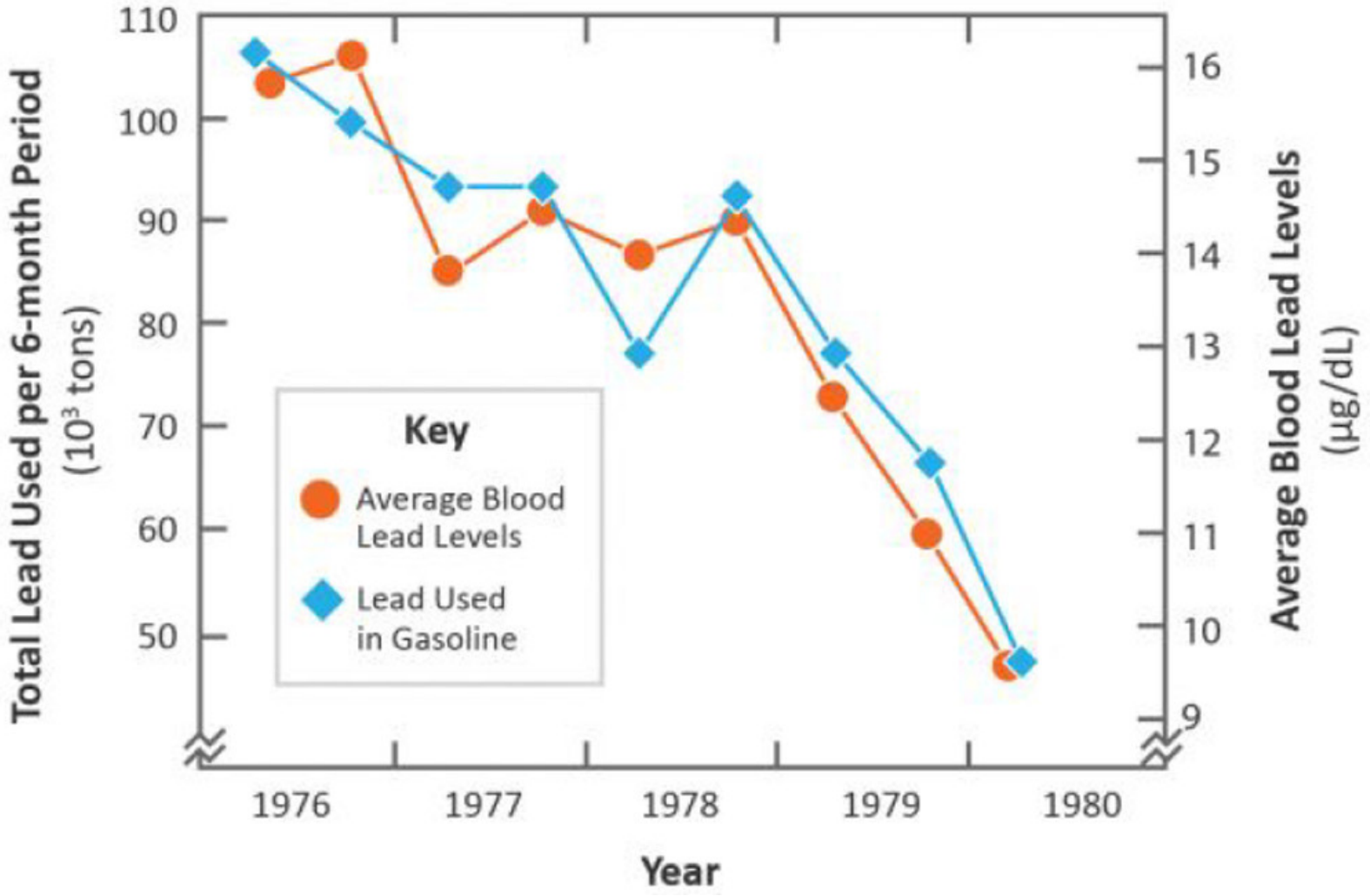
- Clean Air Act (CAA)
- Safe Drinking Water Act (SDWA)
- Food Quality Protection Act (FQPA)
- Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)
- Resource Conservation and Recovery Act (RCRA)
- Toxic Substances Control Act (TSCA)
- Clean Water Act (CWA)

EPA's Impact – Couple Examples



Source: https://www.epa.gov/air-trends/air-quality-national-summary

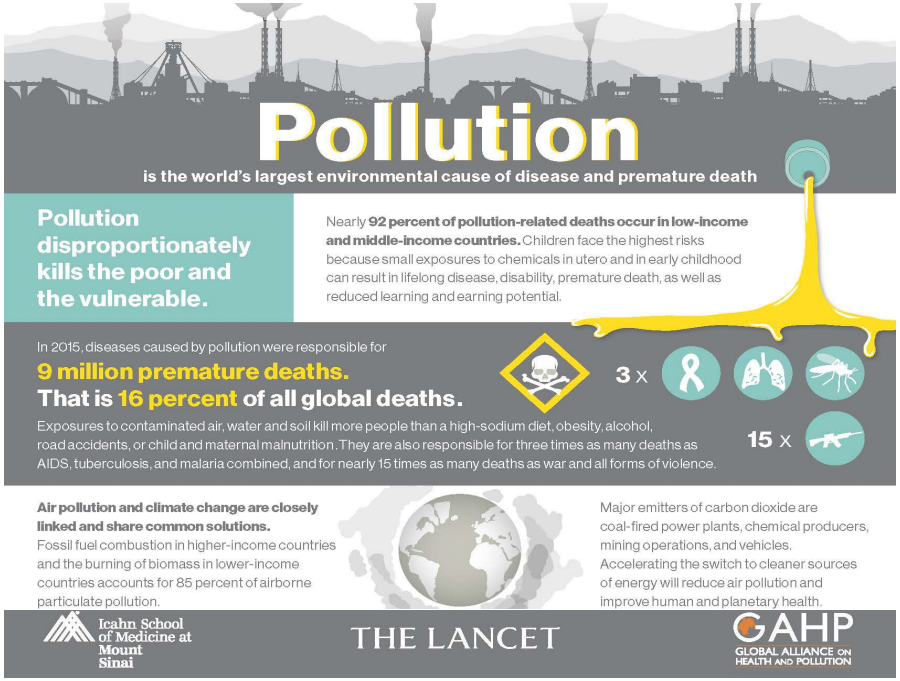
Example 2



Source: U.S. Environmental Protection Agency Air Quality Criteria for Lead; EPA/600/8−83/028AF 1986.

Public Health Context

- Pollution is known to be a leading public health threat
- A large proportion of the environment-attributed disease is of unknown etiology (Rappaport, 2016)
- Effects likely underestimated
- Exposure and effects are poorly understood
- Chemical production and release to the environment vastly outpace ability to test and measure



Source: Landrigan et al. 2017

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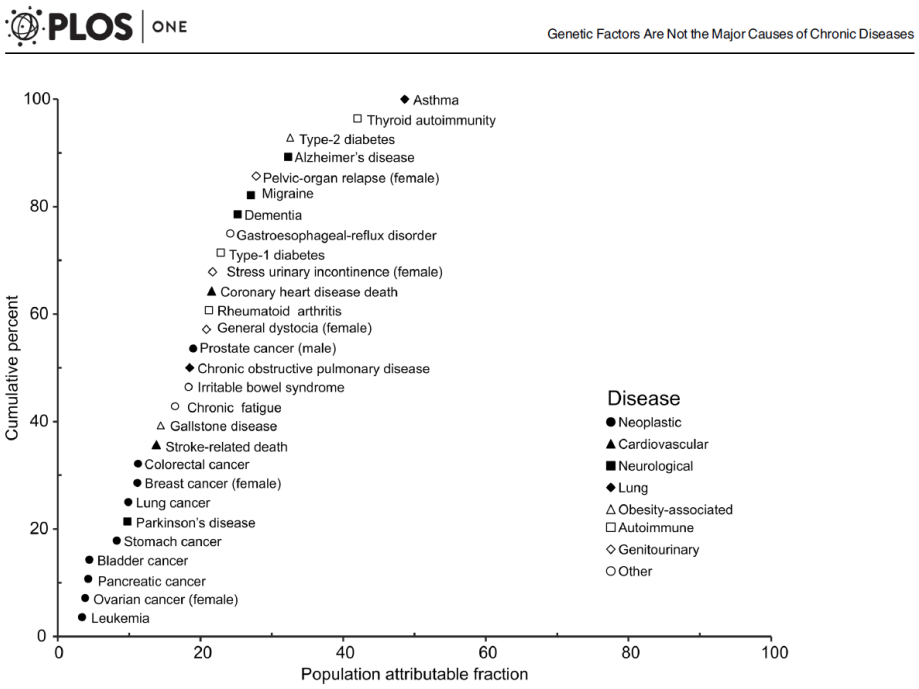

Fig 1. Population attributable fractions (PAFs) for 28 disease phenotypes estimated from studies of monozygotic twins. Sources of data and statistics are summarized in Table 2.

Source: Rappaport, 2016

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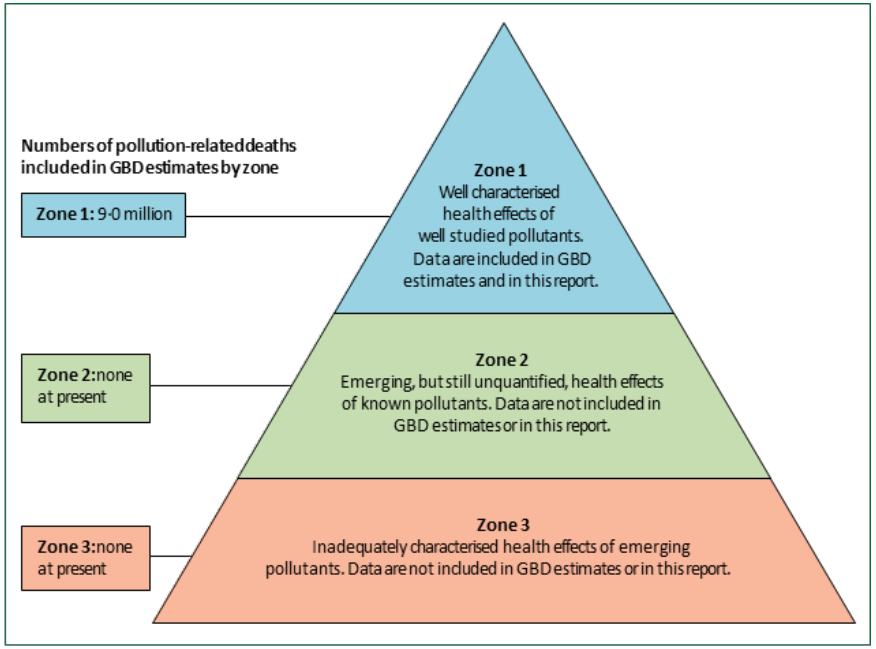

Figure 3: The pollutome

Source: Landrigan et al., 2017

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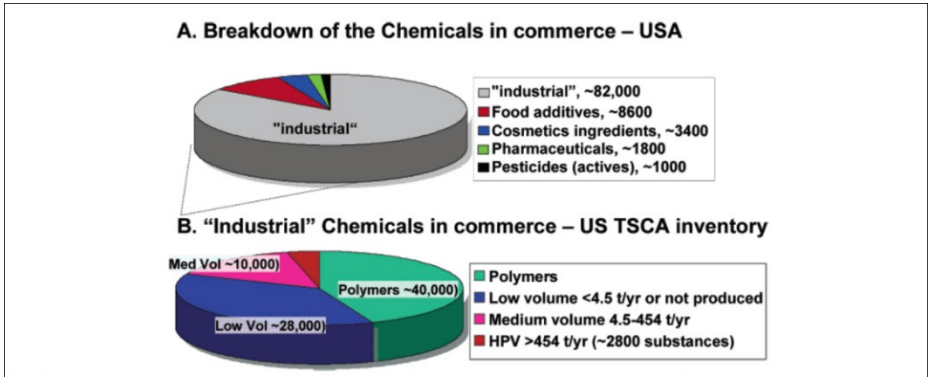
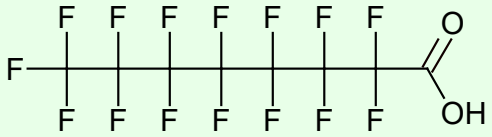


FIGURE 1. Estimated number and categories of chemicals in commerce registered for use in the United States over the past 30 years. Not all chemicals may be in current use. Similar proportions would be anticipated in other countries.

Source: Muir and Howard, 2006

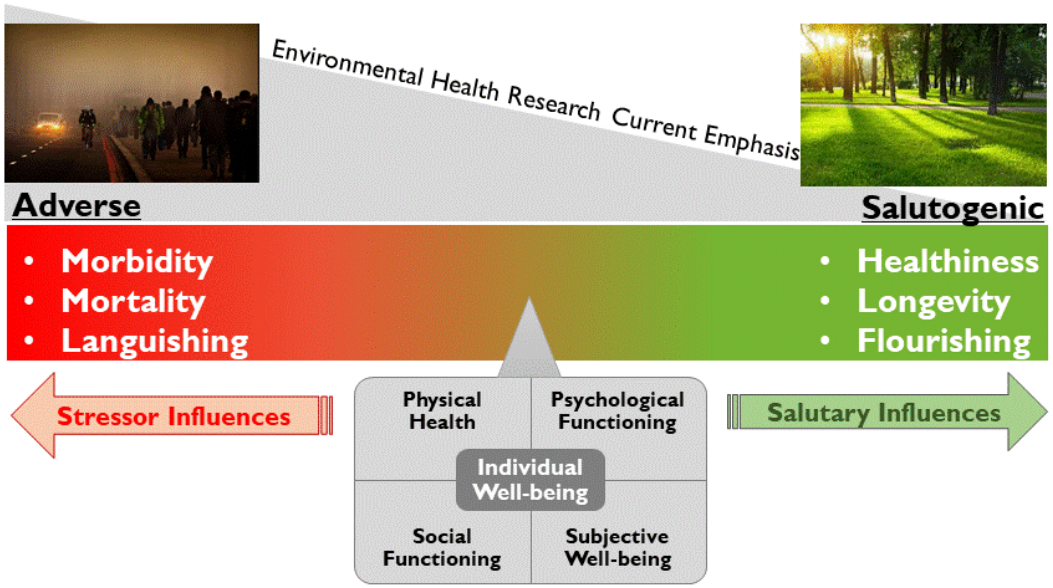
Adverse Effects: Per- and Polyfluoroalkyl Substances (PFAS) Case-In-Point

Per fluorinated = fully fluorinated



Perfluorooctanoic acid (PFOA ,C-8)

Perfluorooctanesulfonate (PFOS)

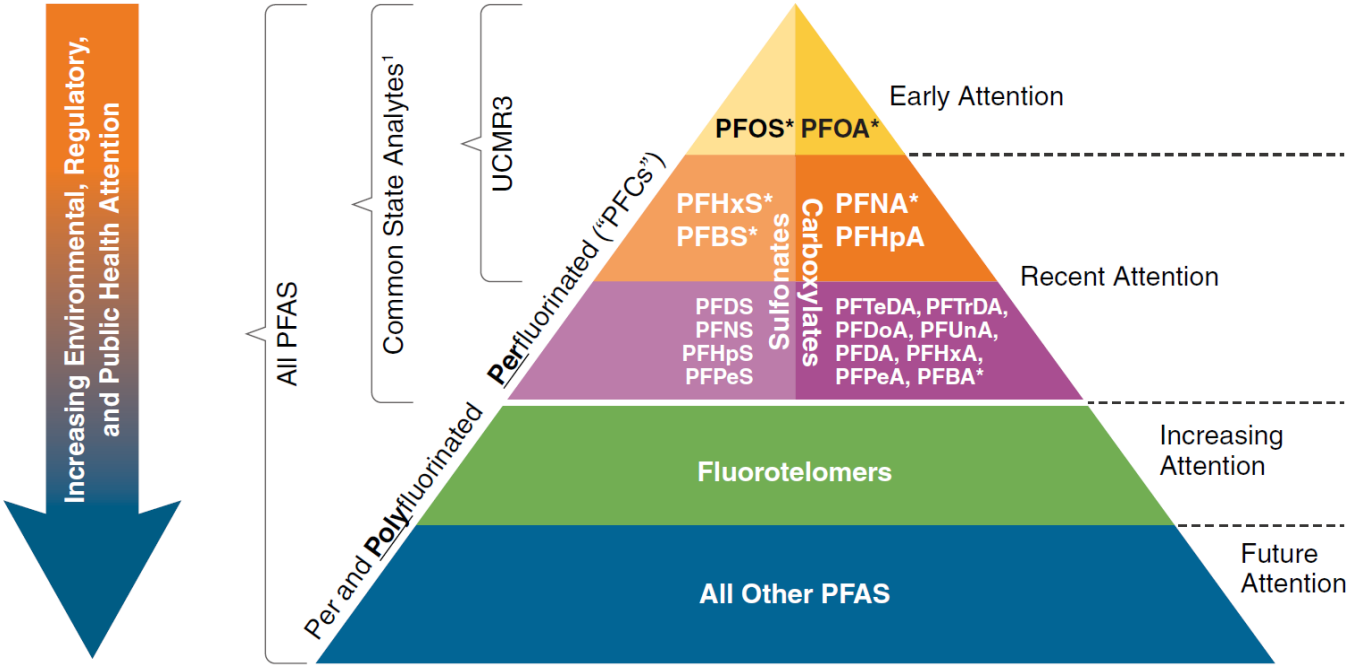


Source: Silva et al. ES&T 2018

PFAS: Environmental Health Challenges

- **Environmental contamination/human exposure**
  - Chemical class includes thousands of different chemicals
  - Highly persistent
  - Leaky production and industrial application
    - Discharges to air
    - Discharges to water
    - Widespread contamination
  - Broad consumer product use: food packaging, stain resistant materials, non-stick cookware and firefighting foam
  - Lack methods for measurement of most new-generation PFAS
- **Human health effects for PFOA and PFOS well established based on human epidemiology and animal studies**
  - Low infant birth weights, effects on the immune system, liver effects, increased cholesterol levels, cancer, and thyroid hormone disruption
  - Largely unknown for other PFAS
- **Many states, regions, and communities concerned about PFAS but lack lab capability for full environmental characterization**

Little Known About Exposure to Most PFAS



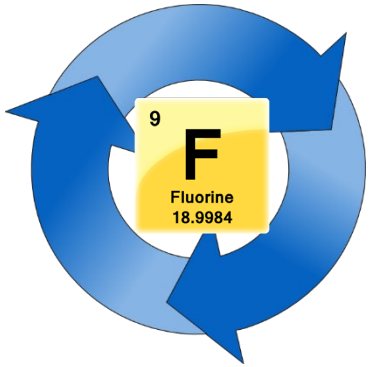
Source

ITRC
50 F St. NW, Suite 350
Washington, DC 20001
itrcweb.org

Non-Targeted Analysis: A Potential Solution to the Pollutome

United States Environmental Protection Agency

Analytical Instruments



Tools & Workflows

FOR IDENT

XCMS Online

MetFrag

Chemical Database

https://comptox.epa.gov/

PFAS in the NC Cape Fear River

The NTA Cape Fear PFAS Story

NTA Methods Development → Application to Cape Fear → Media Attention → State/Region Partnership → NC DEQ Regulatory Action → Reduced PFAS in DW

NTA Identifies GenX

Environmental Science & Technology

November 2015

Article

pubs.acs.org/est

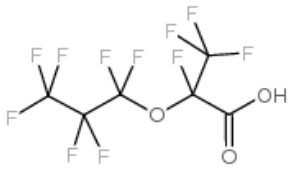
Identification of Novel Perfluoroalkyl Ether Carboxylic Acids (PFECAs) and Sulfonic Acids (PFESAs) in Natural Waters Using Accurate Mass Time-of-Flight Mass Spectrometry (TOFMS)

Mark Strynar,[*,†] Sonia Dagnino,[†,‡] Rebecca McMahen,[†,‡] Shuang Liang,[†,‡] Andrew Lindstrom,[†] Erik Andersen,[†] Larry McMillan,[§] Michael Thurman,[∥] Imma Ferrer,[∥] and Carol Ball[⊥]

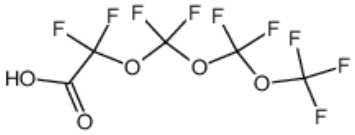
Table 1. Accurate Mass of Polyfluorinated Compounds and In-Source Artifacts Found in Extracted Water Samples

number	formula	CAS no.	name	$[M]^a$	$[M-H]^-$ m/z	$[2M-2H+Na]^-$ m/z	$[2M-H]^-$ m/z
Monoether PFECAs							
1	$C_3HF_5O_3$			179.9846	178.9773	380.9438	358.9619
2	$C_4HF_7O_3$			229.9813	228.9740	480.9372	458.9553
3	$C_5HF_9O_3$	863090-89-5		279.9782	278.9709	580.9310	558.9491
4	$C_6HF_{11}O_3$	13252-13-6	undecafluoro-2-methyl-3-oxahexanoic acid	329.9750	328.9677	680.9247	658.9427
5	$C_7HF_{13}O_3$			379.9718	378.9645	780.9182	758.9363
6	$C_8HF_{15}O_3$			429.9686	428.9613	880.9118	858.9299
Polyether PFECAs							
7	$C_7HF_{13}O_7$	39492-91-6	perfluoro-3,5,7,9,11-pentaoxadodecanoic acid	443.9515	442.9442	908.8776	886.8957
8	$C_6HF_{11}O_6$	39492-90-5	perfluoro-3,5,7,9-butaoxadecanoic acid	377.9598	376.9525	776.8942	754.9123
9	$C_5HF_9O_5$	39492-89-2	perfluoro-3,5,7-propaoxaoctanoic acid	311.9681	310.9608	644.9108	622.9289
10	$C_4HF_7O_4$	39492-88-1	perfluoro-3,5-dioxahexanoic acid	245.9764	244.9691	512.9274	490.9455
PFESAs							
11	$C_7HF_{13}O_5S$	66796-30-3[b]		443.9337	442.9264		
12	$C_7H_2F_{14}O_5S$			463.9399	462.9326		

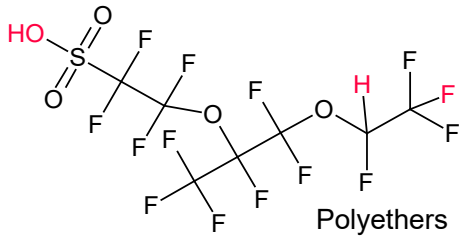
Example Structures



Monoether (6): GenX (HFPO-DA)



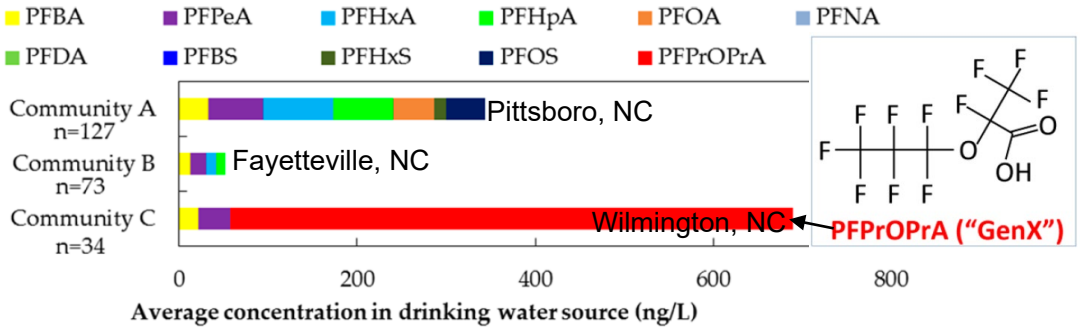
Polyethers (4):



Polyethers sulfonates (2):

Emerging PFAS Quantified

- **GenX found in drinking water downstream of Chemours**



Environmental Science & Technology Letters
November 2016
Letter
pubs.acs.org/journal/estlcu

Legacy and Emerging Perfluoroalkyl Substances Are Important Drinking Water Contaminants in the Cape Fear River Watershed of North Carolina

Mei Sun,[*,†,‡] Elisa Arevalo,[‡] Mark Strynar,[§] Andrew Lindstrom,[§] Michael Richardson,[∥] Ben Kearns,[∥] Adam Pickett,[⊥] Chris Smith,[#] and Detlef R. U. Knappe[‡]

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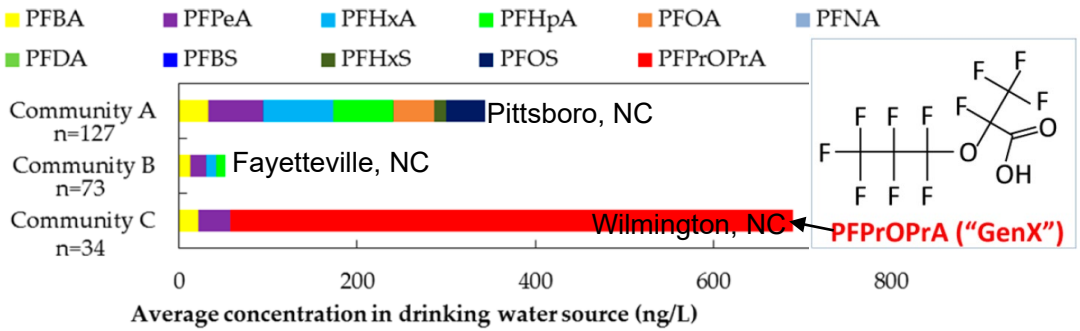
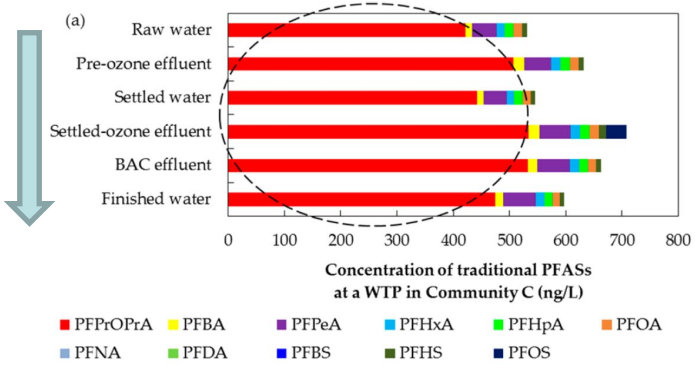


- **Effectiveness of treatment at a conventional WTP**



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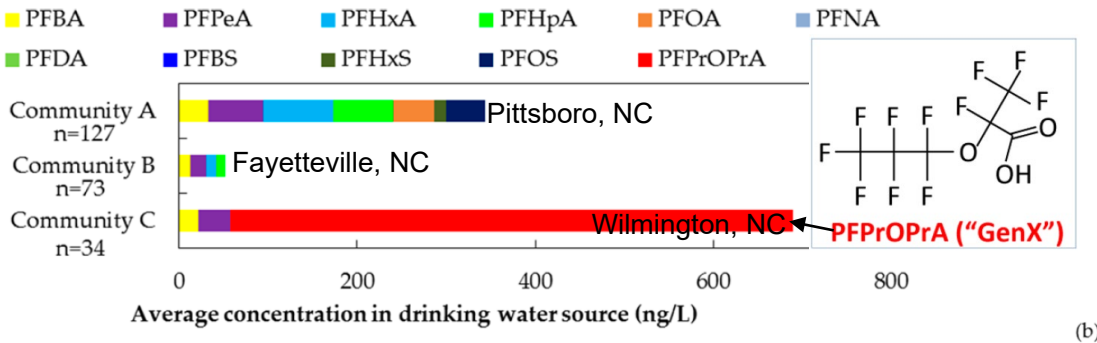

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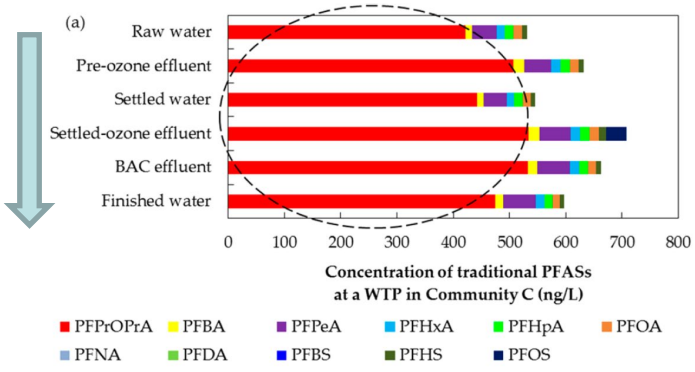

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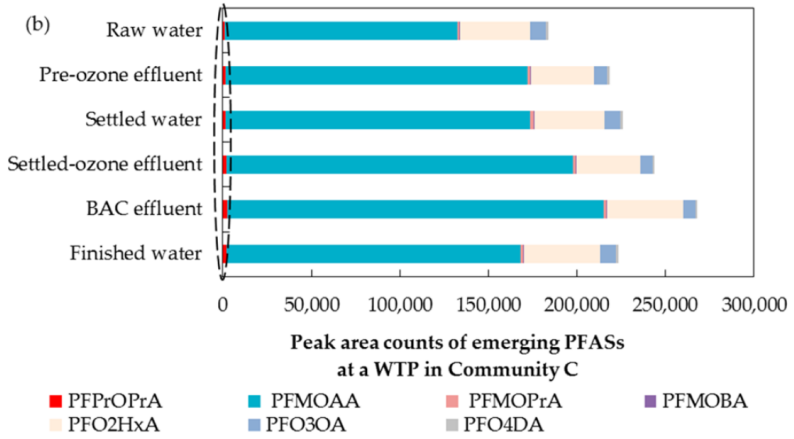
- **And "tip of the iceberg" of total PFAS present**



News Media Picks Up Story

SECTIONS ☰ NEWS SPORTS ENTERTAINMENT LIFE OBITUARIES E-EDITION CARS JOBS HOMES CLASSIFIEDS MEMBER REWARDS

First Broke, June 7, 2017

StarNews 150th 1867 • 2017

Toxin taints CFPUA drinking water

MOST POPULAR

1. Carolina Surf condos - in danger of collapse - condemned, evacuated
   Jul 2 at 5:50 AM
2. Man injured by hook, not bit by shark at Wrightsville Beach
   Jun 30 at 1:43 PM
3. Murder suspect had other charges pending
   Jul 2 at 5:44 AM
4. Residents not allowed back into Carolina Surf condos
   Jul 4 at 7:33 AM

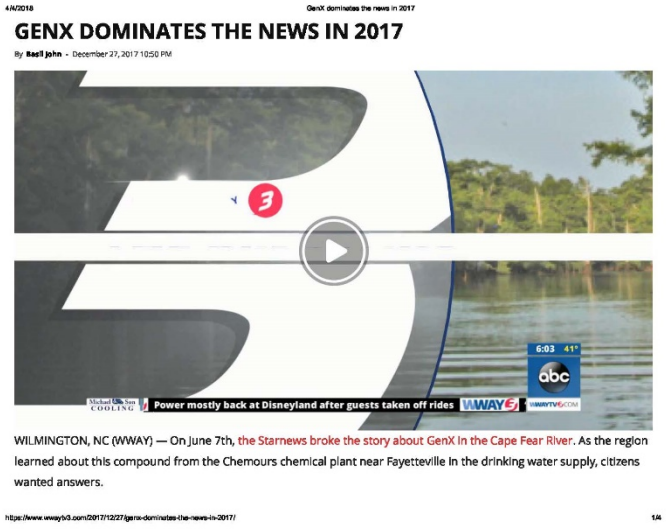
OUR PICKS

▲ HIDE CAPTION

A 2000 aerial photo of Fayetteville Works on the Cumberland-Bladen county line. The site, home to several plants, one of which makes GenX, is about 100 miles upstream from Wilmington. [COURTESY OF THE FAYETTEVILLE OBSERVER]

By Vaughn Hagerty StarNews Correspondent
Posted Jun 7, 2017 at 10:31 AM
Updated Jun 8, 2017 at 10:38 AM

Utility can't filter out chemical produced upriver



4/4/2018 GenX dominates the news in 2017

GENX DOMINATES THE NEWS IN 2017

By Basil John - December 27, 2017 10:50 PM

WILMINGTON, NC (WWAY) — On June 7th, the Starnews broke the story about GenX in the Cape Fear River. As the region learned about this compound from the Chemours chemical plant near Fayetteville in the drinking water supply, citizens wanted answers.

https://www.wwaytv3.com/2017/12/27/genx-dominates-the-news-in-2017/ 1/4

https://www.wwaytv3.com/2017/12/27/genx-dominates-the-news-in-2017/

Translating Research to Action

NTA PFAS research focused on the Lower Cape Fear River published

- Press coverage
  - NC DEQ requests assistance; ORD, R4, NC DEQ partnership formed
    - "Study" designed / QAPP developed / sampling and analysis initiated
      - ORD prepares 8 actionable data reports Aug-Dec 2017
        - NC DEQ makes reports public and basis for regulatory action
          - PFAS discharge to Cape Fear River discontinued
            - PFAS in DW for ~400,000 residents reduced
              - Public health protected

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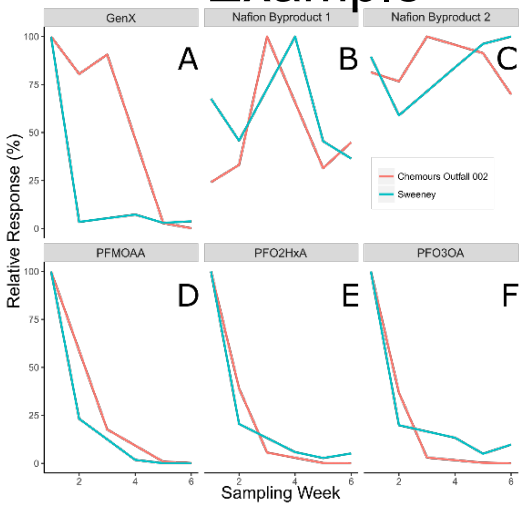
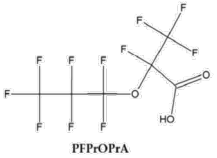
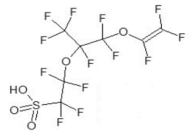
Example

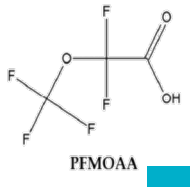


GenX (HFPO-DA)

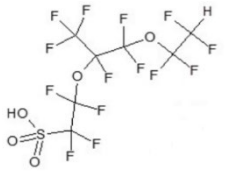


Nafion byproduct 1





Nafion byproduct 2



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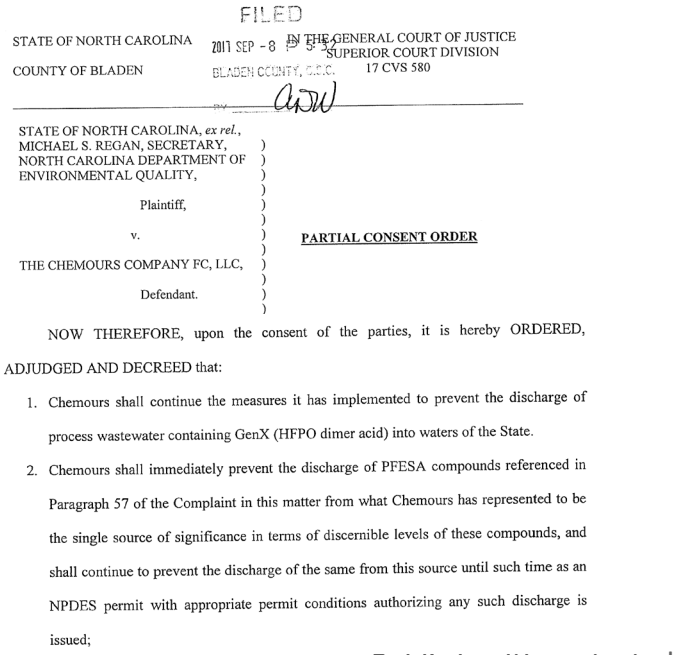


FILED

STATE OF NORTH CAROLINA — IN THE GENERAL COURT OF JUSTICE
2017 SEP -8 P 3:32
COUNTY OF BLADEN — SUPERIOR COURT DIVISION
BLADEN COUNTY, C.S.C. — 17 CVS 580

STATE OF NORTH CAROLINA, *ex rel.*, MICHAEL S. REGAN, SECRETARY, NORTH CAROLINA DEPARTMENT OF ENVIRONMENTAL QUALITY,

Plaintiff,

v.

THE CHEMOURS COMPANY FC, LLC,

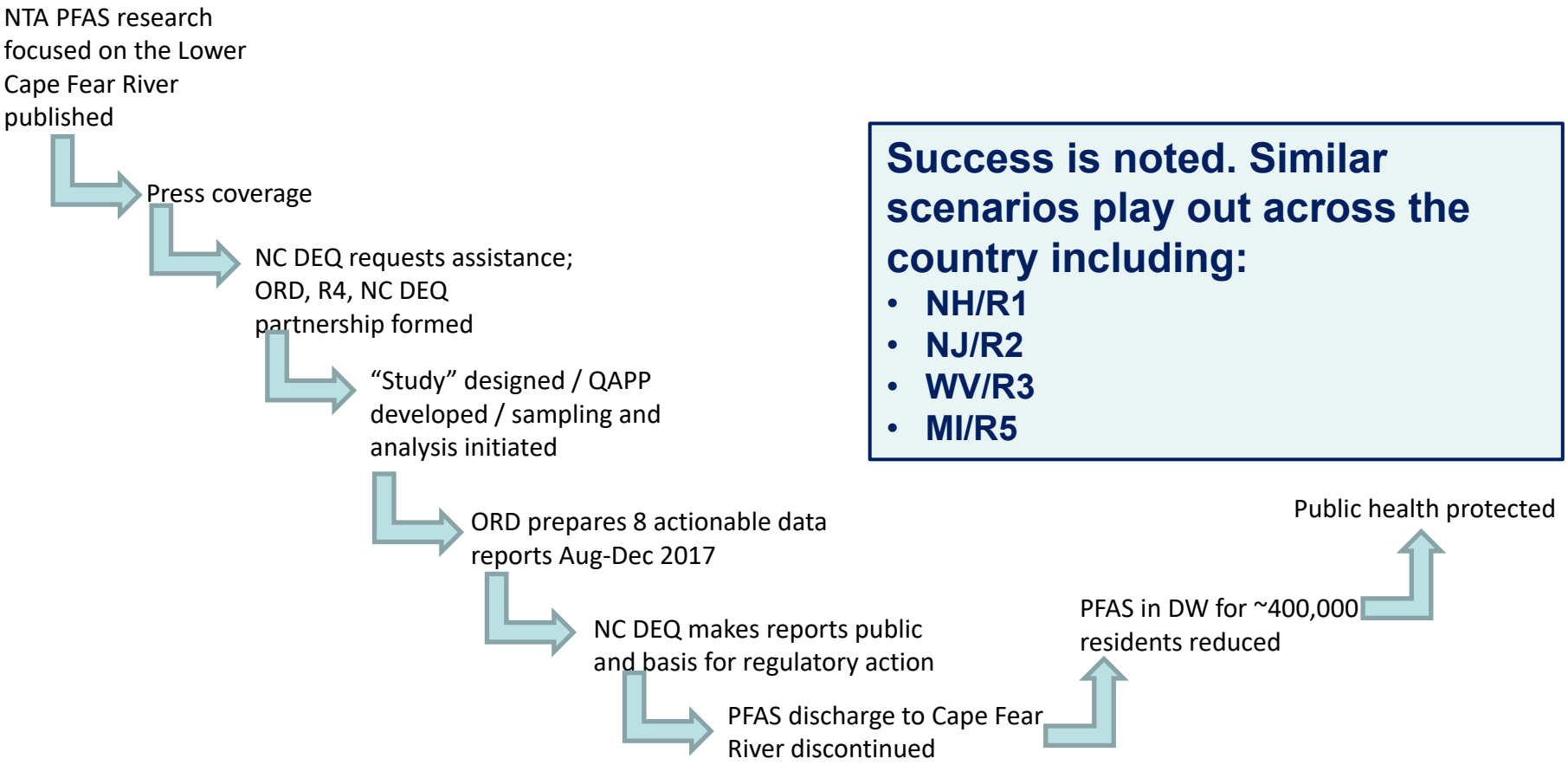
Defendant.

PARTIAL CONSENT ORDER

NOW THEREFORE, upon the consent of the parties, it is hereby ORDERED, ADJUDGED AND DECREED that:

1. Chemours shall continue the measures it has implemented to prevent the discharge of process wastewater containing GenX (HFPO dimer acid) into waters of the State.
2. Chemours shall immediately prevent the discharge of PFESA compounds referenced in Paragraph 57 of the Complaint in this matter from what Chemours has represented to be the single source of significance in terms of discernible levels of these compounds, and shall continue to prevent the discharge of the same from this source until such time as an NPDES permit with appropriate permit conditions authorizing any such discharge is issued;

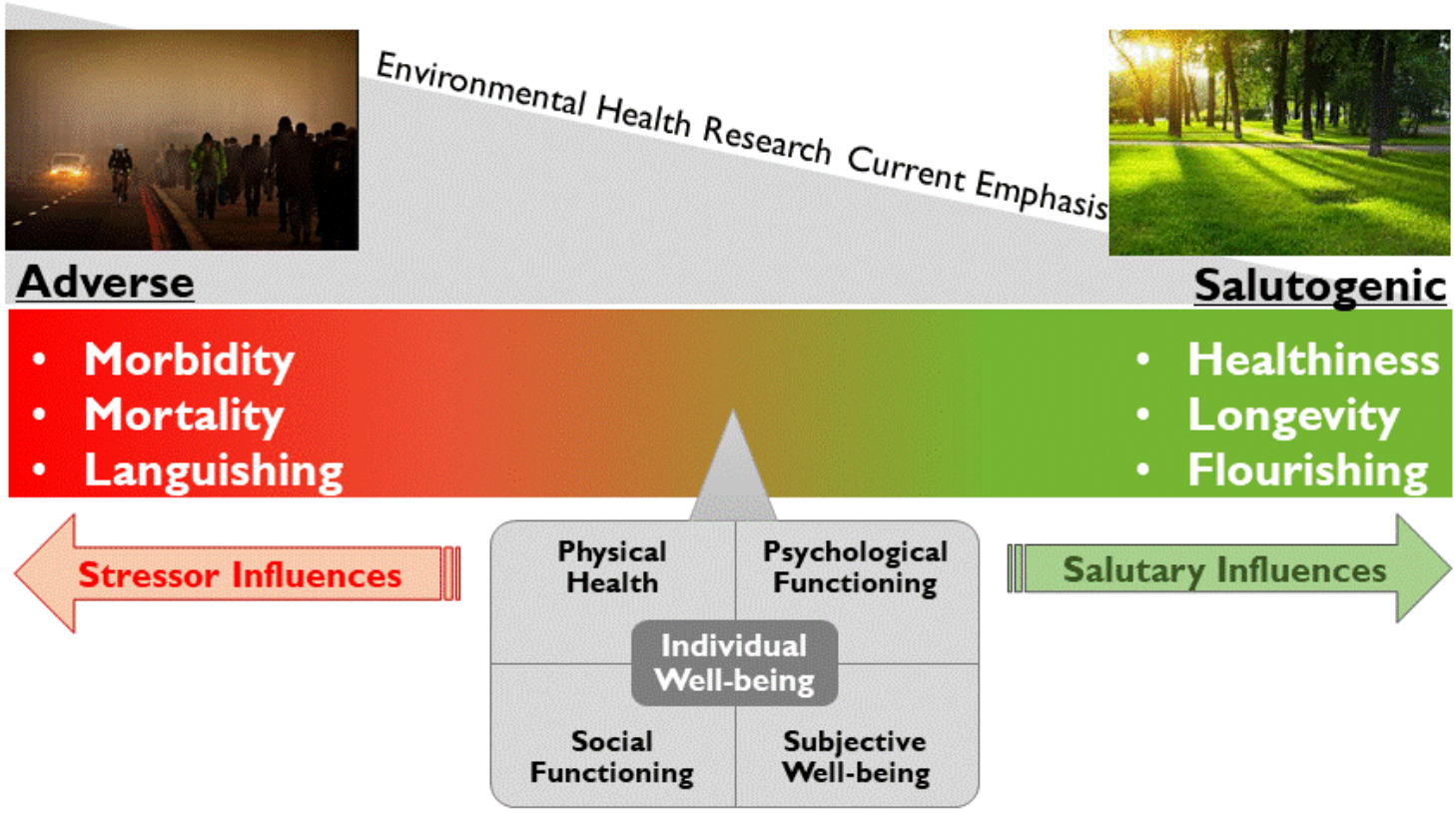
Translating Research to Action



Success is noted. Similar scenarios play out across the country including:

- **NH/R1**
- **NJ/R2**
- **WV/R3**
- **MI/R5**

Research on the Salutogenic End of Spectrum



Source: Silva et al., ES&T 2018

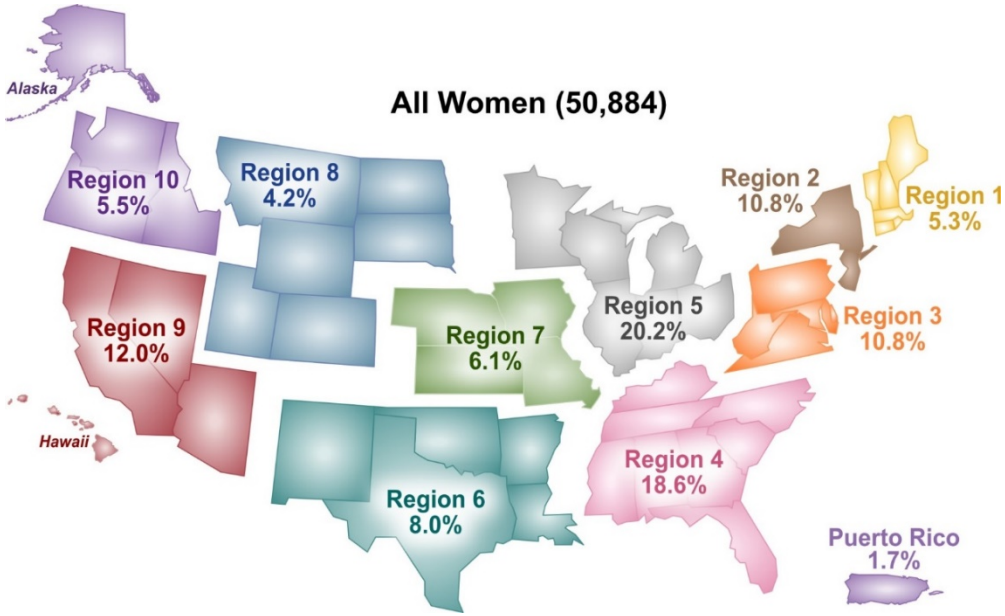
Research Rationale & Hypotheses

- Rationale
  - Salutogenic concept of natural environment introduced by Antonovsky, 1996 but generally understudied especially in the U.S., on a national scale, and based on individual-level analysis (Silva et al. 2018)
  - Prior evidence showed living in an area with more greenness (Dadvand et al., 2016) or more trees (Reid et al., 2017) associated with increased odds of reporting better general health
- Hypotheses
  - Residential increased %Tree Canopy and decreased %Developed Impervious is associated with improved self-reported general health
  - Physical activity, social support, and air quality mediate the association above
  - Exposure – effect associations vary by urbanicity and climate region

Study Population: NIEHS Sister Study Cohort

Question basis of outcome: *In the past 24 months, would you say your health has generally been Poor, Fair, Good, Very Good, or Excellent?*

- **Launched in August 2003**, enrollment closed in July 2009
- **Follow-ups are ongoing** - available data for three follow-ups, spanning 2008-2015
- **Women aged 35-74 years** without a history of breast cancer who had a sister diagnosed with breast cancer
- **Targeted recruitment strategies** for minority, lower education, and older women
- **Large number of variables available** (health outcomes and covariates)

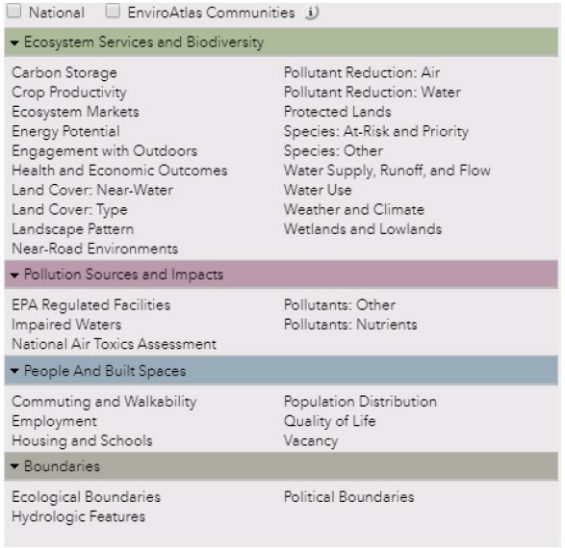


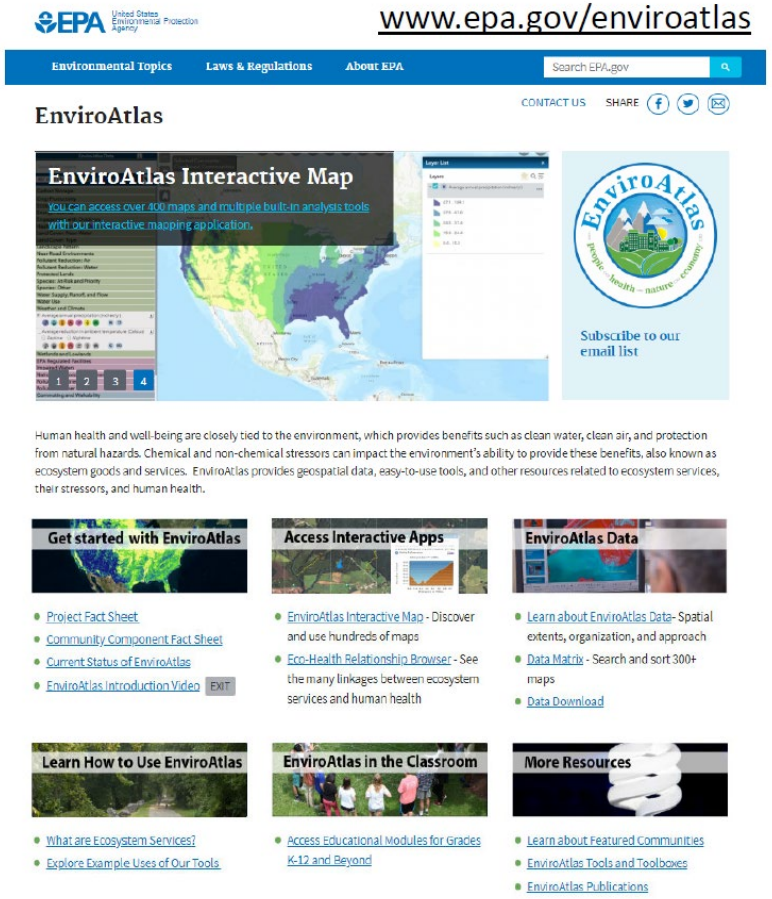
https://sisterstudy.niehs.nih.gov/English/index1.htm

Exposure to the Natural Environment

EnviroAtlas

- National land cover at 30 m^2 resolution
- Interactive tool
- 400+ geospatial data sets





Exposure Metrics

Circular buffer within **250m (near nature) and 1250m (distant nature)** from residences

Examples of buffers within 250m from residences:

Home Location

A) Mean Tree Canopy Based on **USFS Percent Tree Canopy (30m)**	5%	5%	30%
B) Mean Non-Gray Calculated based on **100 - NLCD Percent Developed Imperviousness (30m)**	46%	80%	72%

*USFS - US Forest Service; and NLCD - National Land Cover Database

Green Classification & Example Ecosystem Services Provided

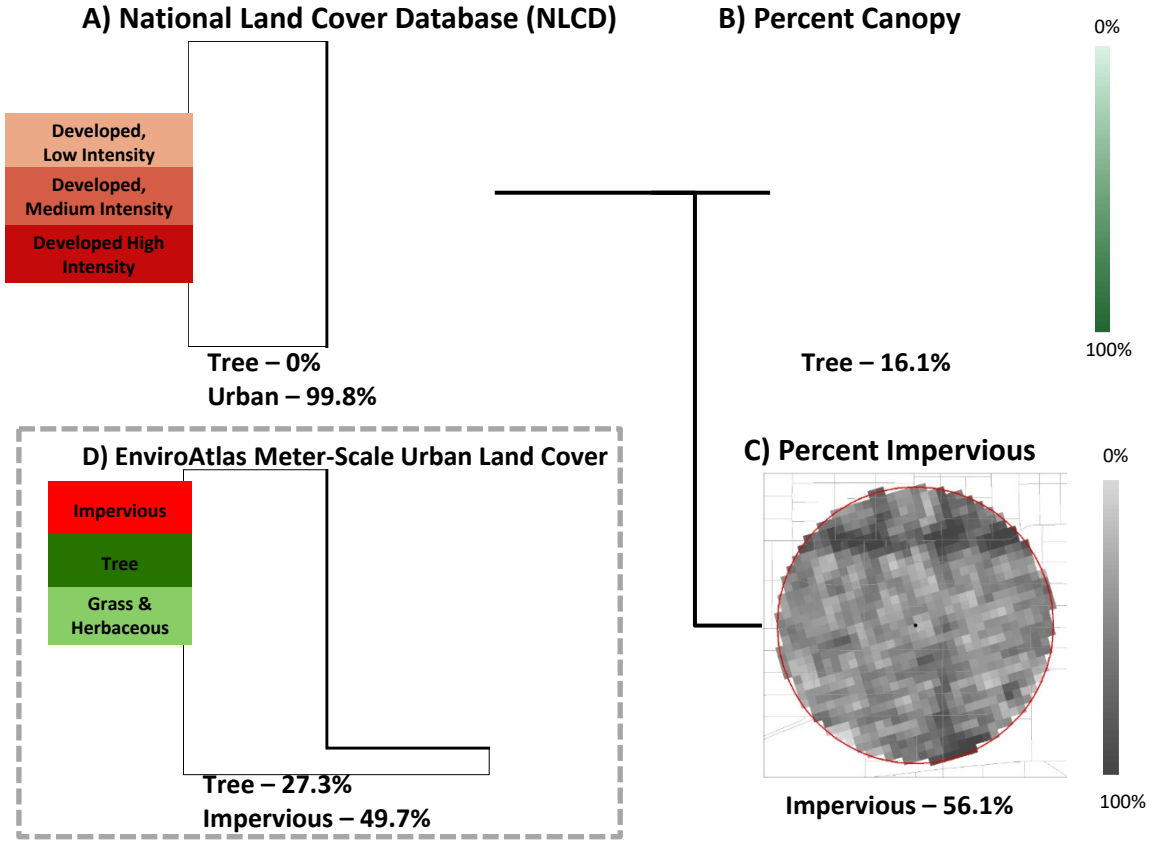
Tree

Temperature reduction
Air pollutant Removal
Carbon Sequestration
Climate Regulation
Storm Water Improvement
Erosion Control
Biodiversity
Recreational, Cultural Values
Landscape Aesthetic Values
...

Herbaceous

Erosion Control
Climate Regulation
Pollination
Biodiversity
Recreational, Cultural Values
Landscape Aesthetic Values

Characterizing Exposure EnviroAtlas Geospatial Data Layers



- **A, B & C derived from NLCD 2011 products including**
  - Land cover class (30 m)
  - Percent Canopy (30 m)
  - Percent Impervious (30 m)
- **D derived from EnviroAtlas**
  - Land cover class (1 m)

33

Data Analysis Framework

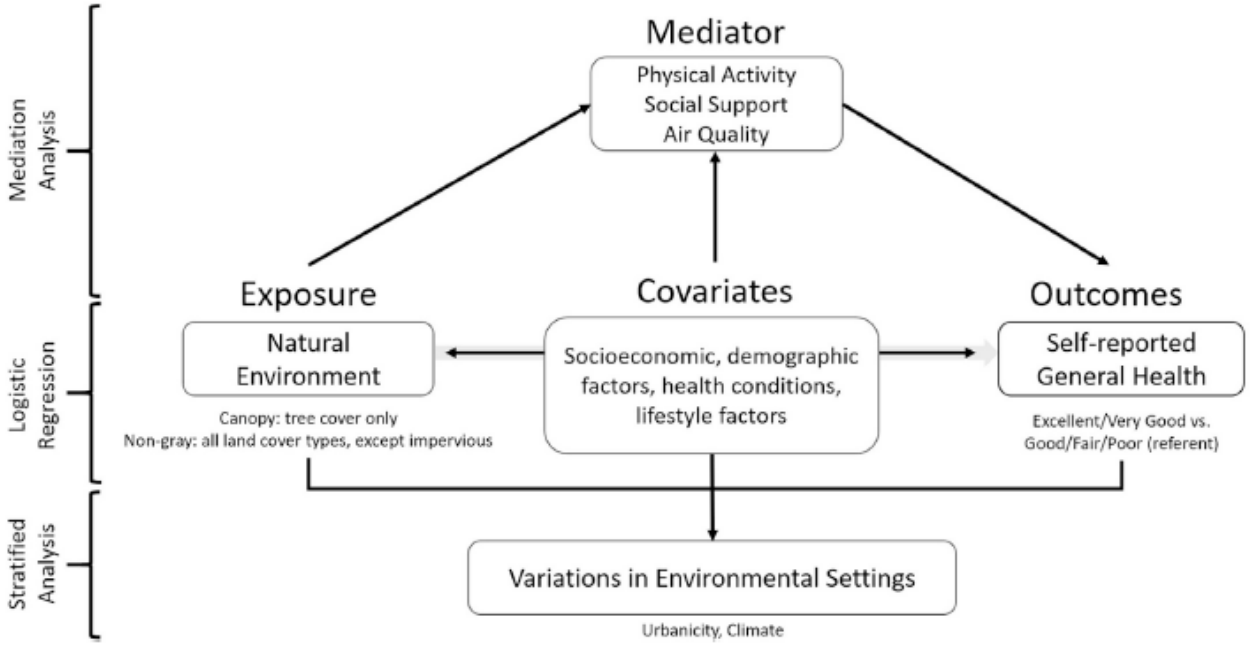


Fig. 2. Analytical approach for examining the associations between self-reported general health and natural environment.

Considerations

- Covariates selected using Gradient Boosted Regression Tree (GBRT) analysis
- Multicollinearity was identified by the generalized variance inflation factors (GVIF)
- Effect modification tested but none significant
- Spatial autocorrelation tested by Moran's *I* using model residuals
- All analyses done using SAS v9.4 except GBRT done in R

Source: Tsai et al., 2020

Sister Study Sample Overlaid on Tree Canopy

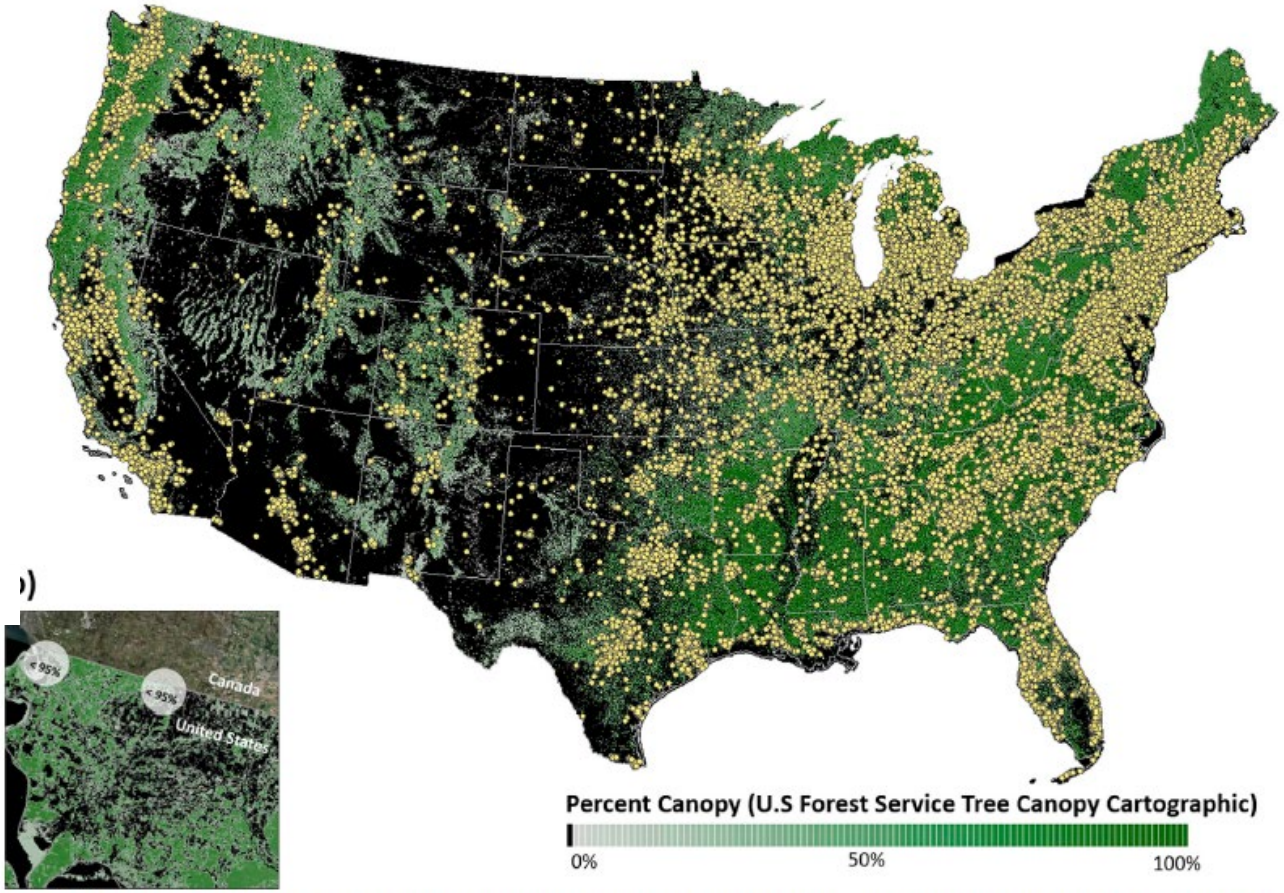


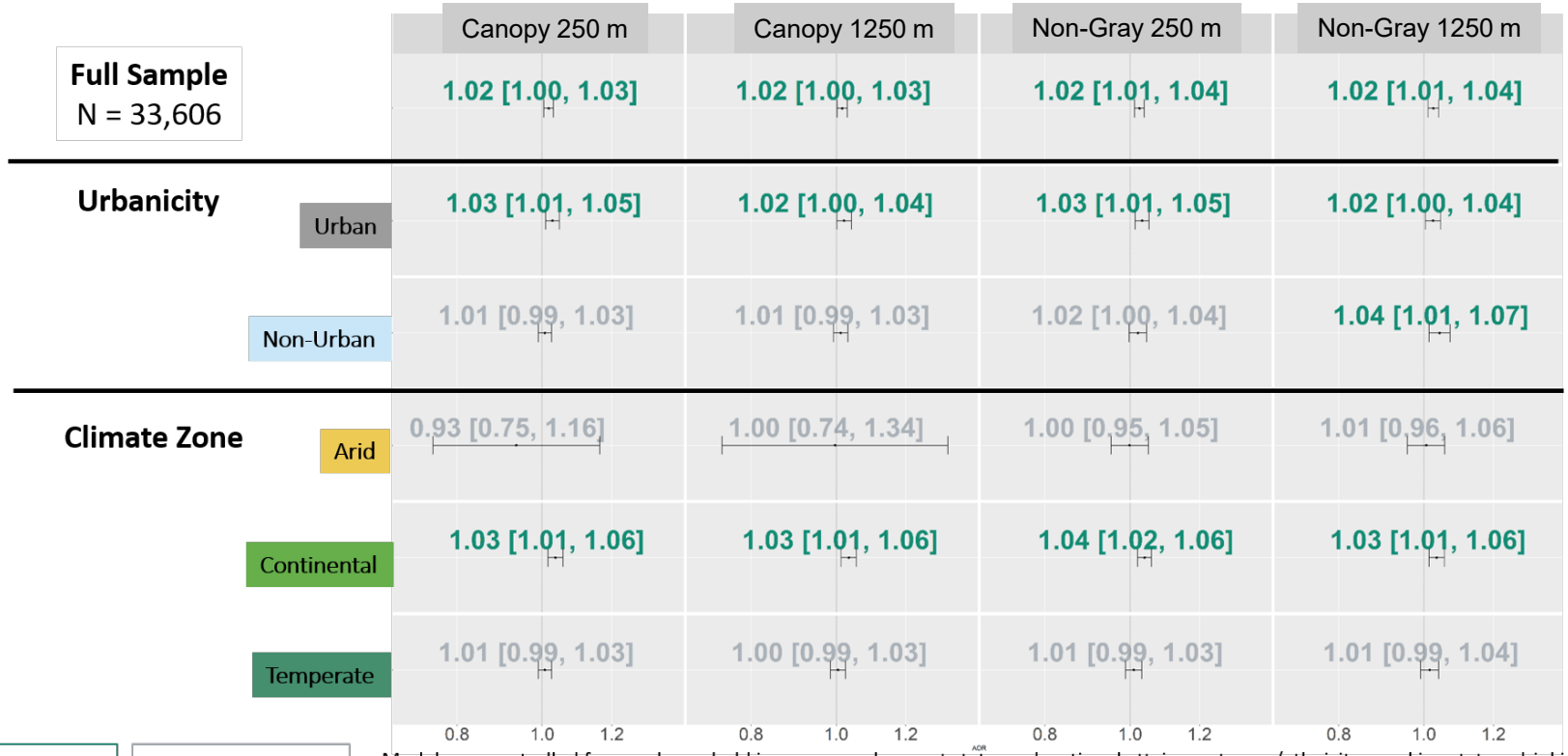
Fig. 1. a) Distribution of Sister Study participants in the conterminous United States. b) An example of participants with less than 95% coverage of their neighborhood analysis units.

Source: Tsai et al., 2020

Results: Association with Self-Reported General Health

(Tsai et al., 2020)

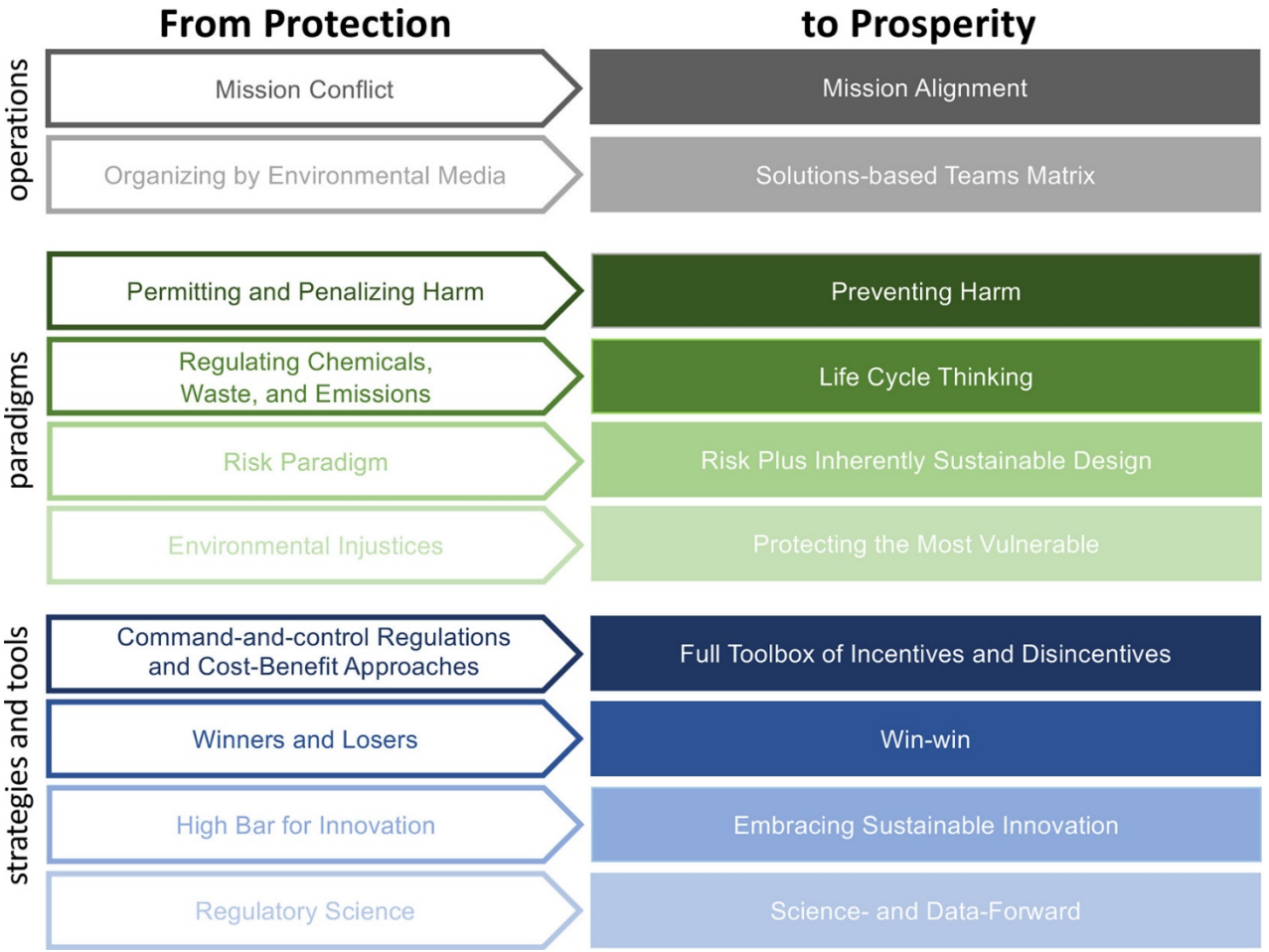
Adjusted odds ratio for reporting excellent/very good vs good/fair/poor health with 10% increase in residential natural environment.



$p < 0.05$ | Not significant

Models are controlled for age, household income, employment status, educational attainment, race/ethnicity, smoking status, drinking status, body mass index, use of depression medication, use of anxiety medication, survey season, and area deprivation index

A Perspective on EPA's Future?



Source: Anastas & Zimmerman ES&T 2021

Summary

- EPA's Mission to protect human health and the environment is of growing importance
- Highly impactful organization
- Large organization ripe with opportunity on research and policy fronts
  - Research is highly leveraged by close engagement with program office and regions
- Research examples: PFAS adverse effect; Environmental salutogenesis

Joining EPA

- Federal jobs at USA Jobs (https://www.usajobs.gov/)
- Oak Ridge Associated Universities (ORAU) (https://www.orau.org/epa/jobs.html)
- Oak Ridge Science Institute for Education (ORISE) (https://orise.orau.gov/epa/current-research-opportunities.html)

Questions / Discussion / Contact Info

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