

# Characterizing Tire Crumb Rubber for Exposure Assessment

ISES Conference Oct. 18, 2017



**Kent Thomas and Annette Guiseppi-Elie**  
U.S. EPA National Exposure Research Laboratory

**Elizabeth Irvin-Barnwell and Angela Ragin-Wilson**  
Centers for Disease Control and Prevention/  
Agency for Toxic Substances and Disease Registry

*The findings and conclusions in this presentation have not been formally disseminated by [the Centers for Disease Control and Prevention/the Agency for Toxic Substances and Disease Registry and should not be construed to represent any agency determination or policy. The views expressed in this presentation are those of the authors and do not necessarily reflect the views or policies of the U.S. EPA]*

## Synthetic Turf – Where Is It Used?



- > 12,000 fields installed
- Indoor and outdoor facilities
- Soccer, football, baseball, softball, practice, military PT
- Community parks, schools, college/universities, private facilities, professional facilities, military installations

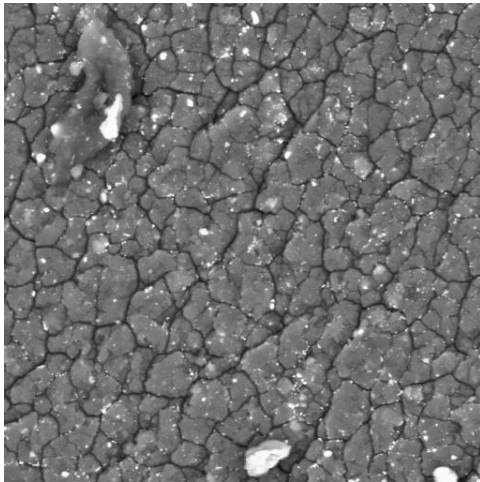
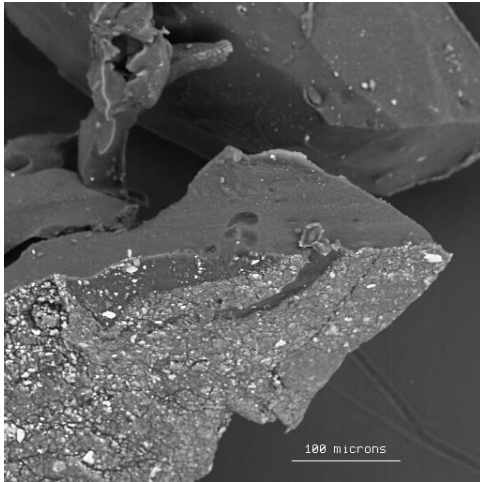


# Synthetic Turf Infill Materials

- Recycled tire crumb rubber - >90% of synthetic turf fields
  - As many as 20,000 tires per field
  - 83 – 120 tons used on typical soccer/football fields
  - Up to 14 kg/m<sup>2</sup>
  - Periodic refreshment or replacement
- Natural materials (such as cork)
- EPDM (ethylene propylene diene monomer)
- TPE (thermoplastic elastomers)
- ‘Nike Grind’ (recycled shoe rubber and/or pre-consumer waste)
- Sand (sometimes as base material or mixed with other infills )



## Tire Composition



- Rubber/elastomers (styrene-butadiene, natural)
- Reinforcement fillers (carbon black, clay, silica)
- Extender oils (naphthenic oils)
- Curatives including
  - vulcanizing agents (e.g. S and S compounds)
  - activators (e.g. ZnO) and accelerators
  - inhibitors and retarders
- Antioxidants and antiozonants
- Phenolic resins
- Plasticizers
- Metal wire; polyester/nylon fabrics; bonding agents



# Federal Research Action Plan EPA & CDC/ATSDR Research Study



Three primary research activities

- Literature review/data gaps analysis
- **Tire crumb rubber characterization**
- Exposure characterization



# Research Objectives

## Tire Crumb Rubber Characterization

- **Aim 1:** Characterize a wide range of chemical, physical, and microbiological constituents and properties for **tire crumb rubber infill** material collected from **tire recycling/crumb rubber manufacturing plants** and **synthetic turf fields** around the U.S.
- **Aim 2:** Collect information from facilities around the U.S. to better understand how synthetic turf fields with tire crumb rubber infill are operated, maintained, and used with regard to characteristics potentially impacting human exposure to tire crumb rubber constituents.



## Research Scope

- Focus on tire crumb rubber and human exposure
- Characterize U.S. tire crumb rubber collected from:
  - 9 Recycling Plants (ambient and cryogenic processes)
  - 40 Synthetic Turf Fields
    - From across four U.S. census regions
    - Outdoor and indoor fields included
    - Fields across a range of ages
    - Not a representative U.S. sample

### Limitations

- No analysis of synthetic blades, backing
- No sampling of grass fields or other infill materials
- Not assessing heat, injury, ecological impacts

# Tire Crumb Rubber Characterization

## Constituents

### Solvent Extraction

SVOCs – GC/MS/MS

SVOCs – LC/TOFMS

### Acid Digestion

Metals – ICP/MS

### Spectrometry

Metals – XRF

Metals – Electron Probe Analysis

### Particle Characterization

Particle Size – Sieve/Gravimetric

Moisture Content

Rubber/Sand Content

Particle Size/Morphology - SEM

### Microbial Characterization

Targeted Species - ddPCR

Non-Targeted Species - PCR



## Exposure-Related

### Small Chamber Emissions

@ 25° and 60° C

Formaldehyde – HPLC/UV

VOCs – GC/TOFMS

### Micro Chamber Emissions

@ 25° and 60° C

SVOCs – GC/MS/MS

SVOCs – LC/TOFMS

### Bioaccessibility

SVOCs – Sweat - GC/MS

SVOCs – Saliva – GC/MS

SVOCs – Gastric – GC/MS

### Bioaccessibility

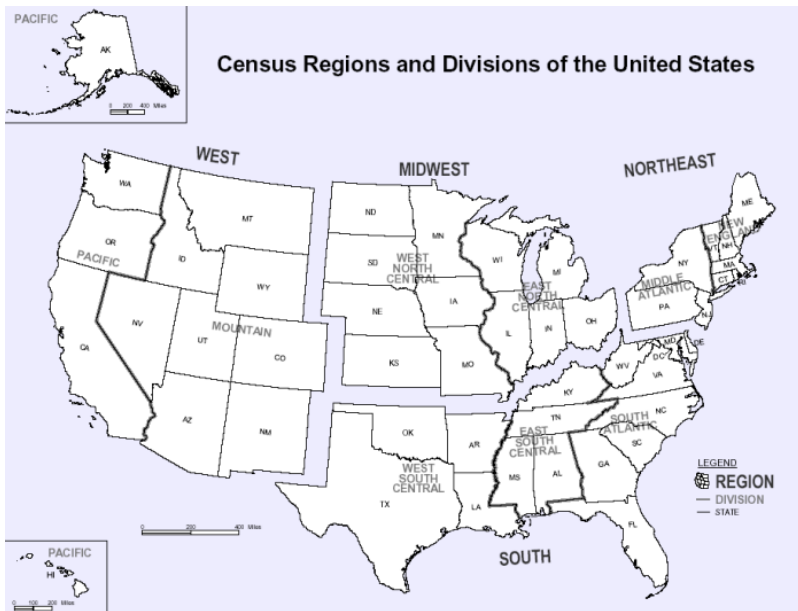
Metals – Sweat - ICP/MS

Metals – Saliva – ICP/MS

Metals – Gastric – ICP/MS



# Synthetic Turf Field and Tire Recycling Plant Tire Crumb Rubber Sample Collection



U.S. Census Region	Outdoor Fields	Indoor Fields	Total Sampled
<b>Synthetic Turf Fields</b>			
Northeast	5	4	9
South	11	2	13
Midwest	2	6	8
West	7	3	10
Total Number of Fields	25	15	40
<b>Tire Recycling Facilities</b>			
Ambient Recycling Process			6
Cryogenic Recycling Process			3
Total Number of Facilities			9

Field Age – Year of Installation	2004 - 2008	2009 - 2012	2013 - 2016
	11	19	10

# Recycling Plant Tire Crumb Characterization

## Recycling Plant

### Super Sack 1



### Super Sack 2



### Super Sack 3



Organics

Metals

Particles

## 3 Individual Samples/Plant

### All Plants/Samples

- SVOC Extraction
- Metals Digestion
- Metals XRF
- VOC Emissions
- SVOC Emissions
- Particle Size Characterization
- Metal Bioaccessibility
- SVOC Bioaccessibility
- Moisture Content
- Rubber/Sand Content

### Subset Plants

- SVOC Extraction Non-Targeted
- VOC Emission Non-Targeted
- SVOC Emission Non-Targeted
- Particle SEM
- Particle EPMA
- VOC Emission Time Series
- SVOC Emission Time Series
- SVOC Wristband Tests in Chambers

Source: U.S. EPA photo during field installation

Office of Research and Development  
National Exposure Research Laboratory

# Synthetic Turf Field Facility Questionnaire

A11. For each of the different age groups, what sports or other activities are played on the synthetic turf fields at this facility during which seasons (check all that apply)?

			Spring	Summer	Fall	Winter
<input type="checkbox"/> 12 - 18	<input type="checkbox"/>	Soccer	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	<input type="checkbox"/>	Football	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	<input type="checkbox"/>	Field Hockey	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	<input type="checkbox"/>	Baseball	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	<input type="checkbox"/>	Softball	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	<input type="checkbox"/>	Rugby	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	<input type="checkbox"/>	Ultimate Frisbee	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	<input type="checkbox"/>	Physical Training (PT)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	<input type="checkbox"/>	Physical Education (PE)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	<input type="checkbox"/>	Other: <input type="text"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	<input type="checkbox"/>	Other: <input type="text"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

A20. Are the following routine field maintenance activities performed on the outdoor synthetic field(s) at this facility?

Activity	Times per
<input type="checkbox"/> Sweeping	<input type="text"/> Day/week/month/year
<input type="checkbox"/> Brushing	<input type="text"/> Day/week/month/year
<input type="checkbox"/> Redistribution/leveling	<input type="text"/> Day/week/month/year
<input type="checkbox"/> Aerating	<input type="text"/> Day/week/month/year
<input type="checkbox"/> Magnet sweep	<input type="text"/> Day/week/month/year
<input type="checkbox"/> Rejuvenation	<input type="text"/> Day/week/month/year
<input type="checkbox"/> Deep Cleaning	<input type="text"/> Day/week/month/year

- Field Characteristics

- Age
- Tire crumb rubber addition
- Indoor/Outdoor

- User Characteristics

- Age groups
- Sports/Training by season
- Numbers/Frequencies of Users

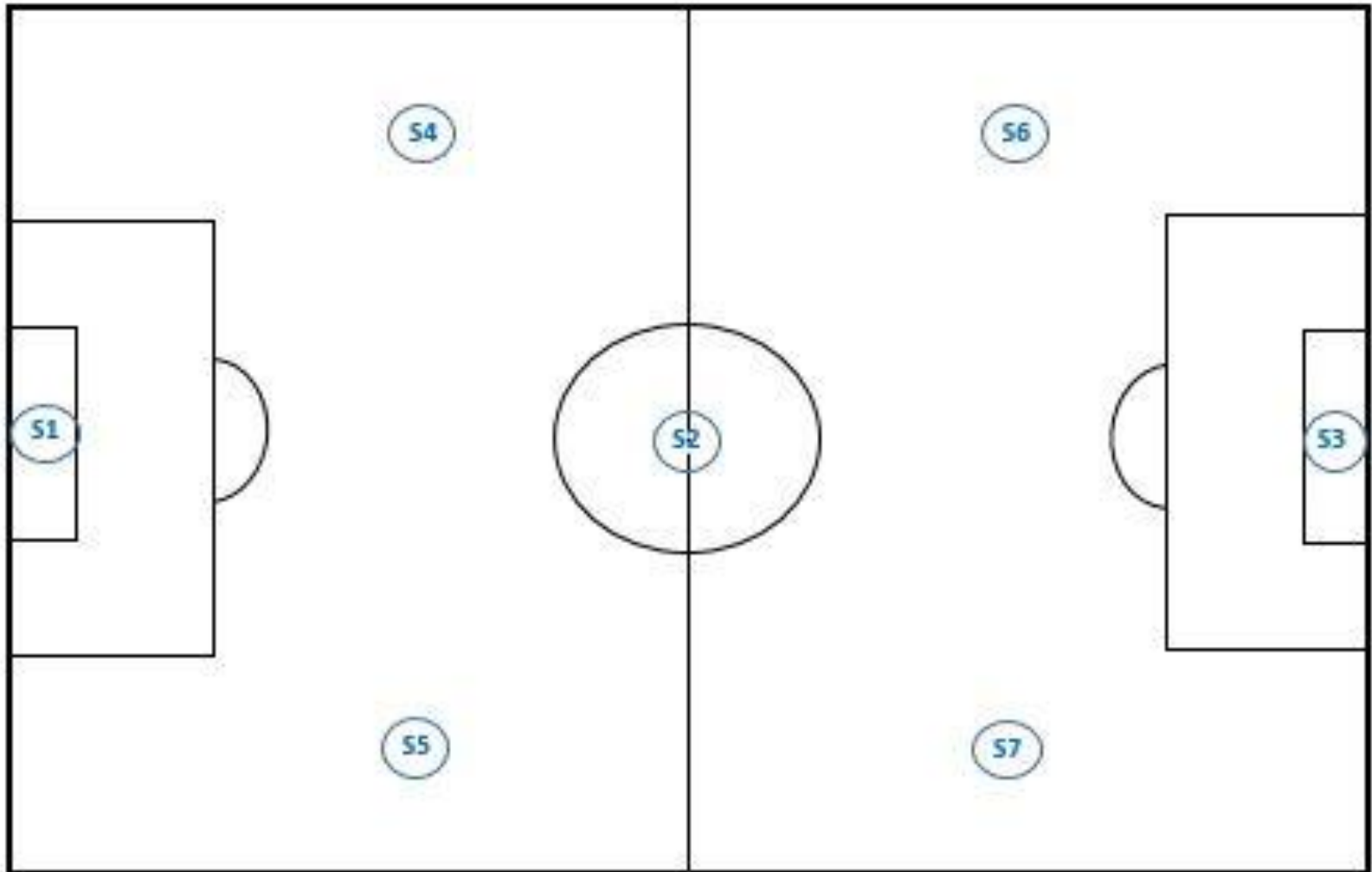
- Maintenance Practices and Frequencies

- Chemicals Used

- Fungicides or other pesticides
- Cleaning/disinfection
- Other

# Tire Crumb Collection Locations on Fields

Soccer, Football, Other Rectangular Fields





# Sample Collection

## Organics



## Metals & Particles



## Microbes



# Synthetic Turf Field Tire Crumb Characterization

## Composite Samples

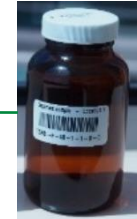
### Subset Fields

- SVOC Extraction Non-Targeted
- VOC Emission Non-Targeted
- SVOC Emission Non-Targeted
- Particle SEM
- Particle EPMA
- VOC, SVOC Emission Time Series
- SVOC Chamber Wristband

## Composite Samples

### All Fields

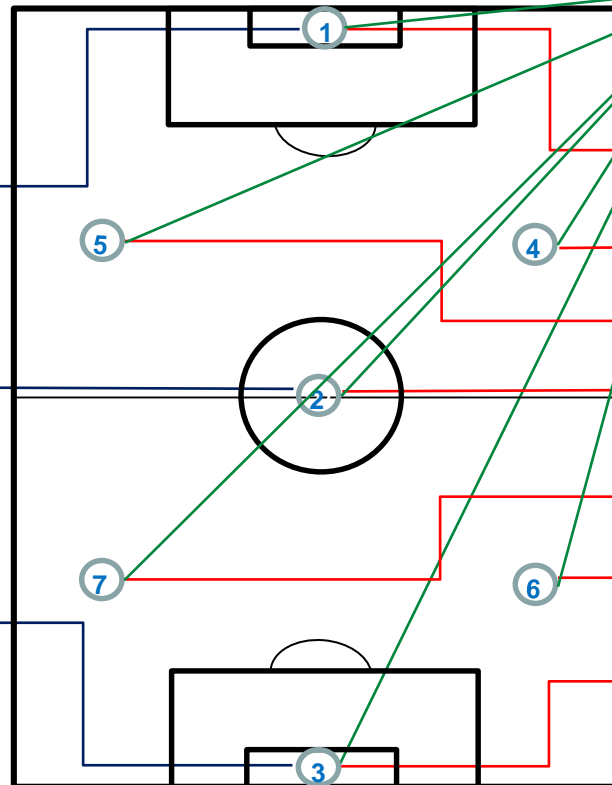
- SVOC Extraction
- Metals Digestion
- Metals XRF
- VOC Emissions
- SVOC Emissions
- Particle Characterization
- Metal Bioaccessibility
- SVOC Bioaccessibility
- Moisture Content
- Rubber/Sand Content



## 3 Individual Samples

### 5 Fields

- VOC Emissions
- SVOC Emissions
- Metals XRF
- Metals Bioaccessibility
- SVOC Bioaccessibility



## 7 Individual Samples

### All Fields

- Microbiological

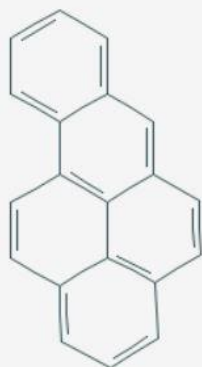
### 5 Fields

- SVOC Extraction
- Metals Digestion

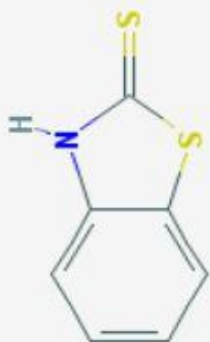


## Tire Crumb Rubber Analytes of Interest

- Metals (21)
  - Examples: Pb, Zn, Cr, Cd
- VOCs (31) *Targeted, Suspect Screening, Non-Targeted*
  - Examples: MIBK, benzothiazole, formaldehyde
- SVOCs (148) *Targeted, Suspect Screening, Non-Targeted*
  - Examples: PAHs, phthalates, 2-mercaptobenzothiazole,
- Particle characterization
  - 7 particle size fractions
  - Particle morphology
  - Moisture and sand content
- Microbial characterization (synthetic fields only)
  - Example: *Staphylococcus aureus*
  - *Targeted and non-targeted*



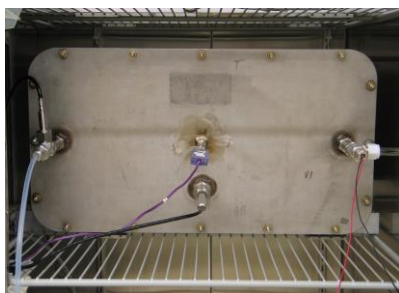
Benzo[a]pyrene



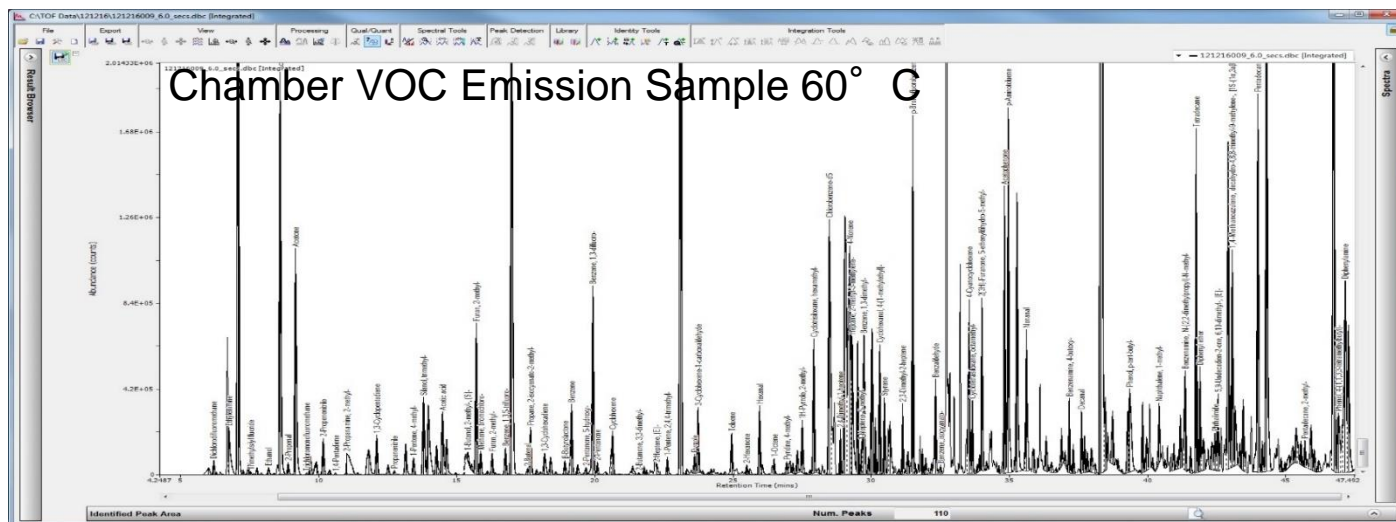
2-Mercaptobenzothiazole



# Tire Crumb Rubber Sample Analysis & Status



- Over 2900 sample analyses scheduled
- Analytical measurements ~ 80% completed
- Data processing and QA reviews in progress
- Considerable time and effort for data processing/review
  - Large numbers of analytes
  - Complex matrix
  - Large analyte concentration range





# Data Analysis and Interpretation Objectives

## **Tire Crumb Characterization**

- Chemical constituent content; microbial presence
- Differences between 'new' material from recycling plants and 'aged' material from fields
- Variability within and between fields
- Differences associated with synthetic field characteristics
  - Outdoor vs. indoor
  - Age
  - U.S. census region

## **Apply Information for Exposure Characterization**

- Tire crumb characterization data must be put into an exposure context
- Emissions and bioaccessibility data address part of this need
- Availability for exposure by inhalation, dermal contact, ingestion

# Acknowledgements

## **EPA/ORD**

Kent Thomas	NERL
Nichole Brinkman	NERL
Matthew Clifton	NER
Carry Croghan	NERL
Gregory Grissom	NERL
Larissa Hassinger	NERL
Paul Jones	NERL
Kasey Kovalcik	NERL
Tammy Lepp-Jones	NERL
Xiaoyu Liu	NRMRL
Myriam Medina-Vera	NERL
Jackie McQueen	OSP
Marsha Morgan	NERL
Karen Oliver	NERL
Linda Phillips	NCEA
Brian Schumacher	NERL
Gene Stroup	NERL
Mark Strynar	NERL
Donald Whitaker	NERL
Jianping Xue	NERL
BJ George	NHEERL
Fu-Lin Chen	NERL
Rich Walker	NERL
Andrea Clements	NERL
Peter Egeghy	NERL

## **JTI**

Matt Allen  
Tamira Cousett

## **EPA/ORD Managers**

Annette Guiseppi-Elie  
Jose Zambrana  
Jennifer Orme-Zavaleta  
Fred Hauchman  
Cynthia Sonich-Mullin  
John Vandenberg  
Ronald Hines  
Kevin Crofton

## **EPA/ORD QA**

Christine Alvarez  
Michelle Henderson  
Brittany Stuart  
Sania Tong-Argao  
Margie Vazquez

## **EPA Communication**

Monica Linnenbrink  
Carolyn Hubbard  
Dale Perry  
Emily Smith

## **EPA/OLEM**

Chris Carusiello  
Rita Chow  
Ksenija Janjic  
Charlotte Mooney  
Nicole Villamizar

## **CDC/ATSDR**

Elizabeth Irvin-Barnwell  
Angela Ragin-Wilson  
Kelsey McCall Benson  
David Chambers  
Stephanie Davis  
Zheng Li

## **CPSC**

Eric Hooker

## **US Army Public Health Center**