Air Measurement Methods and Technologies – Keeping Up with Environmental Priorities

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Environmental Measurement Symposium

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Topics

Environmental Challenges

Near-source Emissions

Ambient Air

Source Emissions

Collaborative Partnerships

Not a Policy Talk …

Research

- The science landscape is constantly evolving
- Pollutants measured at previously unseen levels of detection
- Novel, innovative technology unveiled at a rapid pace
- Emerging environmental issues and contaminants of concern

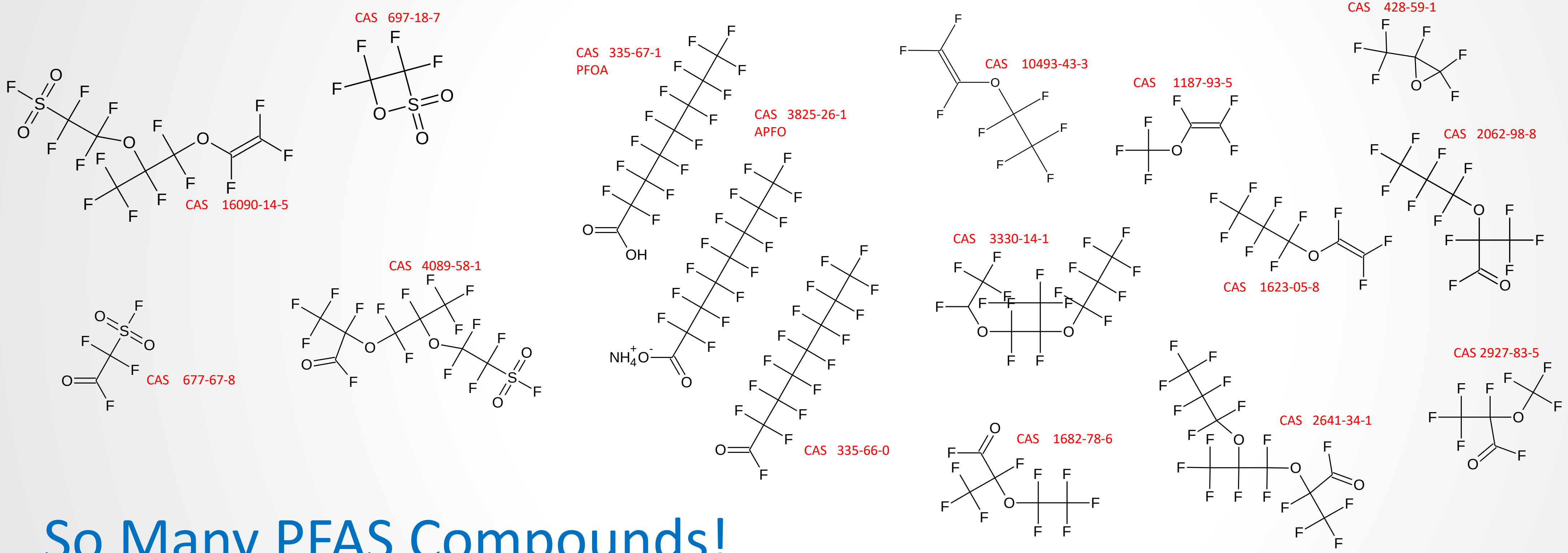
Solutions

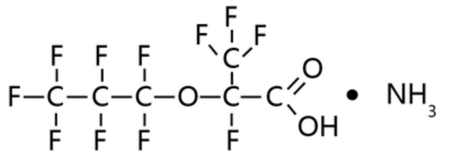
- Development and application of innovative approaches
- Improvement in problem solving capacity
- Formation of successful alliances with stakeholders

Environmental Challenges

Understanding the Problem

Pre – and Polyfluoroalkyl Substances (PFAS)





GenX Chemical Structure

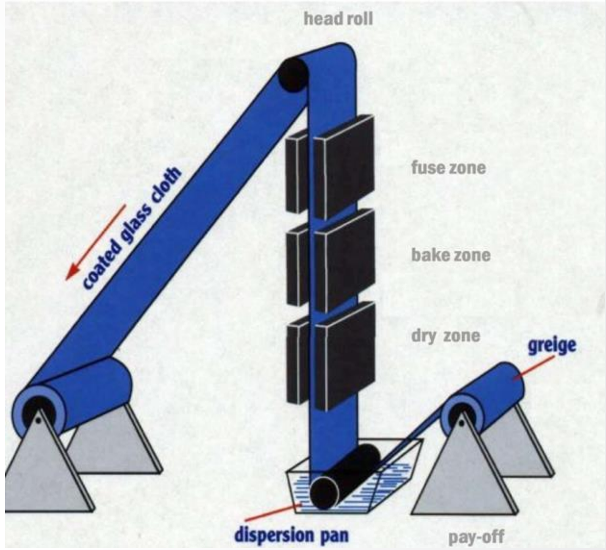
So Many PFAS Compounds!

How do we measure them?

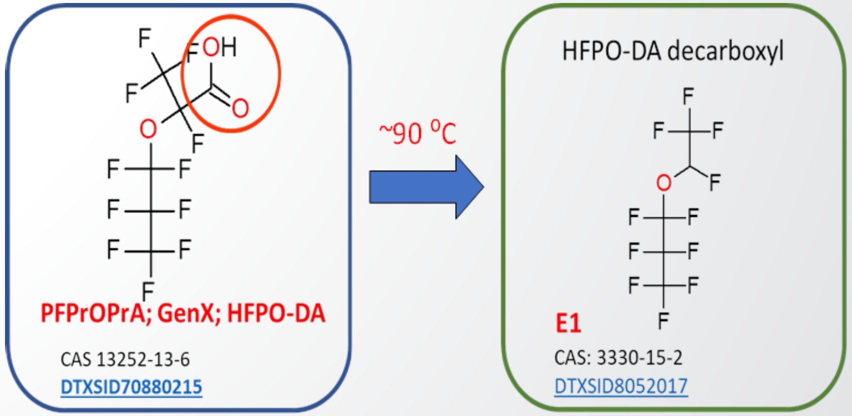
How do we destroy them?

PFAS Air Emissions Measurement Considerations/Challenges

- PFAS emission sources are diverse:
  - chemical manufacturers
  - used in commercial applications
  - emitted during thermal treatment of waste (e.g., AFFF, biosolids, municipal)
  - Products of Incomplete Destruction/Combustion (PIDs/PICs)
    - PICs historical term related to combustion or incineration
    - PIDs include non-combustion degradation species
- Process can alter emission composition
- Validated source and ambient air methods for PFAS do not exist, but some research methods are available
- Current emissions tests often target only a small number of PFAS compounds for analysis while significantly more may be present



Example Coating Process

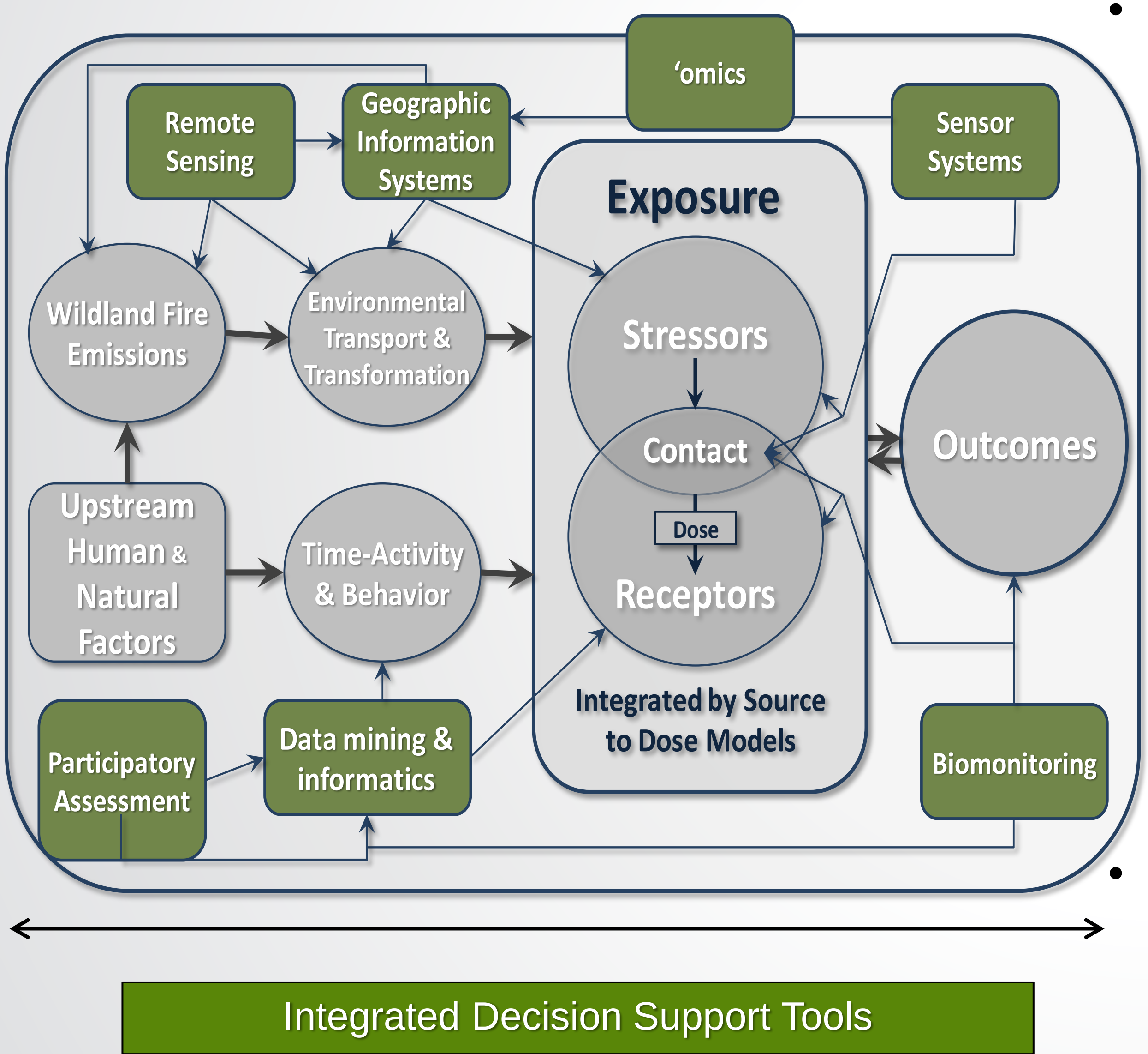


Wildland Fire
Emission Measurements & Characterization

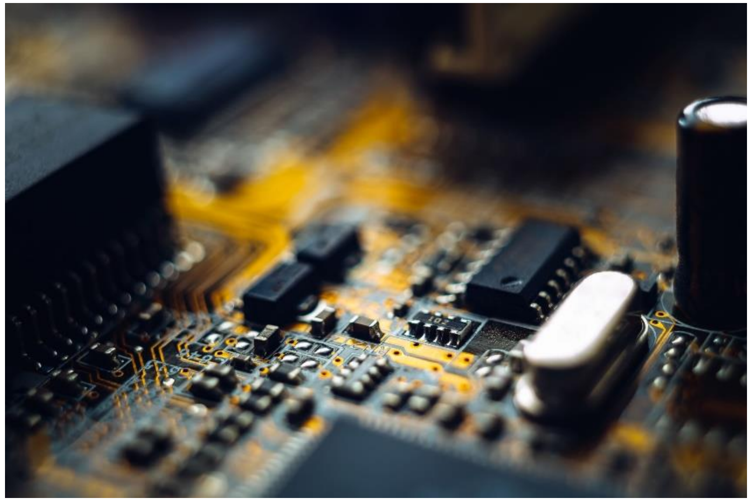
Why are wildfire smoke emissions important to EPA?

- Increasing fire size & intensity
- Community & fire fighter health
  - PM, Toxics
  - Susceptible Subpopulations
- Ambient air quality
  - PM, O_3, NOx, NH_3, CO, VOCs
- Global climate
  - CO_2, CH_4, BC, Organic Aerosols, NOx, N_2O

Wildland Fire Measurement Needs



- Elucidating wildland fire smoke impacts on public health
  - — Source emission to exposure
    - o Emission characterization
    - o Transport
    - o Atmospheric chemistry
    - o Community monitoring (NAAQS)
    - o Human exposure
  - — Model development & assessment
    - o Deterministic modeling (CMAQ)
    - o Receptor modeling (PMF, Unmix)
  - — Health effects
    - o Epidemiological modeling
    - o Mechanistic toxicological effects
- Public health communication
  - — Data integration & risk assessment
  - — Health communication (AirNow, AQI, SmokeSense)



Measure, Monitor, Characterize

Gathering Information

Emission Measurement Tools

Method Modifications

USGS UAS with ORD “Kolibri” Sensor/Sampler

Low-cost PM Sensors

Other Test Method (OTM)-45 Overview

- Covers Sampling and Analysis of PFAS from Stationary Sources
- Written in reference method/compliance format
- Creates first PFAS measurement method under development
- Uses 50 PFAS compound target list consistent with Office of Water (OW), Department of Defense, American Society for Testing Materials (ASTM)
- Makes non-targeted compound identification possible
- Sampling based on established stack sampling methods - SW-846 Method 0010
- Analysis based on OW Method 533
- Written as a performance-based method

FRM / FEM Samplers and Analyzers

Federal Reference Methods (FRMs)

- Designed to provide the most fundamentally sound and scientifically defensible concentration measurement
- FRM measurement principles for each criteria pollutant are published in 40 Code of Federal Regulations (CFR) Part 50
- FRMs serve as the basis of comparison upon which to judge other measurement methods

Federal Equivalency Methods (FEMs)

- Intended to provide a comparable level of compliance decision making quality as provided by FRMs
- May include newer, innovative technologies to reduce overall operating cost and to achieve multiple monitoring objectives (e.g., real-time reporting for health studies and for issuing timely public health advisories)

Complementary Role of Air Sensors

- Goal of the nationwide regulatory monitoring network is to provide high quality data to help assess the public's exposure to the criteria pollutants and for evaluating the effectiveness of pollutant control strategies
- There is a desire for community level monitoring and mobile measurements that may be filled by a new class of complementary technology, air sensors

Regulatory Monitoring Site

More local measurements and temporary sites

Educational exploration

Mobile measurements carried by individuals

Mobile measurements using vehicles

Key Differences

FRMs/FEMs and Sensors Provide Complementary Approaches for Measuring Ambient Air Quality

- Measurements for regulatory use
- Data used for compliance decisions
- Provide high confidence in the data
- Adhere to established data quality control and assurance methods

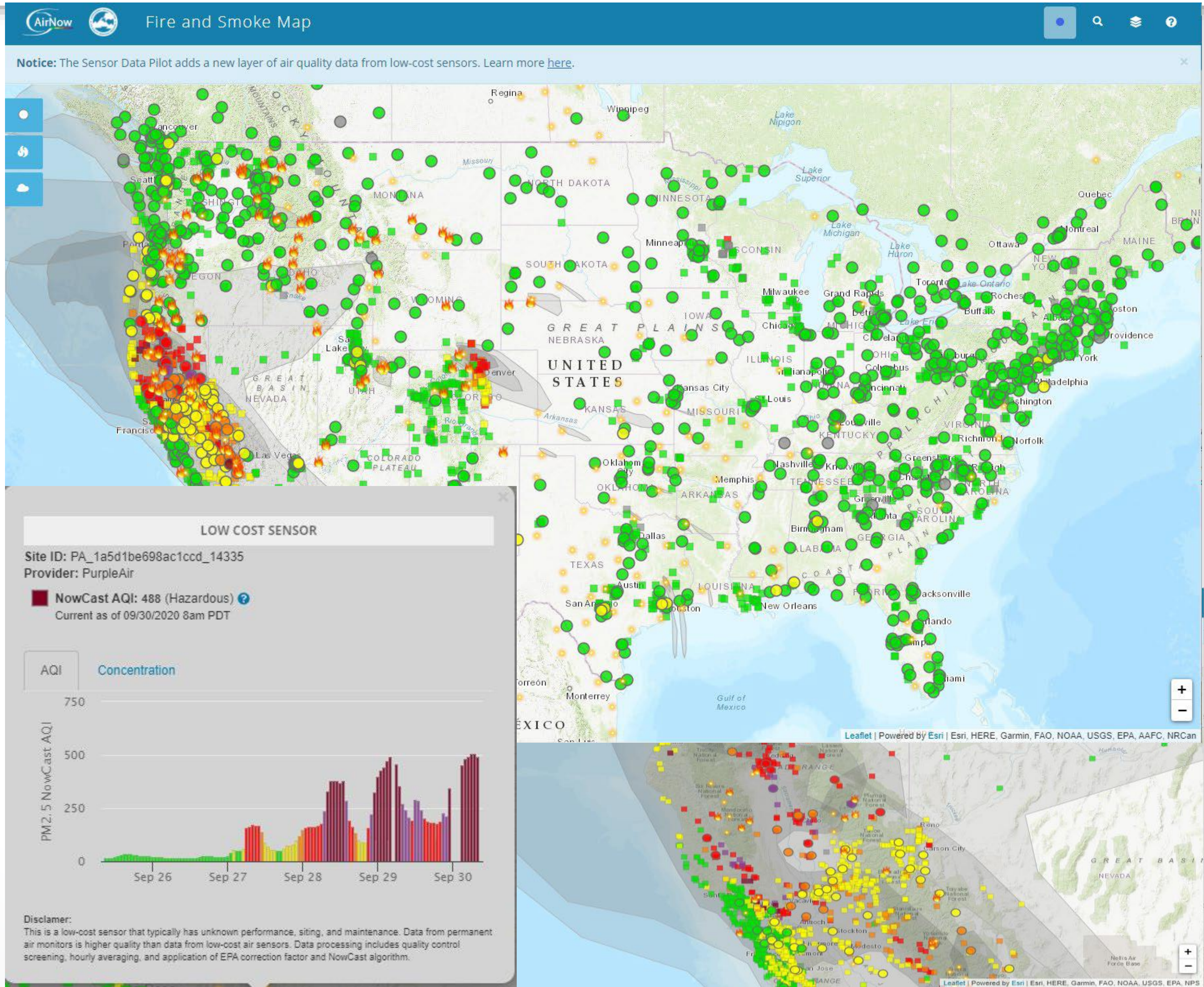
- Measurements for non-regulatory use
- Data used for informational purposes
- Demonstrated accuracy or precision is “good enough” for intended application
- Provide real-time data at high time resolution
- Offer smaller and/or more portable devices at a lower cost

AirNow Fire & Smoke Map – Sensor Data Pilot

To provide the public with additional air quality information they can use to protect their health during wildfires.

- EPA developed a correction equation for low-cost PurpleAir sensor
- Correction data from PurpleAir sensors have been added as a layer to the AirNow Fire & Smoke Map
- Improves coverage of air quality information where there are no regulatory grade monitors

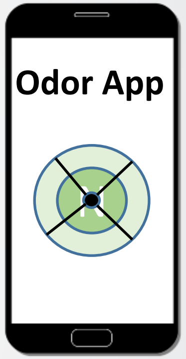
https://fire.airnow.gov



Next Generation Emissions Measurement (NGEM)

- New approaches for difficult sources
- Hybrid measurement/model systems
- Crowdsourcing odor and other observations

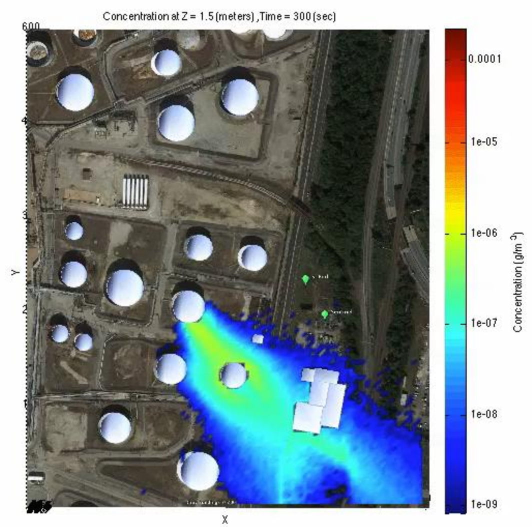
Metrology



Metadata

Facility Sensors

Personal and Community Sensors



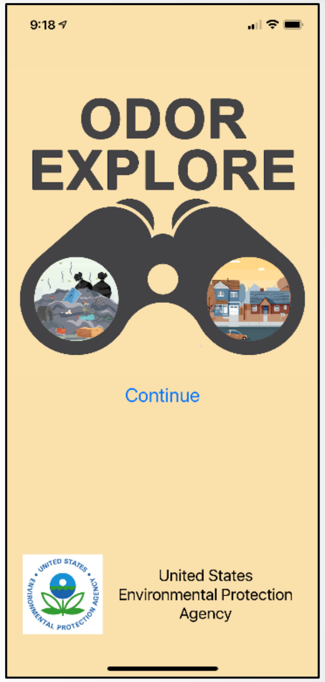
Informetrics

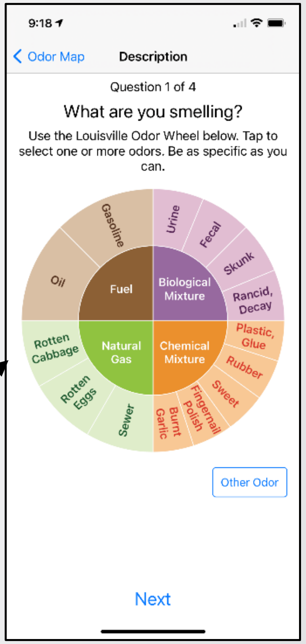
Near Source Impacts/ Energy/ Industry Sensors

Geospatial

Technology Application Programs

- Issue
  - Source emissions can be complex to characterize
  - Many communities (including environmental justice communities) live, work, play, and attend school in and around the vicinity of pollution sources
  - Poor air quality and odors resulting from different emissions can be a nuisance and may cause health concerns and stress for impacted communities
- Approach
  - EPA is developing a mobile app (for iOS and Android) that can be used by community members to report odors and view odor reports in their area
  - Data from the app will be paired with data from next generation emissions measurement (NGEM) systems to capture a chemical ‘fingerprint’ of emissions
- Anticipated Outcomes
  - Demonstrate utility of combining a variety of data types (citizen science and NGEM) to help better understand emissions
  - Engage communities and increase transparency
  - Help EPA Regions, state/local agencies, and industries evaluate air pollution and odor control strategies

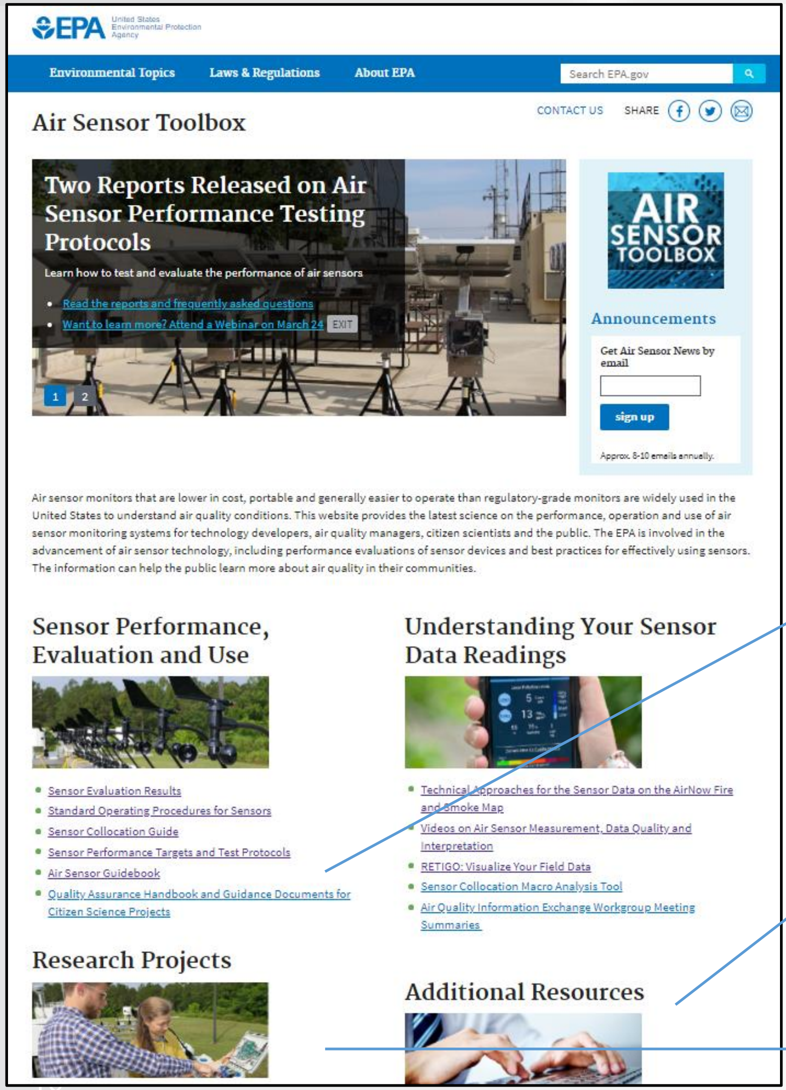


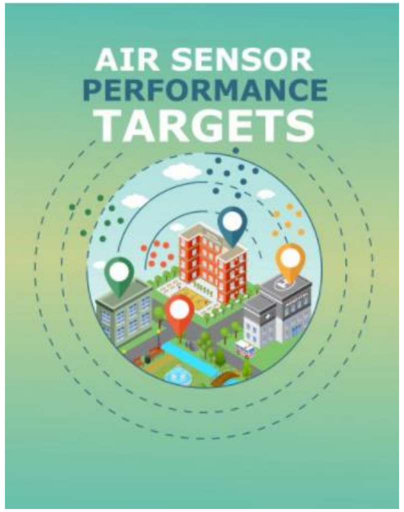


Odor Wheel

Captures detailed information about odors

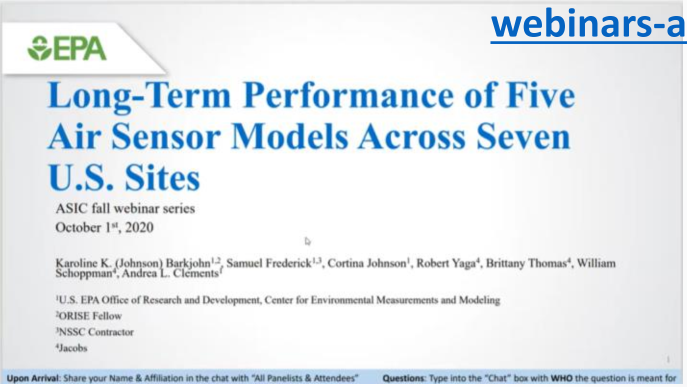
Air Sensor Toolbox





https://www.epa.gov/air-sensor-toolbox/air-sensor-performance-targets-and-testing-protocols

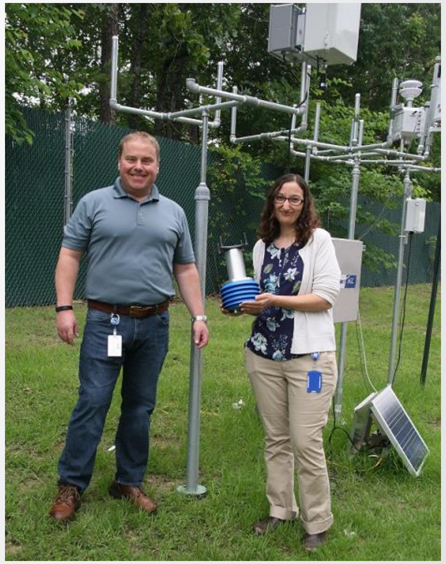
https://www.epa.gov/air-sensor-toolbox/conferences-workshops-and-webinars-air-sensor-technology



https://www.epa.gov/air-sensor-toolbox/epa-air-sensor-research-overview

and

https://www.epa.gov/air-sensor-toolbox/technical-reports-and-journal-articles-air-sensor-technology



https://www.epa.gov/air-sensor-toolbox

Experiment

Exploring the Possibilities

Emission Characterization Tools

- Laboratory and pilot-scale source emissions characterization
  - Stationary diesel genset
  - Multi-Pollutant Control Research Facility (MPCRF)
  - Sterilizer
- Field studies
  - Rural and urban settings
  - Near-source
  - Fugitive emissions

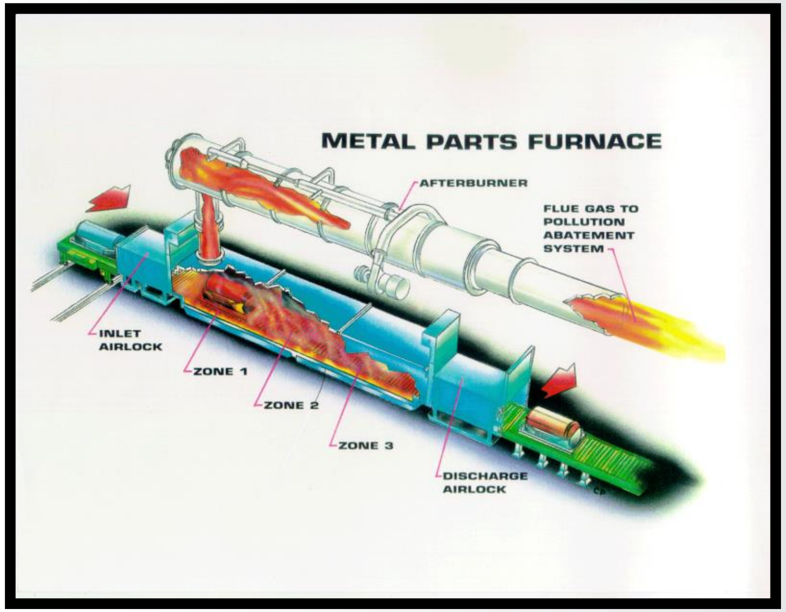
Stationary Diesel Facility (200kW genset)

Laboratory Sterilizer

Multi-Pollutant Control Research Facility (MPCRF)

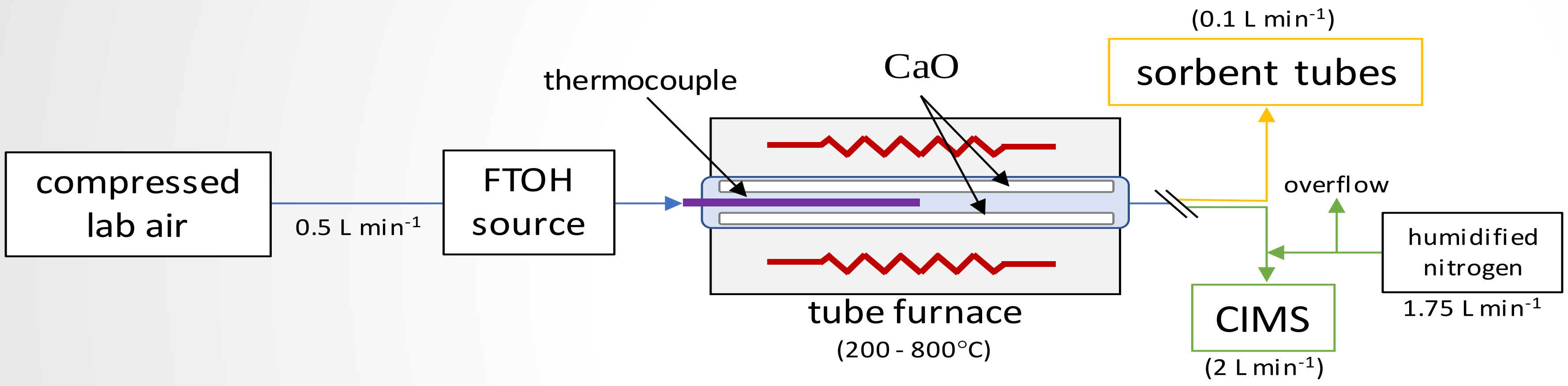
CFS Software for EPA
Reaction Engineering International (REI)

- The Configured Fireside Simulator (CFS)
  - —Developed for the Department of Defense to evaluate operations of the chemical demilitarization incinerators processing the US chemical warfare agent stockpile
- Destruction kinetics developed
- Adapted to provide for the ability to run “what if” scenarios of waste streams contaminated with chemical and biological warfare agents
  - —EPA’s pilot-scale Rotary Kiln Incinerator Simulator (RKIS)
  - —Three commercial incinerators based on design criteria for actual operating facilities
    - o Medical/Pathological Waste Incinerator
    - o Hazardous Waste Burning Rotary Kiln
    - o Waste-to-Energy Stoker type combustor
- CFS uses chemical kinetic data for destruction derived from multiple published kinetic studies, including bench- and pilot-scale experiments at EPA’s Research Triangle Park, NC facility



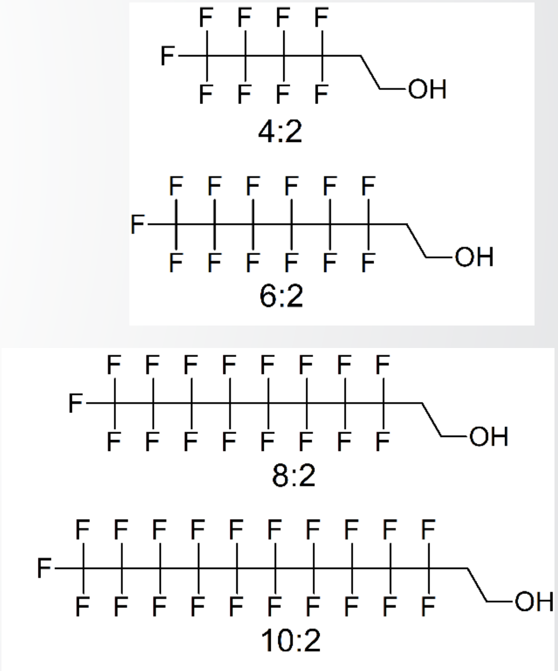
Tube Furnace Experiments

Experimental Setup



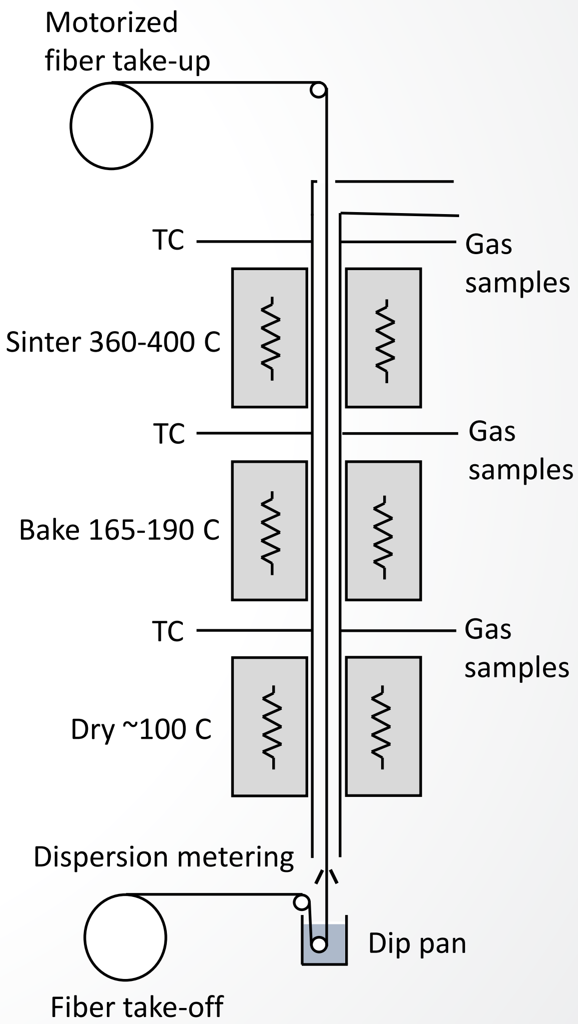
- Thermal treatment with calcium oxide (CaO) from 250 to 800 °C
- Observe destruction of parent compound using two techniques: CIMS and sorbent tube analysis by thermal desorption–gas chromatography–mass spectrometry (TD-GC/MS)
- TD-GC/MS analyses show the presence of degradation products from fluorotelomer alcohols (FTOH) destruction

PFAS Fluorotelomer Alcohols Tested:



String Reactor Experiments

- New experiment that simulates industrial PFAS coating facilities:
  - —Built from 3 existing furnaces
  - —Applies commercial dispersions to fiber (string)
  - —Full control of flows, times, temperatures, application rates
  - —Small scale (L/min & g/min)
  - —Located in lab w/ real-time instruments
- Investigates key research questions:
  - —What PFAS & additives are present in different commercial dispersions?
  - —What PFAS (and other species) are vaporized during application processes?
  - —How do vapor phase PFAS emissions compare to dispersion compositions?
  - —Are processing temperatures sufficient to transform PFAS?
  - —How do processing temperatures and times affect vapor and aerosol emissions (mass and composition)?

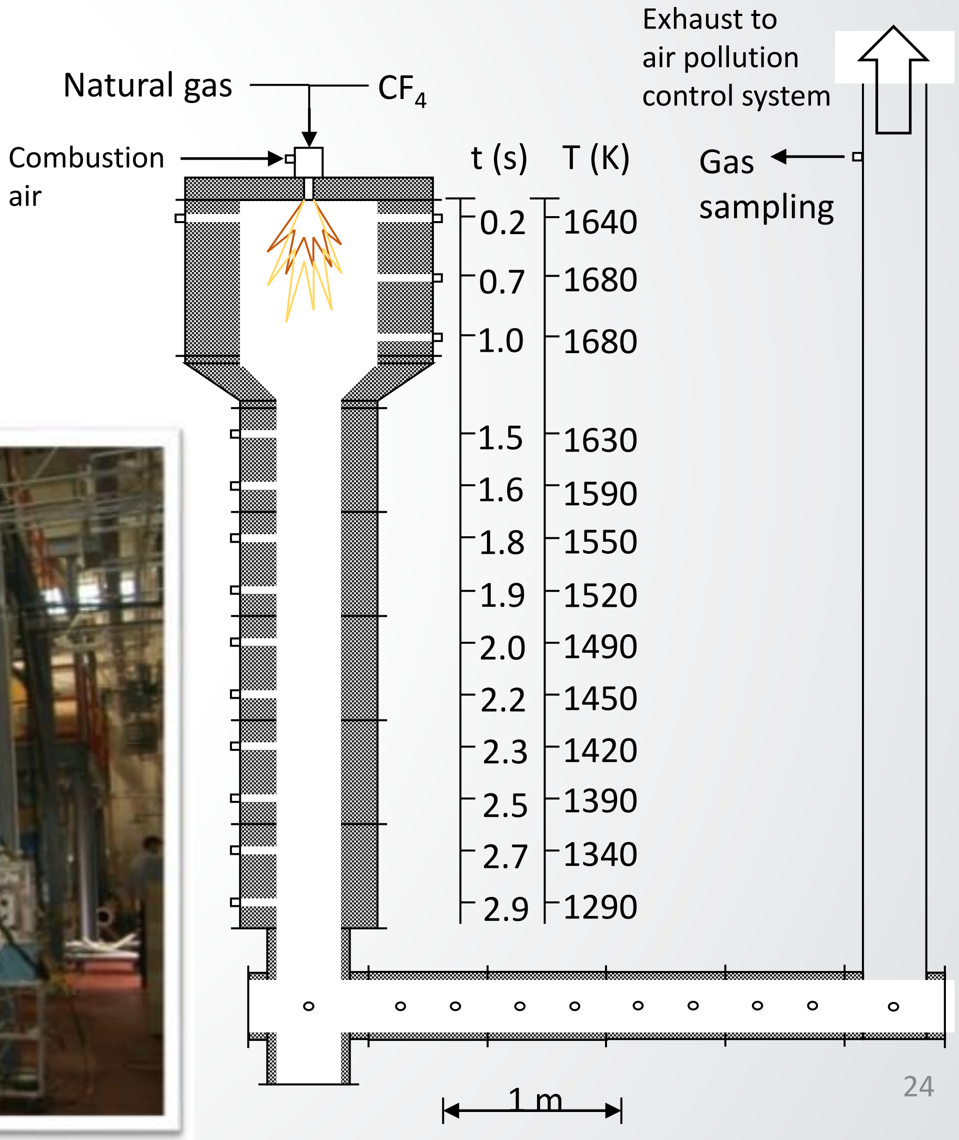


Pilot-scale Incineration Experiments

- 65 kW refractory lined furnace (aka Rainbow Furnace) with peak temperatures at ~1400 ⁰C, and >1000 ⁰C for ~3 sec

- Combustor connected to facility air pollution controls
  - —Afterburner, baghouse, NaOH (sodium hydroxide) scrubber

- Introduce C1 and C2 fluorinated compounds with fuel, air, post flame to measure POHC destruction and PIC formation
  - —FTIR (Fourier-transform infrared spectroscopy) and other real-time and extractive methods

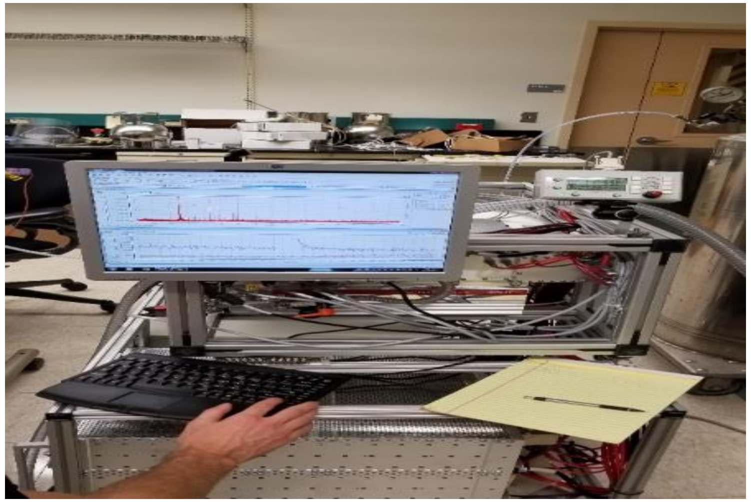


Combustion Technology Field Testing

Incinerators – Hazardous Waste, Municipal Waste, Medical Waste, and more

Rotary Kilns, Cement Kilns, and more





Innovative Approaches

Leaving No Rock Unturned

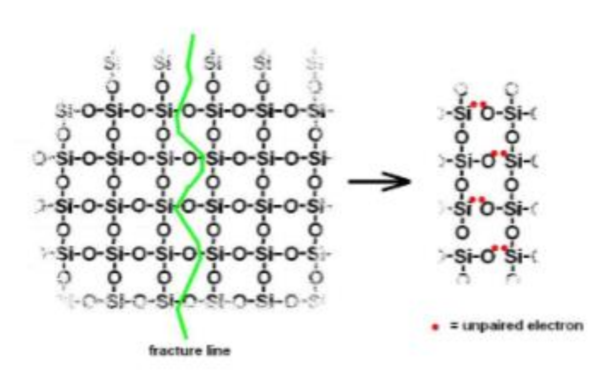
PFAS Innovative Treatment Team (PITT)

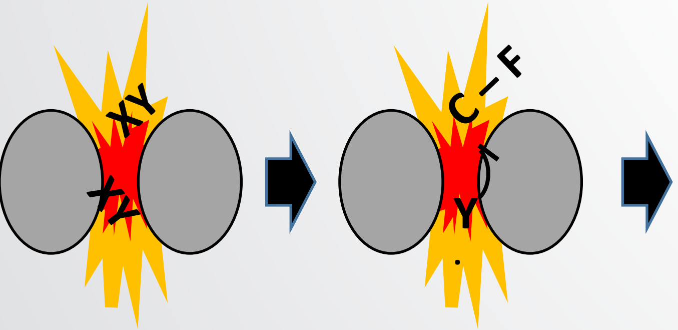
- Full-time team that brought together a multi-disciplined research staff
- Concentrated efforts and expertise on a single problem: how to remove, destroy, and test PFAS-contaminated media and waste
- For 6 months, the PITT worked to achieve the following goals:
  - Assess current and emerging destruction methods being explored by EPA, universities, other research organizations, and industry
  - Explore the efficacy of methods while considering by-products to avoid creating new environmental hazards
  - Evaluate methods’ feasibility, performance and costs to validate potential solutions

Non-Combustion Technologies

Bulley, M.; Black, B. EDL

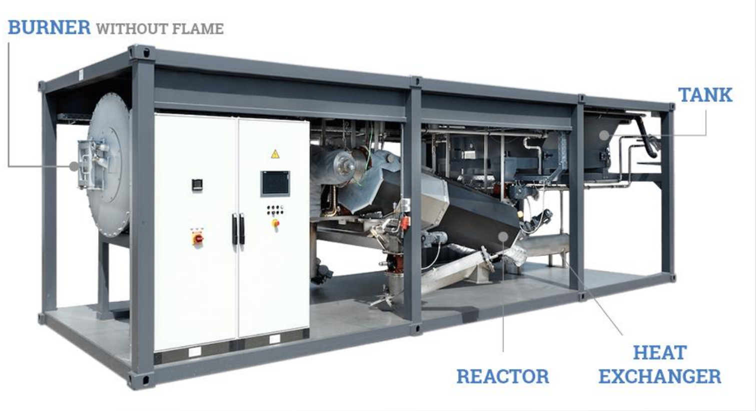
Mechanochemical Treatment
(aka Ball Milling)



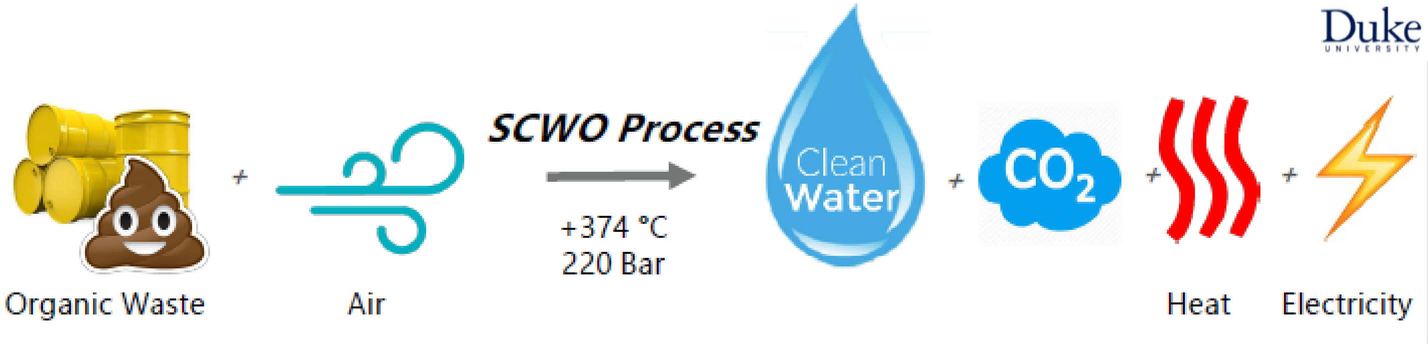


$C_{(s)} + CO_2 + F^-$

Biosolids Pyrolysis/ Gasification



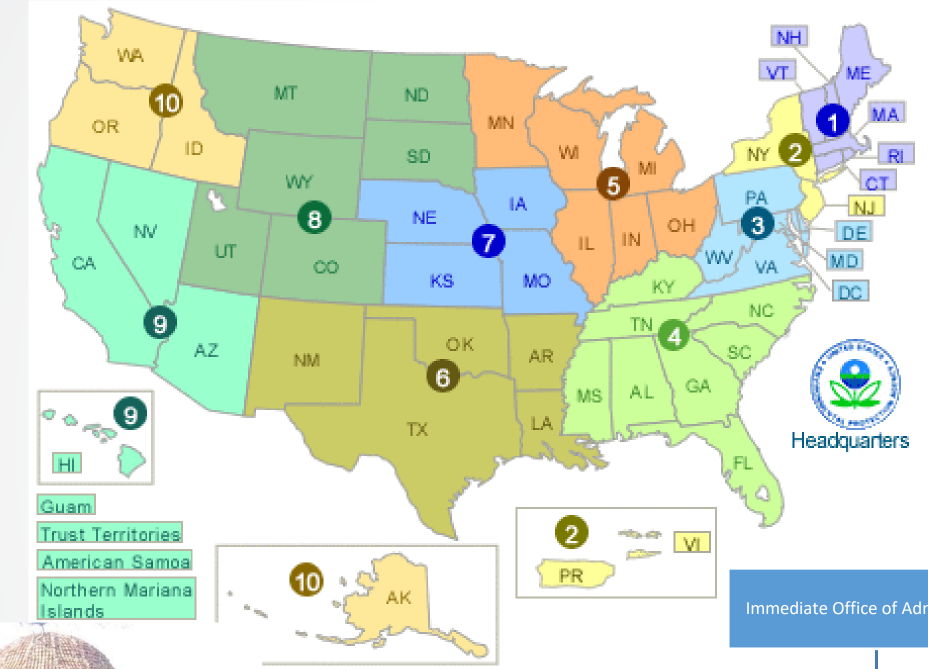
Supercritical Water Oxidation (SCWO)

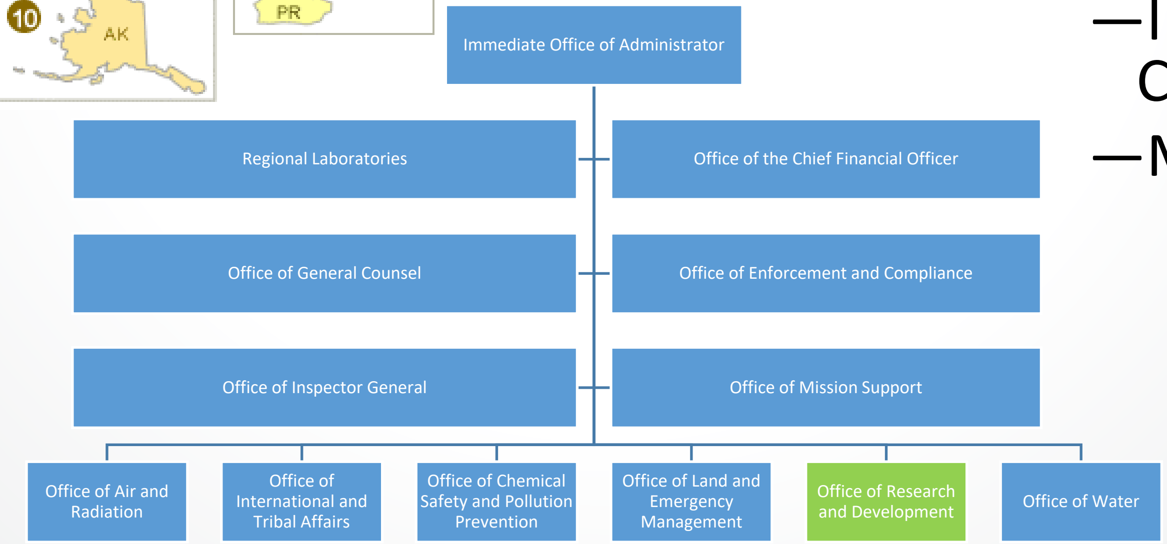


Collaboration

It Takes a Village

Different Players and Opportunities…





- Small Business Opportunities
- Federal Transfer Technology Act Program
  - —Cooperative Research and Development Agreements (CRADAs)
  - —Intellectual Property and Collaborative Agreements
  - —More ….



Wrap-Up

Putting Pieces Together

Summary

- With the ability to measure our environment at previously unseen levels of detection, the landscape of science is constantly evolving
- Emerging environmental issues and contaminants of concern are being investigated to answer the immediate questions of uncertainty with regards to public health and exposure
- Novel, innovative technology is being unveiled at a rapid pace and evaluated for relevance in measuring and monitoring priority areas
- The development or application of an innovative approach; improvement in problem solving capacity; and formation of successful alliances with stakeholders are strategic means for advancing our knowledge to the rapidly changing surroundings

Questions

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