National Institute of Environmental Health Sciences
Your Environment. Your Health.

Potential Solutions for PFAS

NIEHS Superfund Research Program Remediation Research

Biomedical, Health Risks, Stakeholder Engagement, Transport, Detection and Remediation

Heather F Henry, PhD
Program Officer, Superfund Research Program
National Institute of Environmental Health Sciences
National Institutes of Health

Research Triangle Environmental Health Collaborative
Oct 23-24, 2019

Superfund Research Program

Fundamental Knowledge → **NIH Research Mission** → Health Outcomes

National Institutes of Health

…of living systems

…reduced illness & disability

National Institute of Environmental Health Sciences

…with environmental exposures

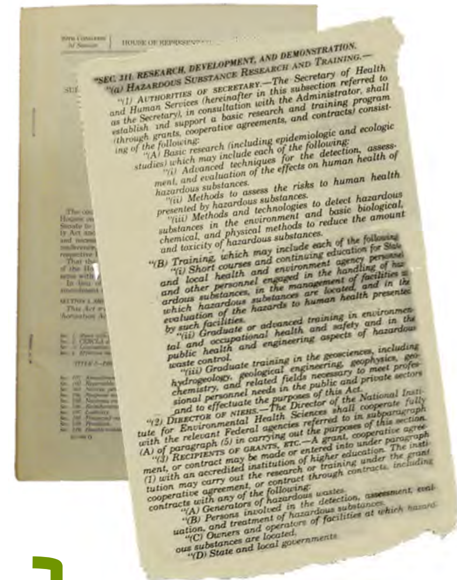
…caused by hazardous substances

Superfund Research Program (SRP)
SARA Legislation, 1986

…including health effects, assessing risks, **detection & remediation**

…problem solving, stakeholder engagement

SRP's Remediation Mandate and PFAS



Development of biological, chemical, physical means to reduce the amount/toxicity of **per- & poly-fluorinated alkyl** substances

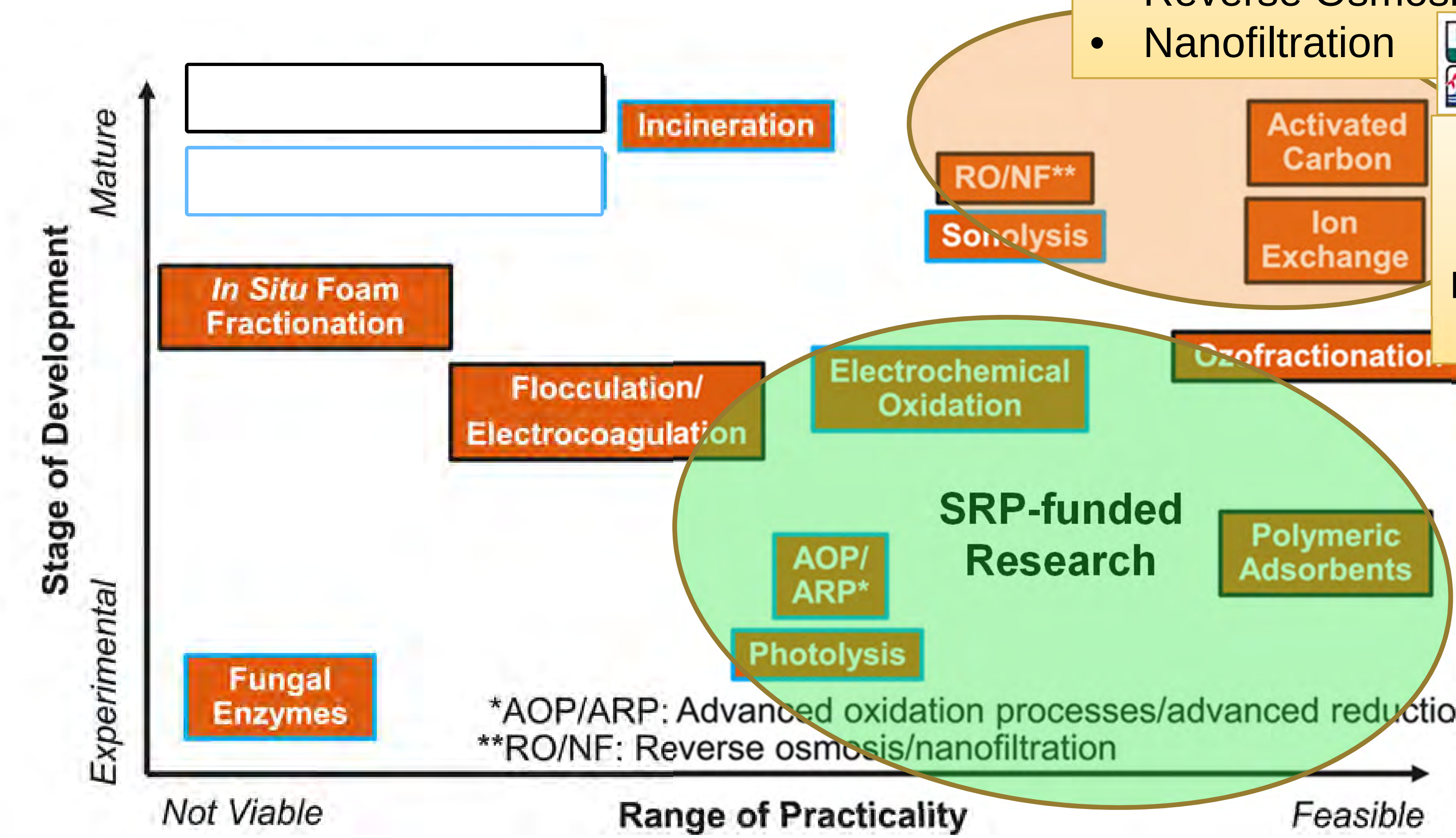
- Conventional Remediation Strategies
  - Biodegradation
  - Chemical Oxidation/Reduction
  - Physical (Phase change / physical destruction)

Combination of Approaches (no silver bullet)

- Optimize remediation technologies to:
  - Remove from water/soil: **Adsorption, separation**
  - Break the C – F bond: **Destruction**

Current State of Innovation - Water

Prevailing Technologies
- Activated Carbon
- Ion Exchange (IX) Resins
- Reverse Osmosis
- Nanofiltration



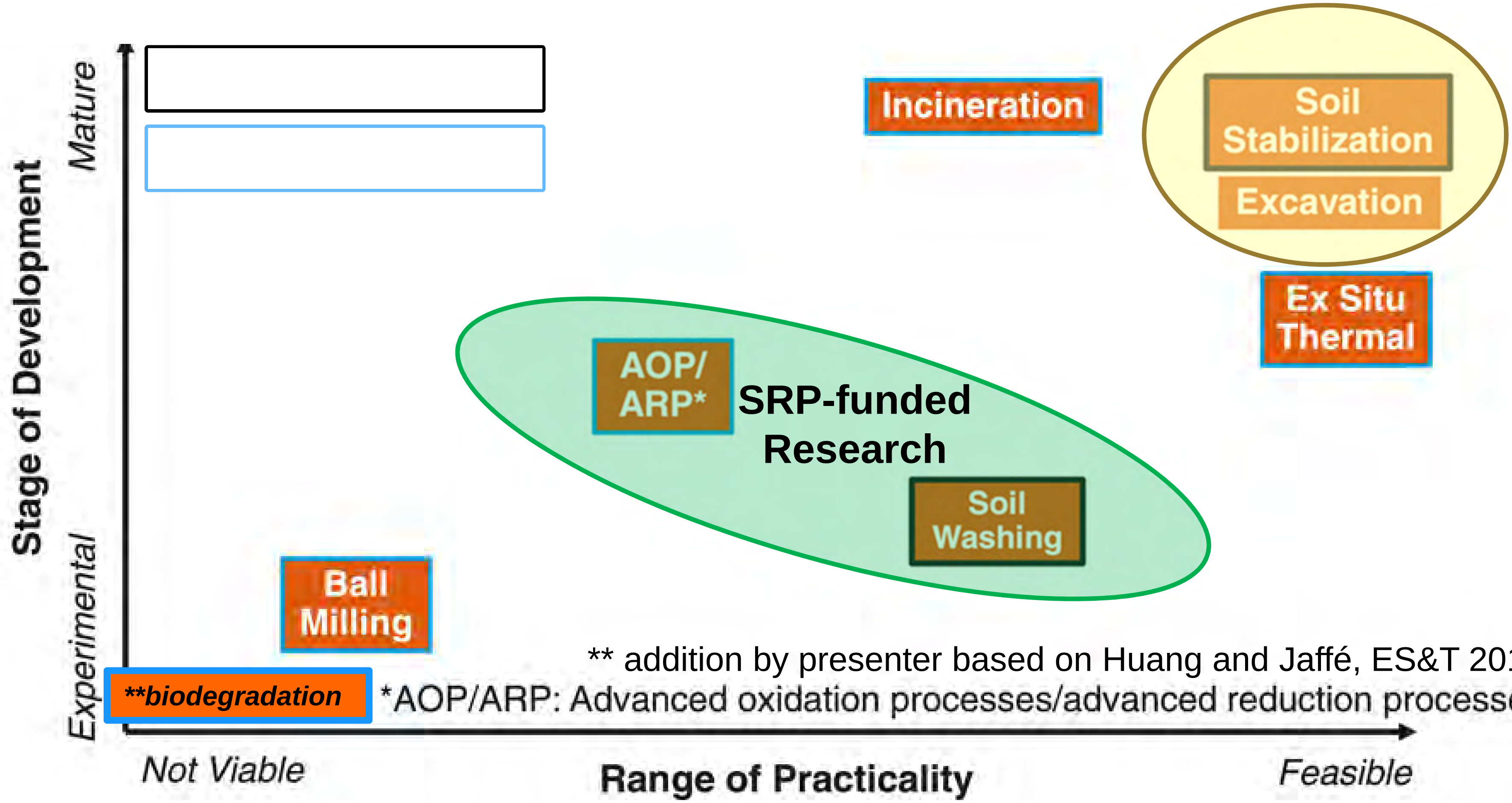
NORTH CAROLINA PFAS Testing Network

PFAST Team 3: Removal & Performance Testing

Ross, McDonough, Miles et al. 2018, Remediation

Soil Stabilization
Excavation (dig/haul)

Current State of Innovation - Soils



** addition by presenter based on Huang and Jaffé, ES&T 2019

*AOP/ARP: Advanced oxidation processes/advanced reduction processes

Ross, McDonough, Miles et al. 2018, Remediation

National Institute of Environmental Health Sciences
Your Environment. Your Health.

Biomedical, Health Risks, Stakeholder Engagement, Transport, Detection and **Remediation**

Technologies for Remediation:

Adsorption/Separation, Destruction

Status: Laboratory / Demonstration
Media: Water / Groundwater / Soil / Sediment
Application: In situ / Ex situ / Point of Use (POU)

(Citation, for more information)

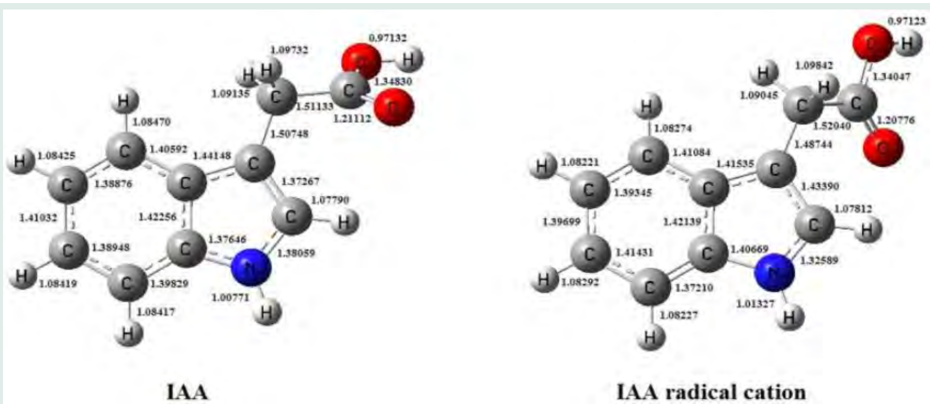
National Institute of Environmental Health Sciences
Your Environment. Your Health.

- Lab
- Water
- Ex situ

Remediation - Destruction

Stephen Boyd, Michigan State University, P42ES004911

- Basic research developing energy efficient **nanoreactors for photoreduction**
- Nanoreactor = Indole with smectite (clay) interlayers
- Reported complete defluorination of PFOA and PFOS using hydrated electrons at **low energy irradiation**
- Tested at concentrations >> environmental



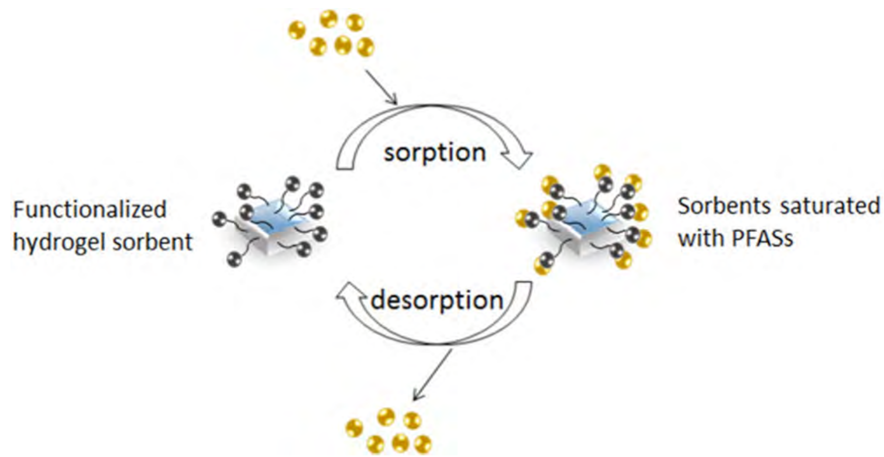
The optimized molecular structures of indole acetic acid (IAA) and IAA radical cation as obtained from density functional theory calculations.
(Tian et al., Sci Rep, 2016)

- Lab
- Water
- Ex situ

Remediation – Adsorption / Separation

Tim Phillips, Texas A&M University, P42ES027704

- Collaborating with Kung-Hui Chu to develop **reusable hydrogel sorbents** for removing PFAS from aqueous solution.
- Reported removal and recovery of 5 target long- and short-chain PFAS. (Huang et al., 2018)
- Compounds studied:
  - PFOA
  - PFOS
  - Perfluorobutanesulfonic acid (PFBS)
  - Perfluorobutanoic acid (PFBA)
  - GenX
- Regenerated using 70% methanol/ 1% NaCl



Sorbents: fluoridation and/or amination of poly(ethylene glycol) diacrylate (PEGDA) hydrogel

(Huang et al., ACS Omega, 2018)

National Institute of Environmental Health Sciences
Your Environment. Your Health.

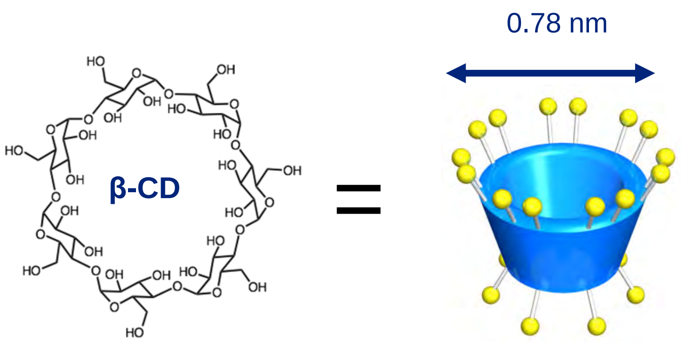
- Demo
- Water
- POU

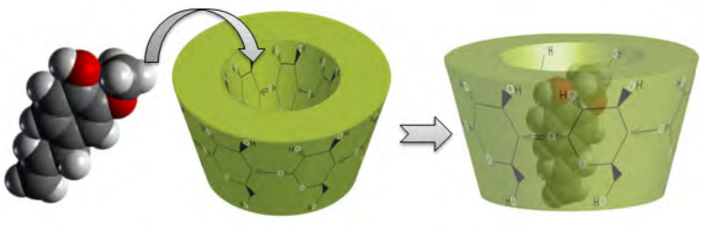
Remediation – Adsorption, Concentration

Gokhan Barin, CycloPure, Inc., R44ES029401

CycloPure
MAKING WATER SAFE

- Tunable high-affinity **cyclodextrin polymers adsorb PFAS,** polymer **structure concentrates PFAS**
  - Polymers derived from corn, safe material
  - Binds thousands of organic molecules in their cup-shaped structures
  - Removal takes place within cyclodextrin cups sized to maximize attraction and capture of micropollutants
  - **Point of use** (personal filtration device)
  - DEXSORB-MP and DEXSORB-PFAS



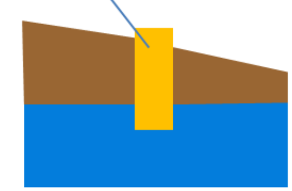


- Lab/Demo
- Groundwater
- In situ

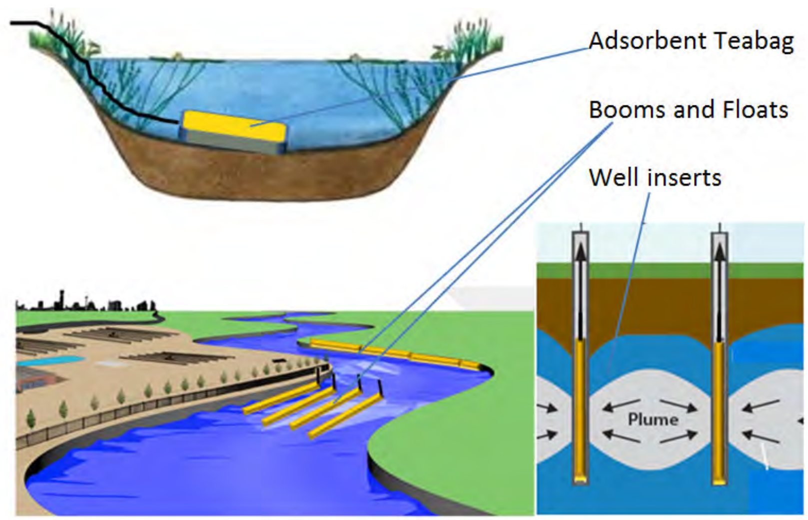
Remediation – Adsorption, Concentration

David Dumas, Amaratek, Inc., R43ES030678

Developing novel **polymer-diatom composite materials** that can be used as passive and easily **regenerated sponges**. Technology will bind a spectrum of PFAS under a range of environmental conditions



- Design tight PFAS binding ligands for PFAS with computer modeling
- Synthesize panel of prototype ligands
- Attach ligands to porous support (diatomaceous earth)
- Evaluate extraction efficiency under range of environmental conditions
- Apply in barrier wall, "teabag," booms/floats, well inserts
- **Regenerate** via supercritical CO_2

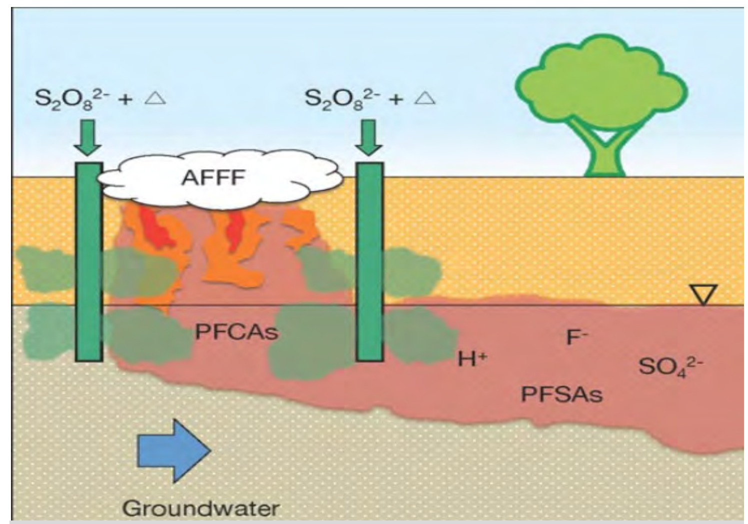


- Lab
- Groundwater
- In situ

Remediation – Destruction

David Sedlak
University of California, Berkeley, P42ES004705

- Combining treatment options to degrade and destroy AFFF and PFAS in groundwater
- In research testing heat-activated persulfate (H-AP) – lab test mimicking field conditions:
  - Low pH results in formation of shorter-chain perfluorocarboxylic acids (PFCAs)
  - Chloride must be converted into chlorate before PFOA removal occurs.
  - The presence of aquifer solids slows but does not prevent PFOA mineralization



Graph depicting heat activated persulfate treatment of PFAS

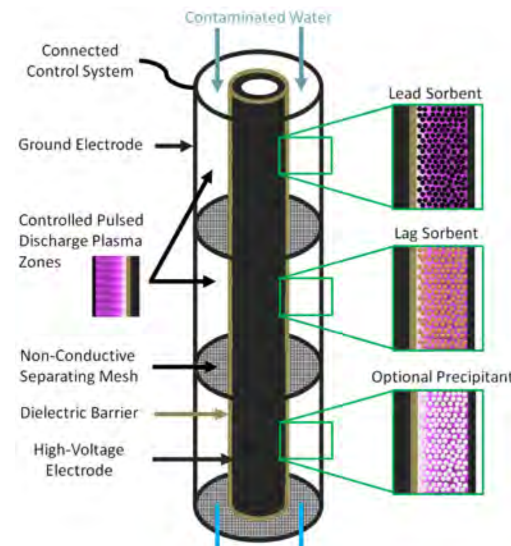
(Bruton and Sedlak, Environ Sci Technol, 2017; Bruton and Sedlak, Chemosphere, 2018)

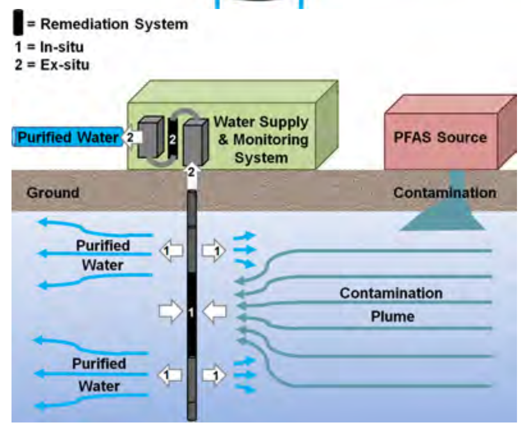
- Lab
- Water
- In/Ex situ

Remediation – Adsorption, Separation, Destruction

Joseph Miller, Lynntech, Inc., R43ES030250

- **Continuous removal/disposal** system for the concurrent sorption and breakdown of contaminants into harmless precipitates
  - **Lead and lag sorbent** process coupled to pulsed **plasma**
  - **Decomposes** contaminants and **regenerates** the sorbents at the same time
  - Scalable, efficient
  - Integrated monitoring system
- Concept: In-situ and ex-situ groundwater purification of contaminants without need for frequent sorbent replenishment and disposal





Lynntech

National Institute of Environmental Health Sciences
Your Environment. Your Health.

- Demo
- Soil/Sed
- In/Ex situ

Remediation – Adsorption, Destruction

Raymond Ball, EnChem Engineering, Inc., R44ES028649

EnChem Engineering, Inc.

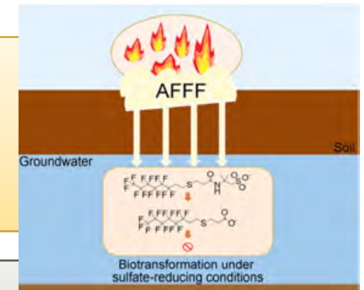
- **Combined in-situ / ex-situ** technology to expedite PFAS removal (soil and groundwater)
  - **In situ - XCT® non-toxic** cyclic sugar (CS) flush
  - **Ex situ - OxyZone®** -patented persulfate-based oxidant mixture (alkaline ozonation, 99+ percent removal)
  - Process effective for Ex situ and potentially In situ treatment of PFAS
- Destruction of broad range of PFAS in water including PFOS. Recent results went from 700 ug/kg Total PFAS to 70 ppt for 5 of the 6 UCMR PFAS
- Has worked with Joint Base Cape Cod Superfund Site

Ex-situ treatment reactor can be used as pretreatment to existing Granular Activated Carbon

Other Tools / Research to Support PFAS Remediation

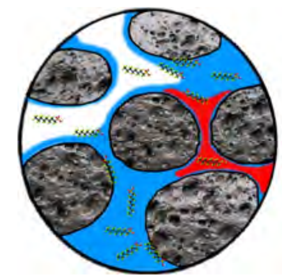
Impact of PFAS on TCE/BTEX Biodegradation

- Lisa Alvarez-Cohen, U California, Berkeley, P42ES004705
- Harding et al., Env Sci Tech, 2016; Yi et al., Env Sci Tech Lett, 2018



Modeling PFAS Fate and Transport

- Mark Brusseau, U Arizona, P42ES004940
- Brusseau et al. Water Res, 2019; Brusseau, Sci Total Environ, 2018



Passive Samplers for PFAS Detection

- Rainer Lohman, U Rhode Island, P42ES027706
- Dixon-Anderson, 2018 Environ Toxicol Chem.

GIS-based database to find towns at high risk for PFAS exposure

- Jen Guelfo (Texas Tech) & Eric Suuberg, Brown U, P42ES013660
- Guelfo et al., EHP, 2018; Guelfo et al., Enviro Poll, 2018

Summary

Established, effective technologies:

- Optimization research underway (PFAST)
- Most mature/feasible technologies are adsorption/separation
- Need for destructive technologies (otherwise just transferring to another media)

New Experimental Approaches

- Optimizing for:
  - Adsorbent affinity
  - Regeneration/Reuse of materials
  - Energy efficiency, natural “green” materials
- Complementary to existing technologies
- Innovative process (treatment train)

Concluding Thoughts

Importance of Cross-disciplinary Coordination: How to prioritize?

- Which compounds are the most common? (Fate and Transport Group)
- Which compounds are the most toxic? (Risk Group)

Coordination is Key

- Between Grantees and Funding Agencies
  - PFAST, SRP: cross-disciplinary efforts, community engagement
  - SERDP/ESTCP (DOD): coordinating funding programs
- Between States: e.g. Interstate Technology Regulatory Council (https://pfas-1.itrcweb.org/)

National Institute of Environmental Health Sciences
Your Environment. Your Health.

Thank you!

Biomedical, Health Risks, Stakeholder Engagement, Transport, Detection and Remediation

Acknowledgements:
SRP Staff and MDB, Inc.
Jeffery McDonough, (Arcadis)
RTEHC Organizers and Group B – Treatment and Disposal

Questions??
Heather Henry, PhD
heather.henry@nih.gov
919-609-6061 mobile

Recent/Upcoming PFAS Meetings:

- PFAS Contamination: An Emerging Problem in California (Berkeley, CA) Dec 13, 2019
- National Academy of Science: Identifying Opportunities to Understand, Control, and Prevent Exposure to PFAS (Washington, DC) Sept 23-24 ***Video Archive Available**
- SETAC: Environmental Risk Assessment of PFAS Compounds (Durham, NC) Aug 12-14, 2019 ***Manuscripts under development**
- 2019 Per- and Polyfluoroalkyl Substances: Second National Conference (Boston, MA) June 10-12, 2019 ***Video Archive Available**

For Complete List of Ongoing NIEHS Research:
https://www.niehs.nih.gov/research/supported/exposure/pfas/researchers/index.cfm