Potential Solutions for PFAS

NIEHS Superfund Research Program Remediation Research

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

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National Institute of Environmental Health Sciences

National Institutes of Health

Research Triangle Environmental Health Collaborative

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Superfund Research Program

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

...of living systems

National Institutes of Health

...reduced illness & disability

...with environmental exposures

National Institute of Environmental Health Sciences

...caused by hazardous substances

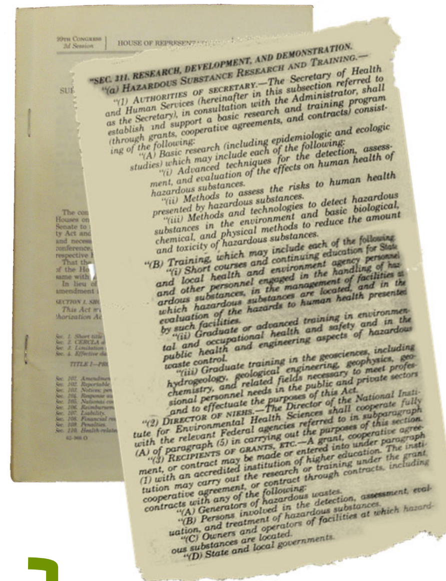
...including health effects, assessing risks, **detection & remediation**

Superfund Research Program (SRP)
SARA Legislation, 1986

...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


99th Congress 2d Session | HOUSE OF REPRESENTATIVES

"SEC. 311. RESEARCH, DEVELOPMENT, AND DEMONSTRATION.
"(a) HAZARDOUS SUBSTANCE RESEARCH AND TRAINING.—
"(1) AUTHORITIES OF SECRETARY.—The Secretary of Health and Human Services (hereinafter in this subsection referred to as the Secretary), in consultation with the Administrator, shall establish and support a basic research and training program (through grants, cooperative agreements, and contracts) consisting of the following:
"(A) Basic research (including epidemiologic and ecologic studies) which may include each of the following:
"(i) Advanced techniques for the detection, assessment, and evaluation of the effects on human health of hazardous substances.
"(ii) Methods to assess the risks to human health presented by hazardous substances.
"(iii) Methods and technologies to detect hazardous substances in the environment and basic biological, chemical, and physical methods to reduce the amount and toxicity of hazardous substances.
"(B) Training, which may include each of the following:
"(i) Short courses and continuing education for State and local health and environment agency personnel and other personnel engaged in the handling of hazardous substances, in the management of facilities at which hazardous substances are located, and in the evaluation of the hazards to human health presented by such facilities.
"(ii) Graduate or advanced training in environmental and occupational health and safety and in the public health and engineering aspects of hazardous waste control.
"(iii) Graduate training in the geosciences, including hydrogeology, geological engineering, geophysics, geochemistry, and related fields necessary to meet professional personnel needs in the public and private sectors and to effectuate the purposes of this Act.
"(2) DIRECTOR OF NIEHS.—The Director of the National Institute for Environmental Health Sciences shall cooperate fully with the relevant Federal agencies referred to in subparagraph (A) of paragraph (5) in carrying out the purposes of this section.
"(3) RECIPIENTS OF GRANTS, ETC.—A grant, cooperative agreement, or contract may be made or entered into under paragraph (1) with an accredited institution of higher education. The institution may carry out the research or training under the grant, cooperative agreement, or contract through contracts, including contracts with any of the following:
"(A) Generators of hazardous wastes.
"(B) Persons involved in the detection, assessment, evaluation, and treatment of hazardous substances.
"(C) Owners and operators of facilities at which hazardous substances are located.
"(D) State and local governments.

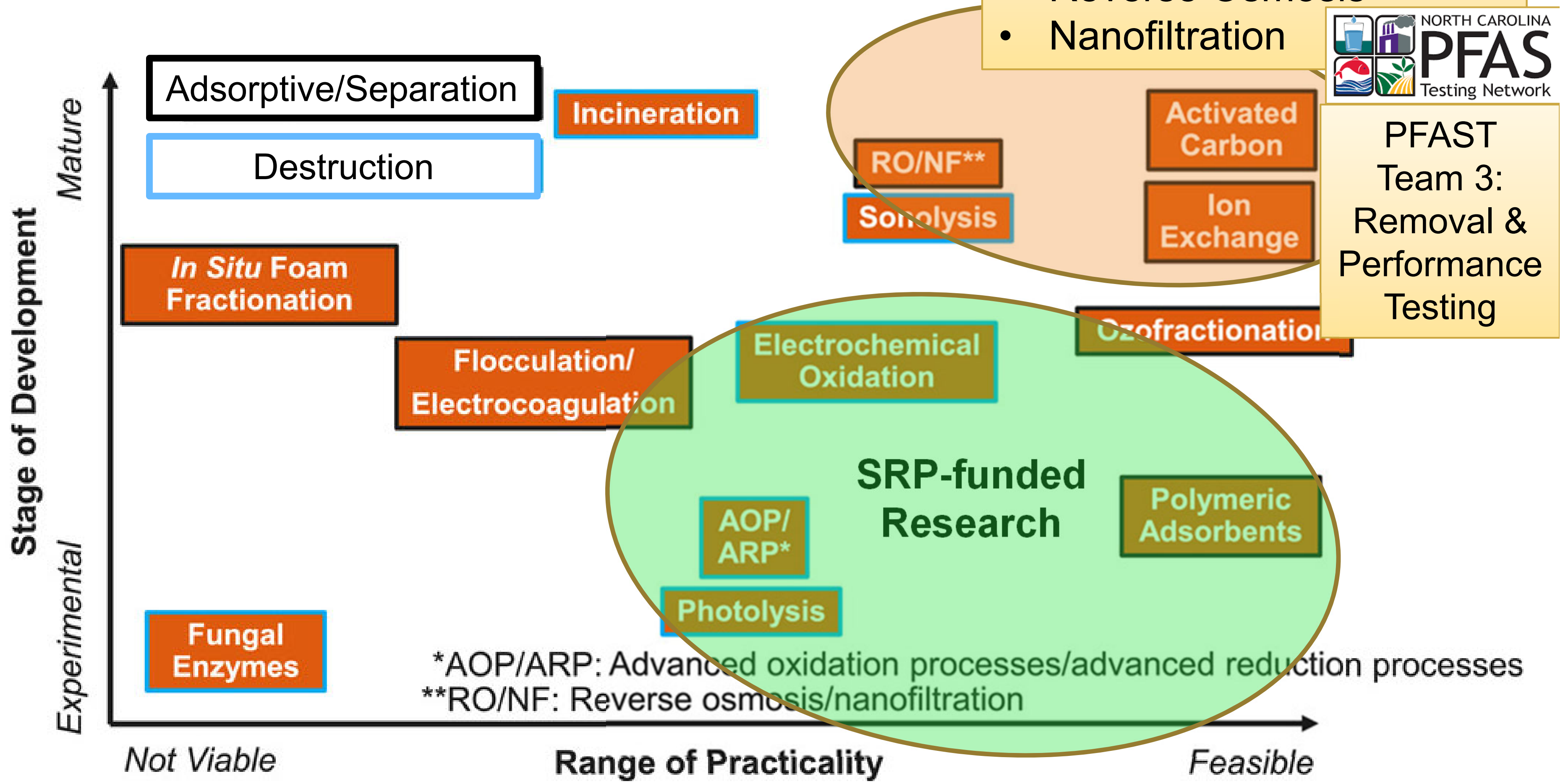
- Conventional Remediation Strategies
  - Biodegradation
  - Chemical Oxidation/Reduction
  - Physical (Phase change / physical destruction)

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



Ross, McDonough, Miles et al. 2018, Remediation

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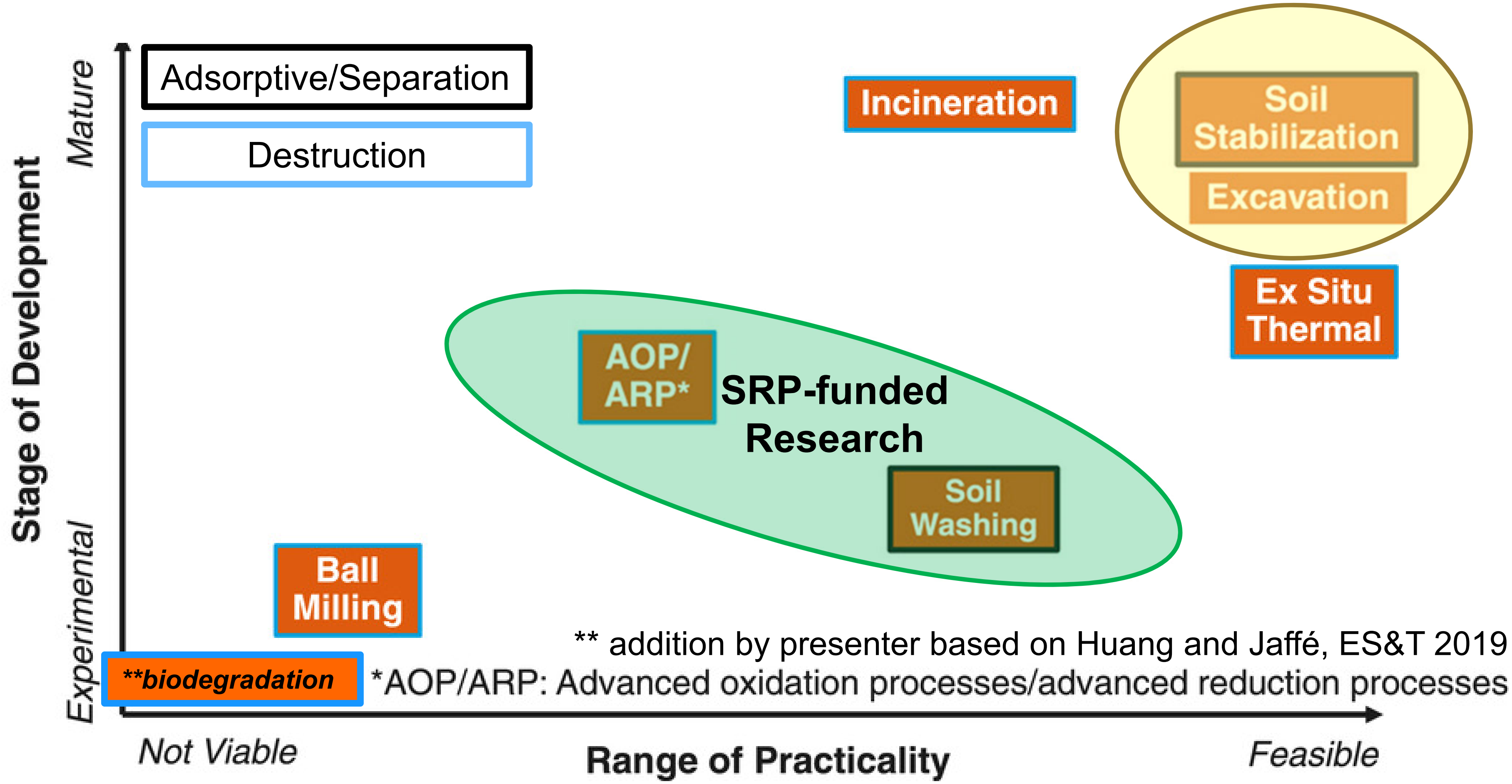
Soil Stabilization
Excavation (dig/haul)

Current State of Innovation - Soils



Ross, McDonough, Miles et al. 2018, Remediation

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)

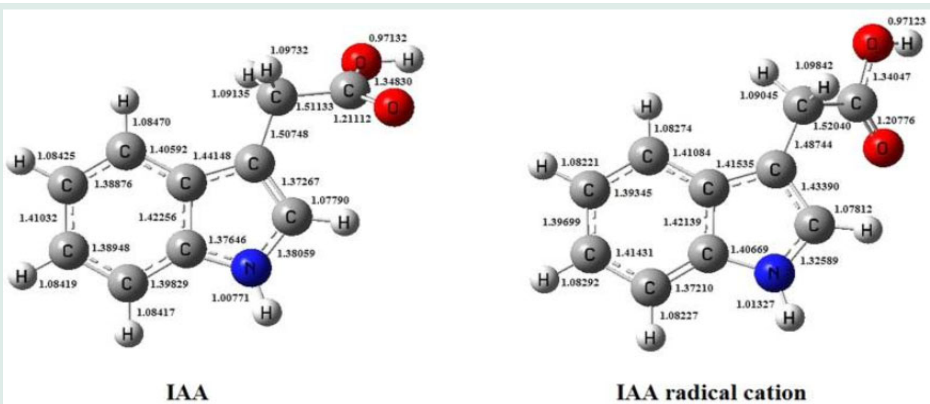
(Citation, for more information)

- 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)

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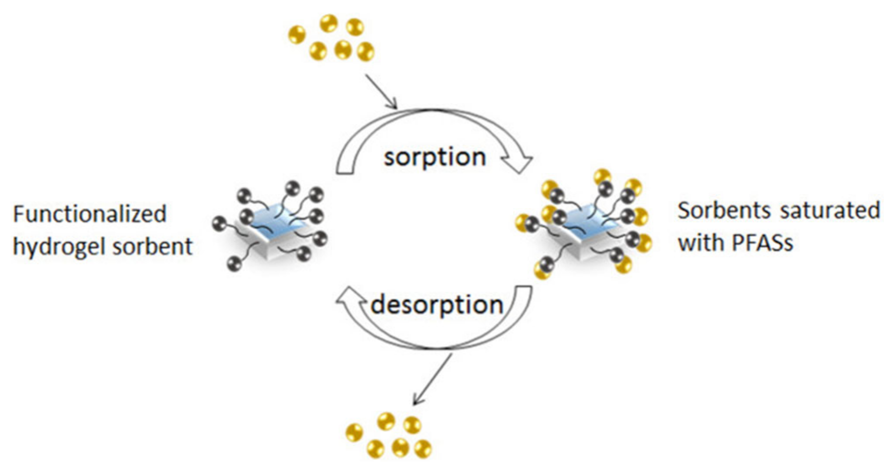
- Lab
- Water
- Ex situ

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)

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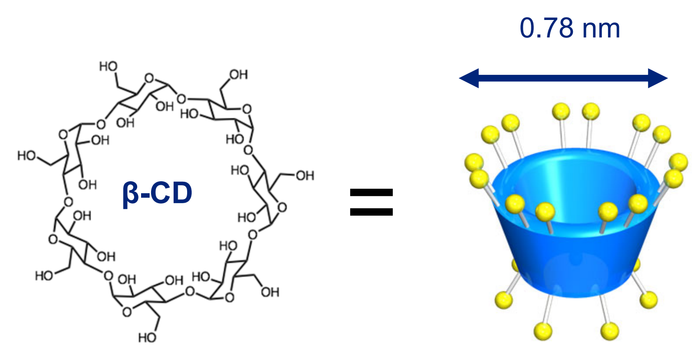
- Demo
- Water
- POU

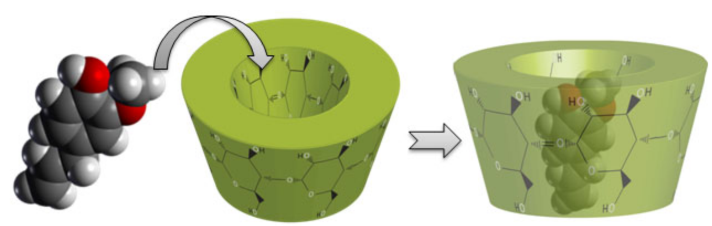
Remediation – Adsorption, Concentration

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



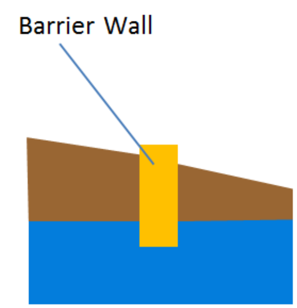


- Lab/Demo
- Groundwater
- In situ

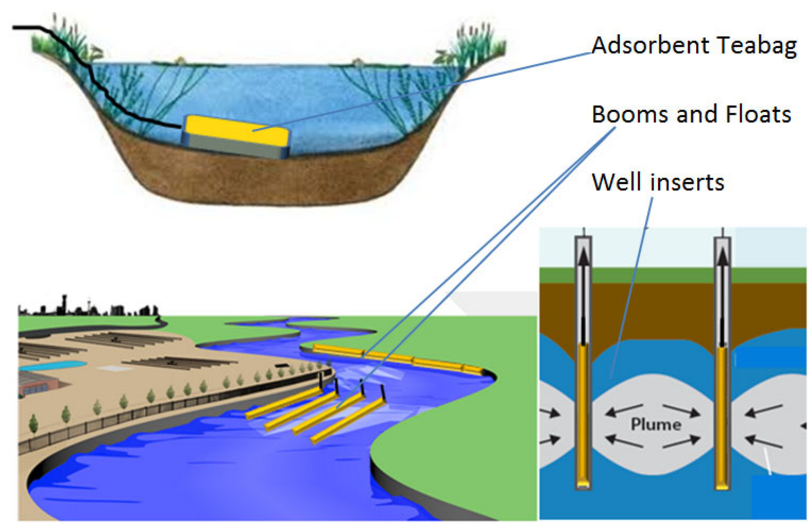
Remediation – Adsorption, Concentration

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

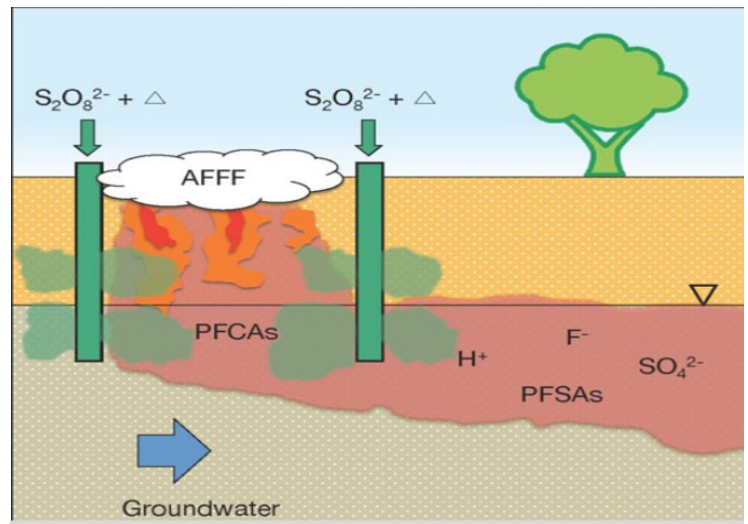


- Lab
- Groundwater
- In situ

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

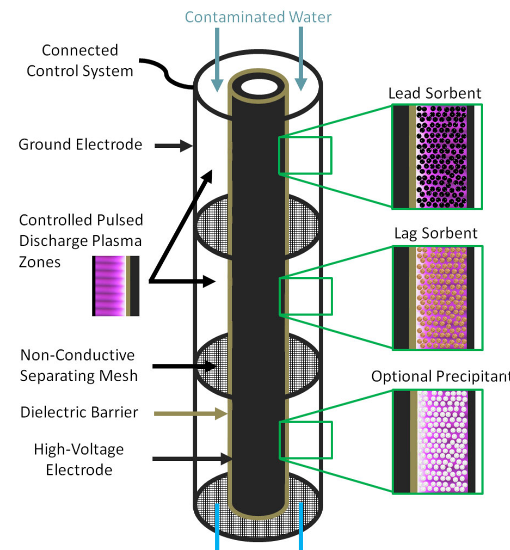
(Bruton and Sedlak, Environ Sci Technol, 2017; Bruton and Sedlak, Chemosphere, 2018)

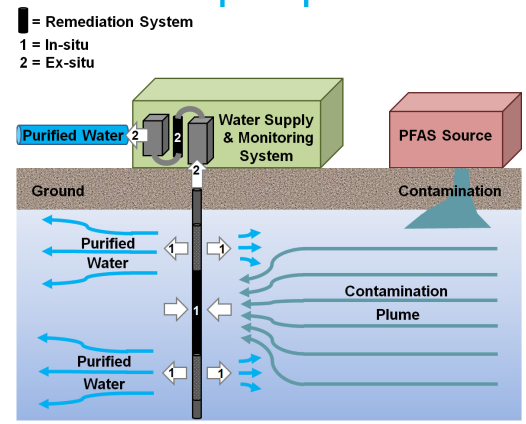
- Lab
- Water
- In/Ex situ

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

- Demo
- Soil/Sed
- In/Ex situ

Remediation – Adsorption, Destruction

EnChem
Engineering, Inc.

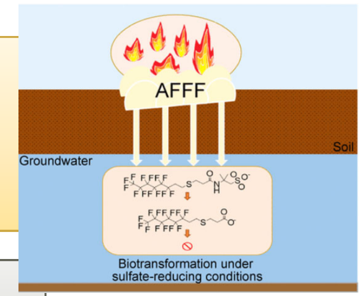
Raymond Ball, EnChem Engineering, Inc., R44ES028649

- **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

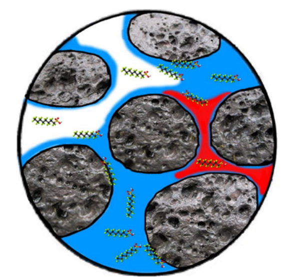
Ex-situ treatment reactor can be used as pretreatment to existing Granular Activated Carbon

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/)

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Thank you!

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RTEHC Organizers and Group B – Treatment and Disposal

Questions??
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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