# *Environmental Engineering for the 21st Century:* **A Practitioner's Perspective … and a Case Study**

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Geosyntec consultants

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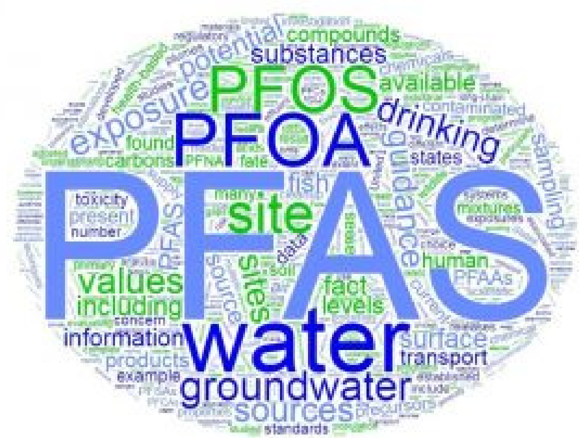
# Outline

- Recap: The grand challenges and opportunities in environmental engineering for the 21st century
- A case study
  - PFAS as an issue that is relevant to at least three of the identified challenges
- Addressing PFAS impacts
  - Opportunities for the environmental engineering community
  - 5 example of successes
- Conclusions and recommendations




# Environmental Engineering Challenges

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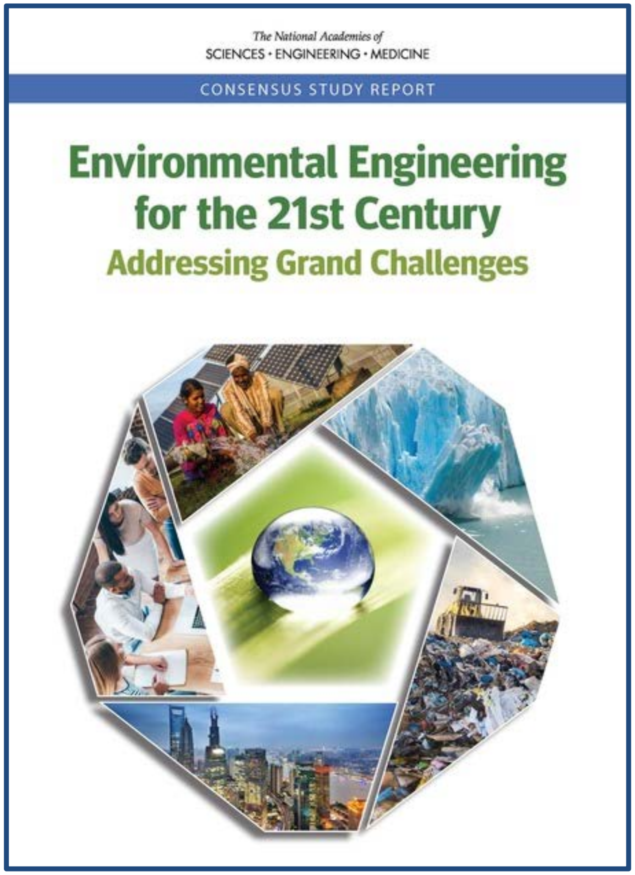
- Five broad and interconnected challenges
- To ensure people and ecosystems thrive
- How the field of environmental engineering might evolve to address identified future needs

*1. Sustainably supply food, water, and energy*
*2. Curb climate change and adapt to its impacts*
*3. Design a future without pollution and waste*
*4. Create efficient, healthy, resilient cities*
*5. Foster informed decisions and actions*



# PFAS and the Grand Challenges of Environmental Engineering

## PFAS Overview

# What are PFAS?

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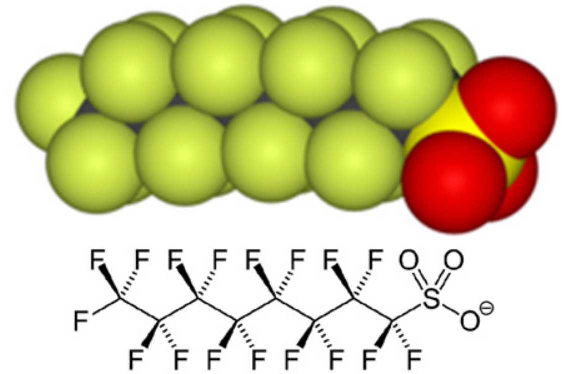
- Per- and polyfluoroalkyl substance are synthetic organics that contain multiple fluorine atoms
  - Perfluorooctanoic acid (PFOA)
  - Perfluorooctane sulfonic acid (PFOS)



- C-F bond is shortest and strongest bond in nature so extremely persistent in environmental media
- Likely more than 5,000 individual PFAS in use
- Multiple used in various industries since the 1940s but recent detection in the environment

# PFAS Uses

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- Military
  - Aqueous film forming foams (AFFF)
- Industrial
  - Chemical manufacturing processes
  - Textiles and carpets
  - Heavy industry (chrome plating)
  - Petrochemical industry (AFFF systems)
  - Aerospace industry
- Municipal
  - Airports

# PFAS: Key Technical Issues

- What we know
  - Occurrence, fate, transport and toxicity of some PFAS
  - Limitations of conventional treatment systems
- What we want to know
  - Occurrence, fate, transport, toxicity of more PFAS
  - Potential for using new treatment methods
- What we don't know
  - Assessment of alternatives to PFAS
  - Long-term, community and ecosystem effects

# PFAS in Drinking Water

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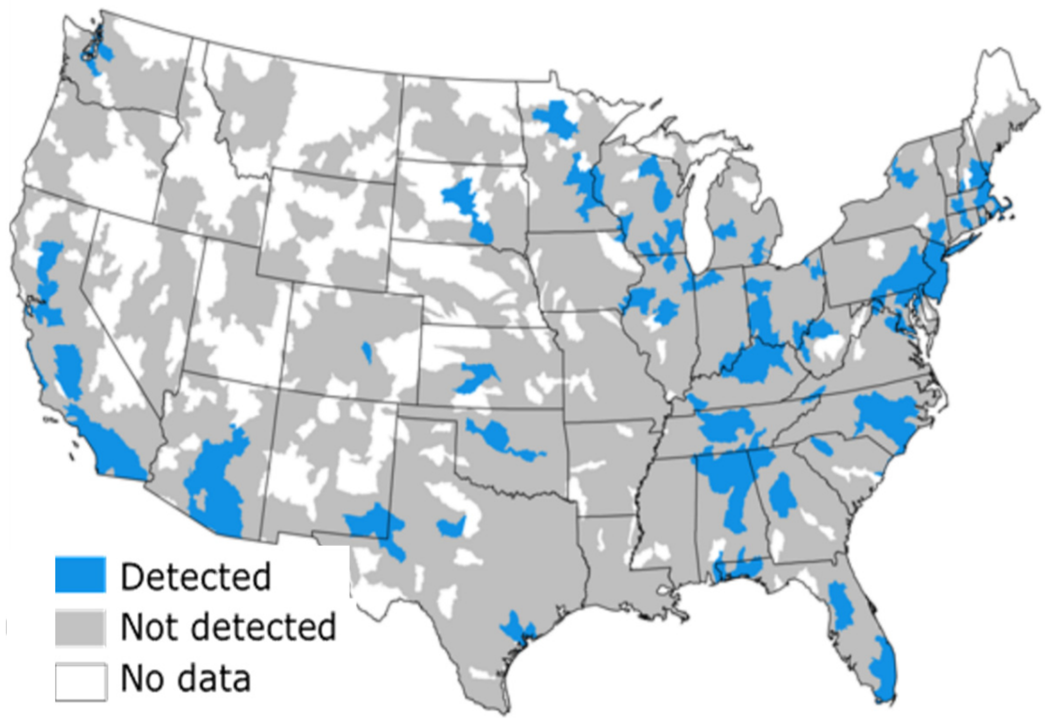
- PFAS detected above drinking water health criteria > 60 drinking water systems
  - EPA Unregulated Contaminants Monitoring program (UCMR3)
- Monitored 6 PFAS
  - PFOS
  - PFOA
  - PFBS
  - PFNA
  - PFHxS
  - PFHpA




From Hu et al. 2016. Detection of Poly- and Perfluoroalkyl Substances (PFASs) in U.S. Drinking Water Linked to Industrial Sites, Military Fire Training Areas, and Wastewater Treatment Plants. ES&T Letters. 2016, 3 (10) pp. 344-350 (open access article). 

# PFAS at Contaminated Sites

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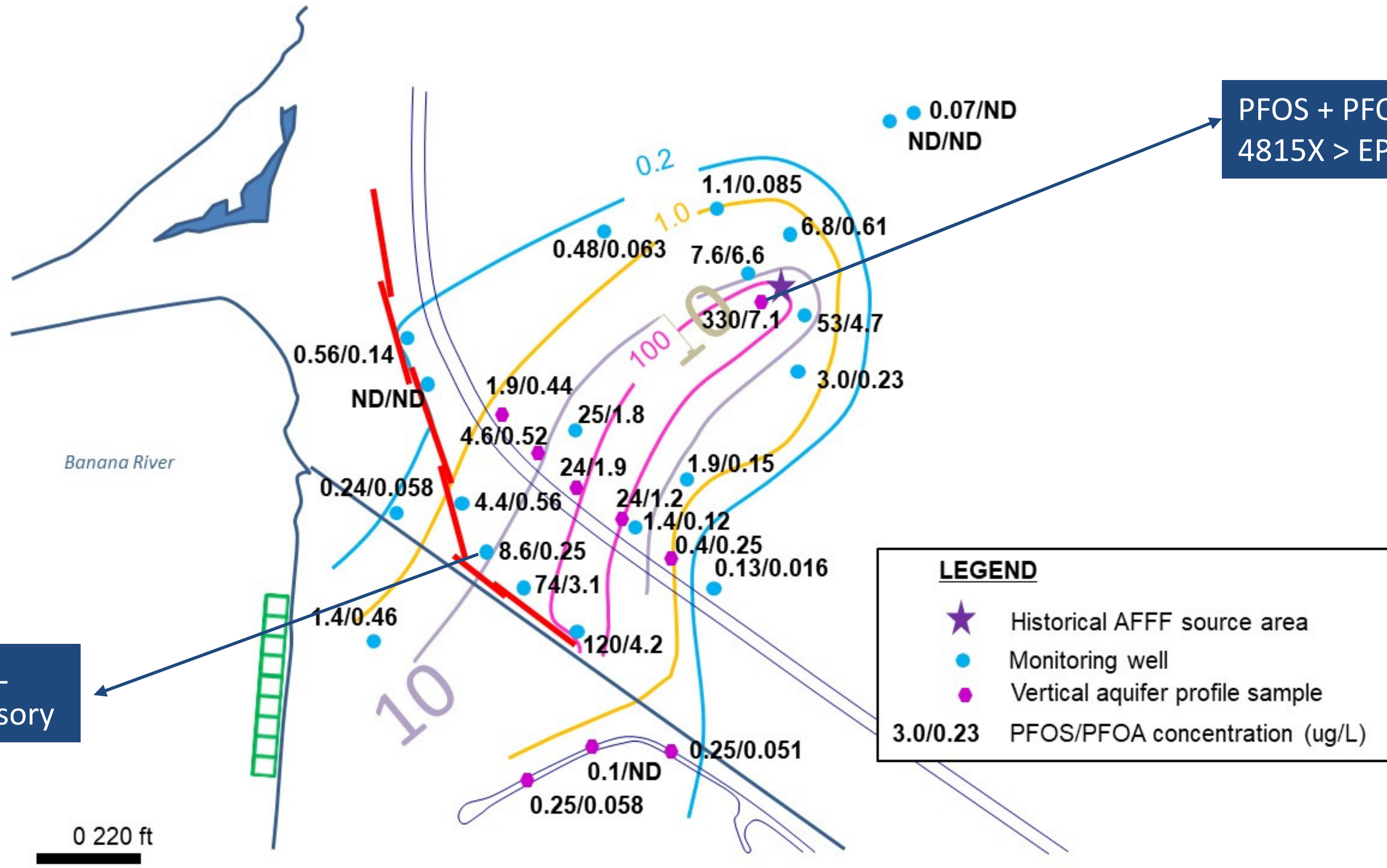
*Cape Canaveral Air Force Station Fire Training Area (FT-17); Operated before 1970*




PFOS + PFOA = 337,100 ng/L
4815X > EPA Health Advisory

PFOS + PFOA = 885 ng/L
126X > EPA Health Advisory

# PFAS: Key Regulatory Issues

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- Drinking Water Health Advisories finalized in 2016 by EPA for PFOA and PFOS (70 ng/L)
- Recent EPA actions
  - National PFAS Leadership Summit (May 2018)
  - Community Events (June – September 2018)
  - PFAS Action Plan (February 2019)
- Multiple states have issued standards/guidance for PFOS and PFOA (and other PFAS) in the absence of enforceable federal cleanup standards

# PFAS State Guidelines and Standards (ng/L)

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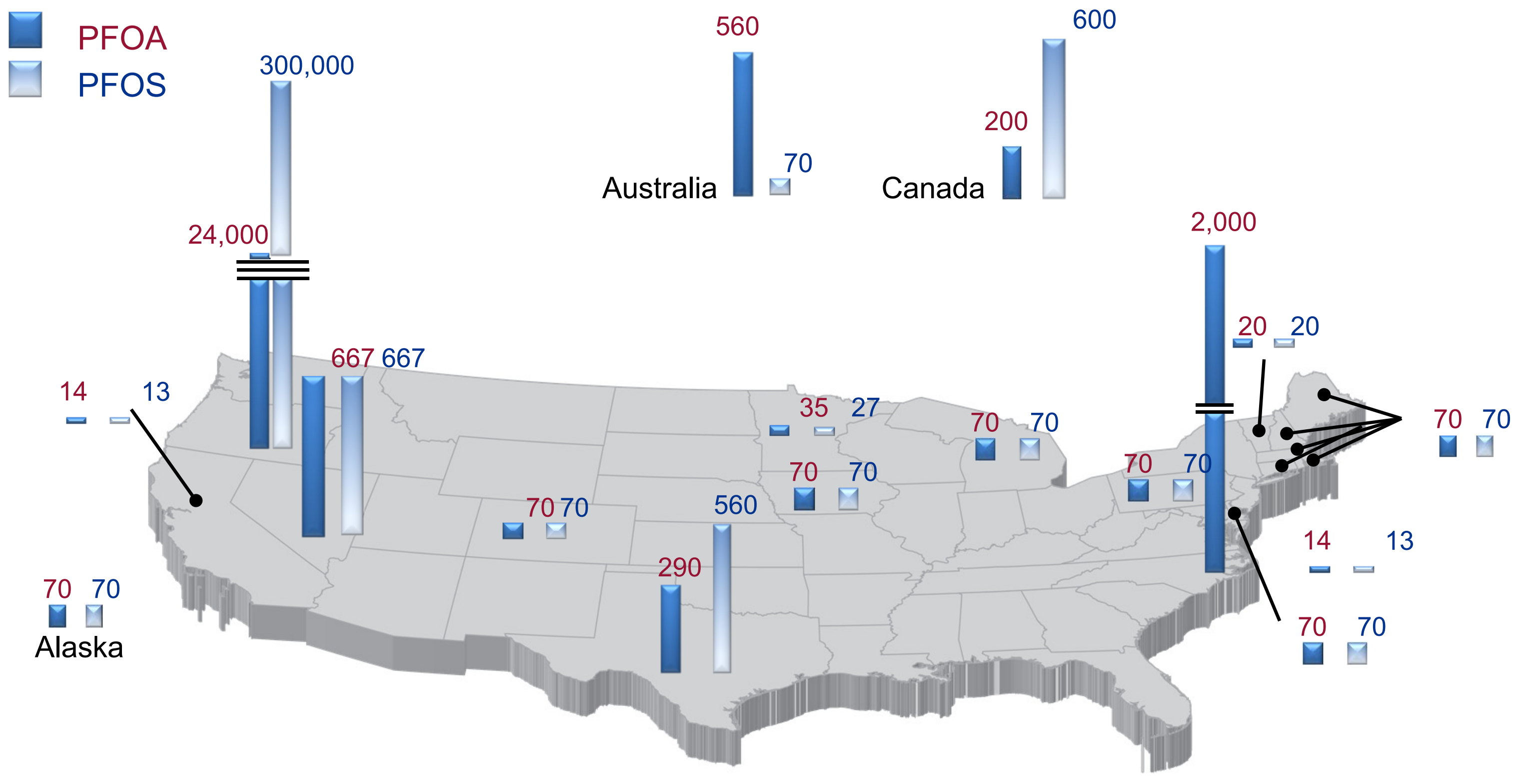


*Data Source: ITRC Table 4-1 Feb. 28, 2019*

# PFAS: Regulatory Status in CA

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- California State Water Resources Control Board Phased Investigation Plan (March 2019)
- Phase I
  - Airports: 31 airports with training/fire response sites
    578 drinking water wells (2 mile radius)
  - Landfills: 252 Municipal solid waste landfills
    353 drinking water wells (1 mile radius)
- Phase II
  - Source investigation and nearby drinking water well sampling at primary manufacturing facilities, refineries, bulk terminals and non-airport fire training areas, and 2017-2018 urban wildfire areas
- Phase III
  - Source investigation and nearby drinking water well sampling at secondary manufacturing sites, wastewater treatment and pre-treatment plants, and domestic wells

# PFAS: Other Key Issues

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- Legal
  - Liability for releases can be challenging
  - Litigation cases due to alleged damages to water resources
- Insurance
  - Coverage limitations and exemptions
- Replacement and reformulation products
  - The next frontier of PFAS chemicals


Rose are red
but some are pink
there's PFAS in more products than
you might think.
CLEAN WATER ACTION | CLEAN WATER FUND

# PFAS in the News

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Erin Brockovich
20 hrs

Be very careful... anyone coming around door-to-door offering you reduced price testing or home water treatment systems are there to take advantage of you in a very vulnerable time.

My best recommendation is if you are near the identified contamination site treat your water supply as contaminated until the MDEQ test results are in. PFAS tests are very complex, very expensive and MUST be taken and analyzed by skilled professionals... they cannot be performed for $300... that is a scam.

I am investigating all of the sites of the illegal dumping by Wolverine Worldwide... as well as the other sites in Michigan that have been impacted by PFAS chemical contamination... it is not easy, it is not going to be quick... stay vigilant. I am with you!

*Hoosick Falls NY*

*Kent County MI*


# PFAS and the Grand Challenges of Environmental Engineering

Linkages

# PFAS and the Grand Challenges of Environmental Engineering

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1. Sustainably supply food, water, and energy
2. Curb climate change and adapt to its impacts
3. Design a future without pollution and waste
4. Create efficient, healthy, resilient cities
5. Foster informed decisions and actions

# 1. PFAS and "Sustainable Water Supply"

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- Water quality and reliability
- Agricultural activities
  - PFAS bioaccumulation in produce from biosolids and impacted water sources
- Water recovery and reuse
- Conventional water, wastewater and groundwater treatment technologies either not effective or cost-effective for PFAS

# 3. PFAS and Preventing Pollution

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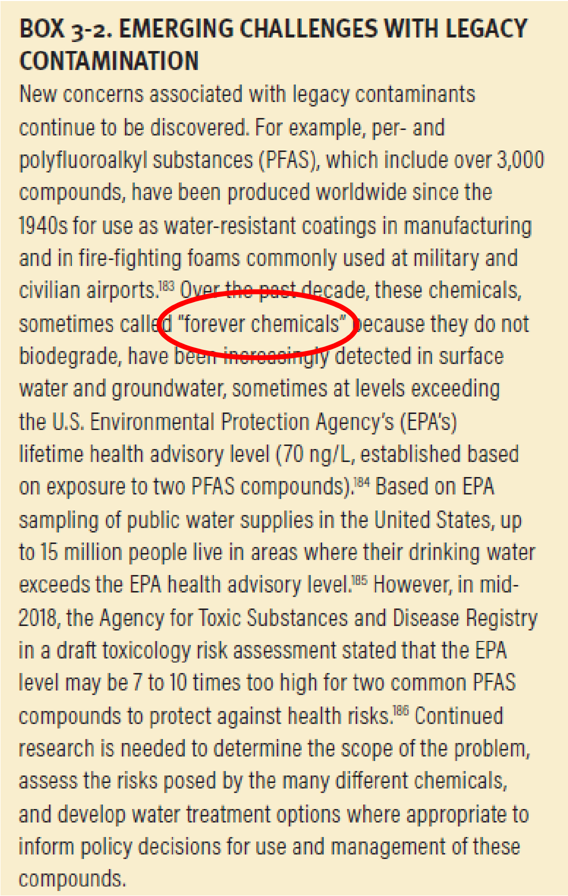
**BOX 3-2. EMERGING CHALLENGES WITH LEGACY CONTAMINATION**

New concerns associated with legacy contaminants continue to be discovered. For example, per- and polyfluoroalkyl substances (PFAS), which include over 3,000 compounds, have been produced worldwide since the 1940s for use as water-resistant coatings in manufacturing and in fire-fighting foams commonly used at military and civilian airports.[183] Over the past decade, these chemicals, sometimes called "forever chemicals" because they do not biodegrade, have been increasingly detected in surface water and groundwater, sometimes at levels exceeding the U.S. Environmental Protection Agency's (EPA's) lifetime health advisory level (70 ng/L, established based on exposure to two PFAS compounds).[184] Based on EPA sampling of public water supplies in the United States, up to 15 million people live in areas where their drinking water exceeds the EPA health advisory level.[185] However, in mid-2018, the Agency for Toxic Substances and Disease Registry in a draft toxicology risk assessment stated that the EPA level may be 7 to 10 times too high for two common PFAS compounds to protect against health risks.[186] Continued research is needed to determine the scope of the problem, assess the risks posed by the many different chemicals, and develop water treatment options where appropriate to inform policy decisions for use and management of these compounds.

- Manage/remediate existing legacy hazardous waste and contaminated sites to eliminate harmful exposures and return sites to productive use
- Develop and use tools to better predict the risks of new and existing chemicals in the environment, including toxicity, fate, and transport
- Eliminates pollution by relying on life-cycle and systems thinking
- Green chemistry and engineering
- Anticipate consequences and avoid unintended consequences of chemicals

# 5. PFAS and "Informed Decisions and Actions"

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- Tools to help stakeholders understand the consequences of decision alternatives
- Screening new chemicals and collaborative problem solving with manufacturers and chemical alternatives assessment

# PFAS Challenges and Opportunities

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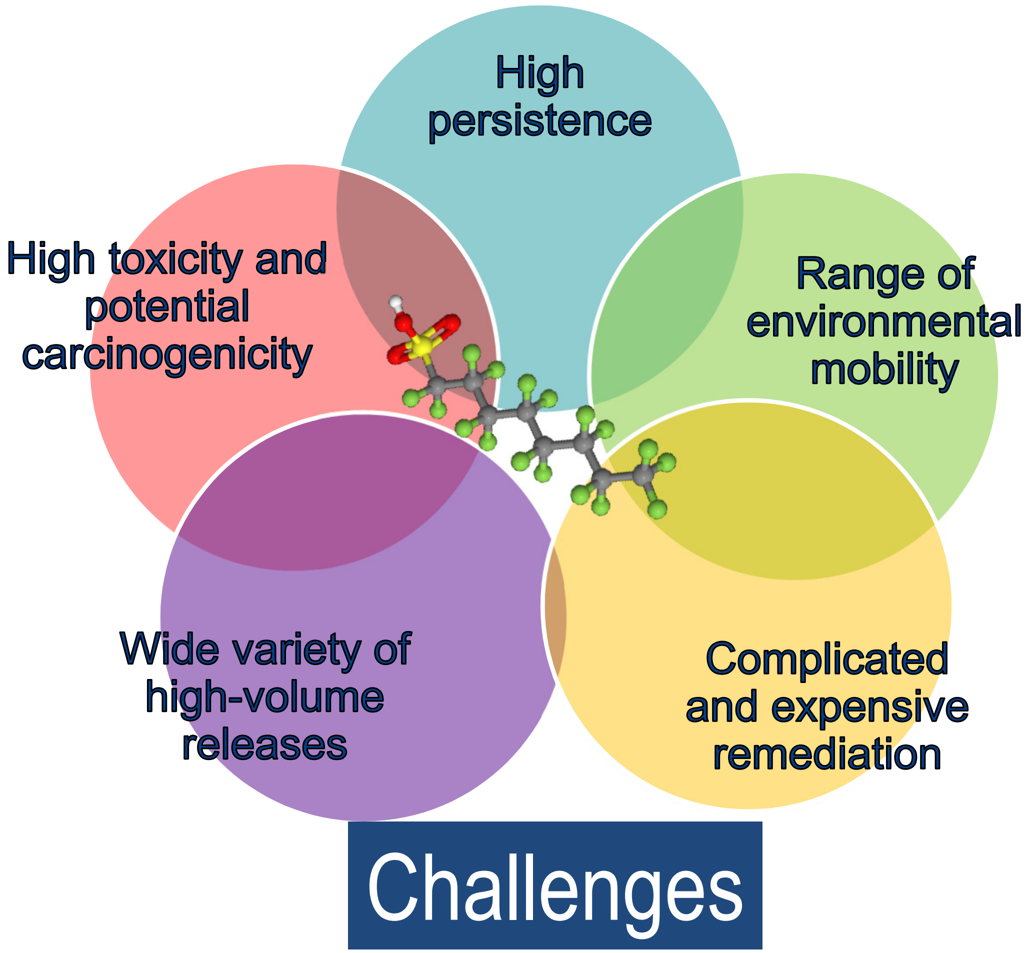


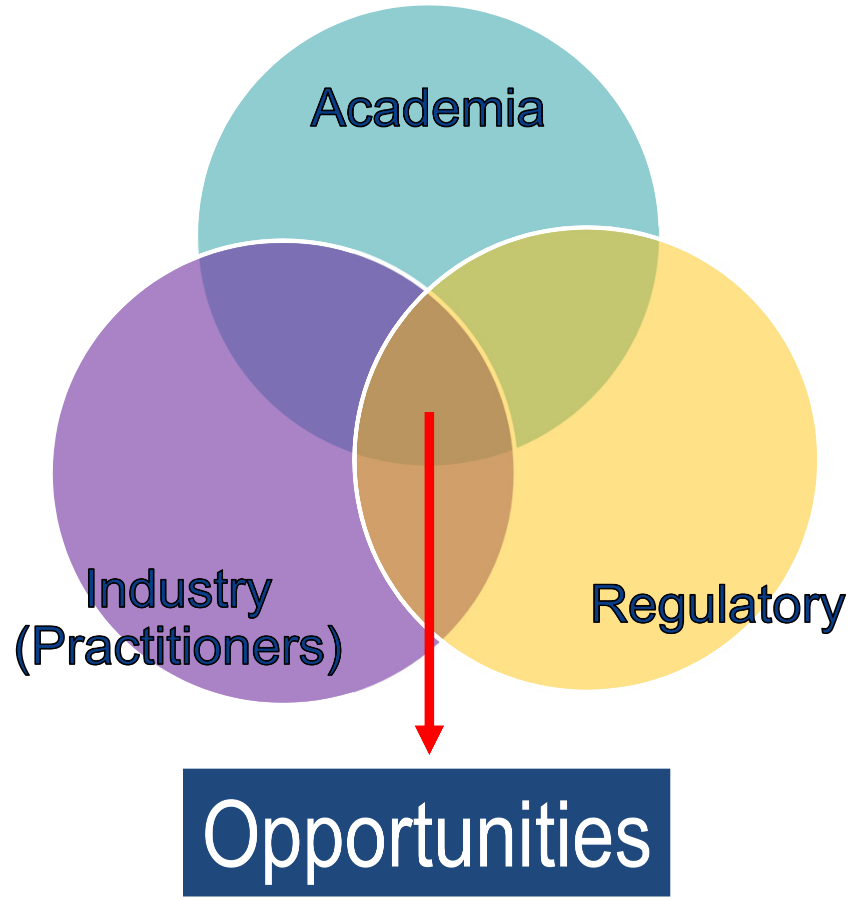

# Addressing PFAS Challenges

# Example 1. Cleanup of Legacy Contamination

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- Geosyntec teaming partners: UC Berkeley, NAVFAC, ESTCP
- Title: “PFAS Degradation Using Thermally-Enhanced Persulfate Oxidation
- Objective: Demonstrate the effectiveness of an in situ technology for PFAS treatment for managing contaminated sites (sources areas and plumes)
- Technology overview
  - Fully degrades polyfluoroalkyl substances that are known precursors of perfluoroalkyl acids
  - Fully degrades perfluorocarboxylic acids
  - Not effective for perfluorosulfonic acids so must be used in a treatment train approach

https://www.serdp-estcp.org/Program-Areas/Environmental-Restoration/Contaminated-Groundwater/Persistent-Contamination/ER-20172

# Example 1. Cleanup of Legacy Contamination

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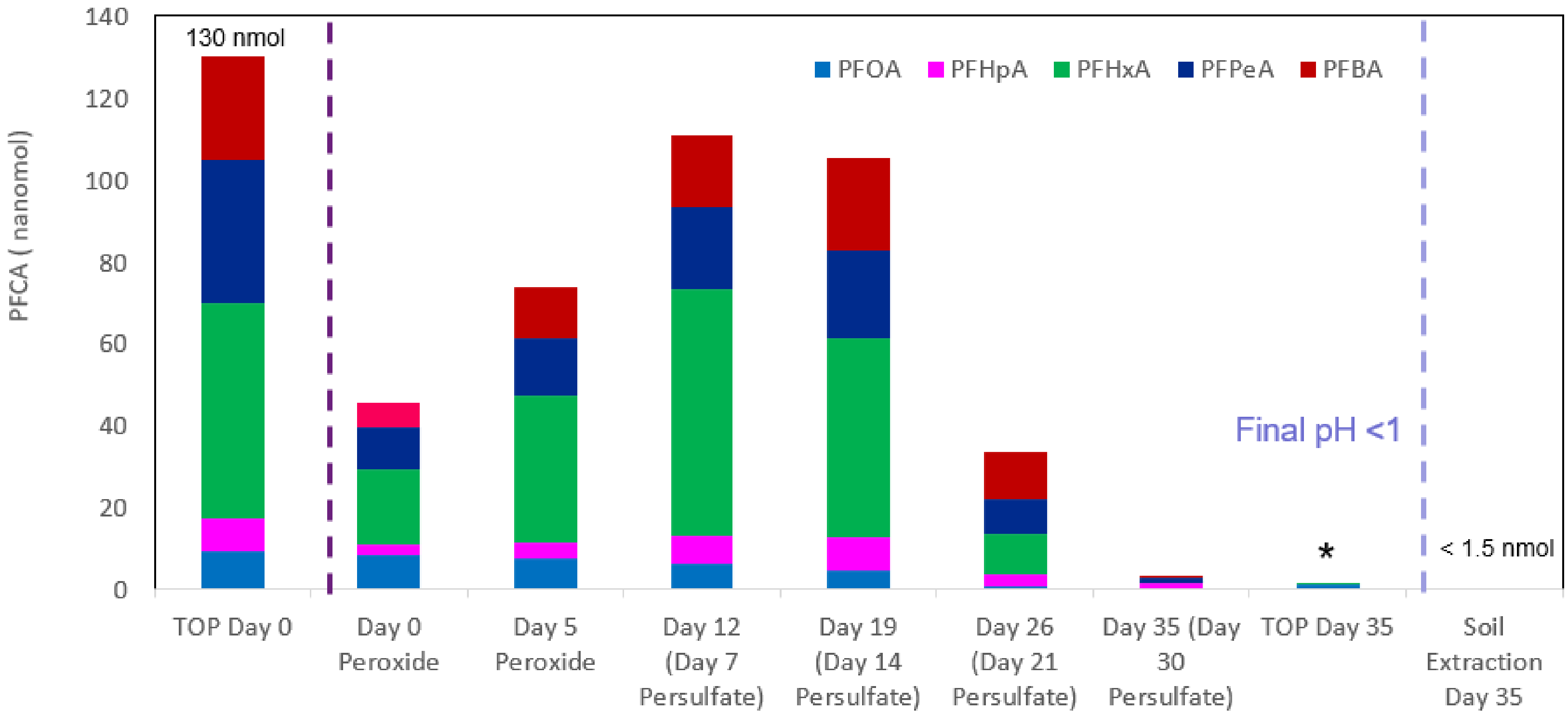
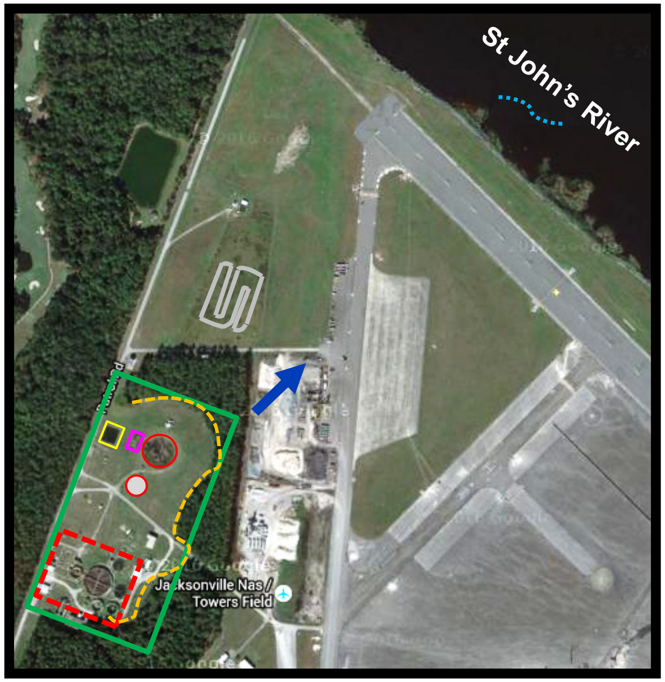



**Conditions**

Groundwater and solids, 1:1 water:solids, $[H_2O_2]$= 12%,
$[S_2O_8^{2-}]_0$ = 200 mM, T = 40$^o$ C, no acidification. $H_2O_2$ added day 0, $S_2O_8^{2-}$ added weekly after 5 days

# Example 1. Cleanup of Legacy Contamination

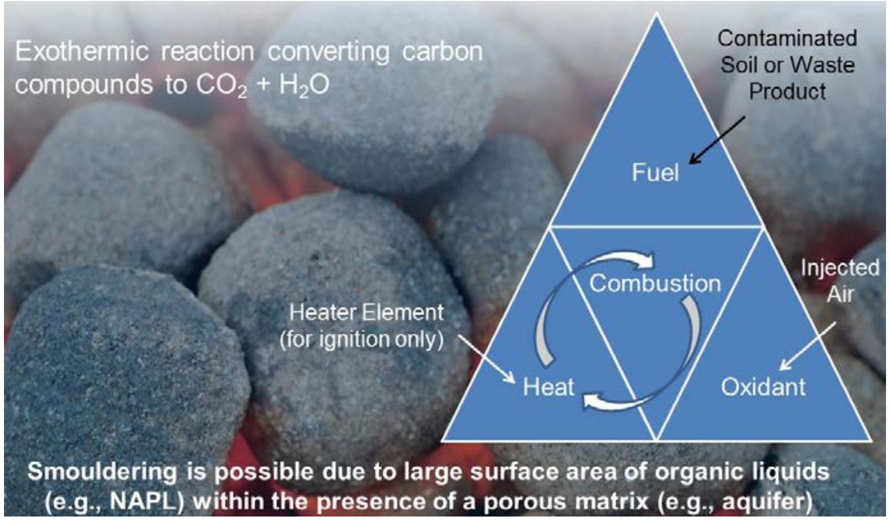
- Key findings from treatability studies at UC Berkeley
  - Overall PFAS mass destruction
  - Sequential formation of shorter-chain PFAS
  - Demonstrated fluoride mass balance
  - Effective in PFAS-spiked groundwater, groundwater/soil mixture, Ansul AFFF
- Next steps
  - Field demonstration this summer at a Navy site
- Benefits
  - Expedited technology transfer and adoption
  - Collaboration is key to buy-in from stakeholders and technology users




*FT-02, NAS Jacksonville, Florida*

# Example 2. Contaminant/Waste Destruction

- Geosyntec teaming partners: University of Western Ontario, Savron, Royal Military Collage of Canada and SERDP
- Title: "Demonstration of Smoldering Combustion Treatment of PFAS-Impacted Investigation-Derived Waste"
- Objective
  - Demonstrate that surrogate fuels can support smoldering >900°C that destroy PFAS in soils or spent activated carbon



# Example 2. Contaminant/Waste Destruction



mg PFAS/g GAC & Sand
(Pre Treatment)

| | II-1 | II-2 |
|---|---|---|
| PFOA | 0.59 | 0.51 |
| PFOS | 0.14 | 0.12 |
| PFHxS | 0.24 | 0.22 |


Measured Concentration

mg PFAS/g Ash & Sand
(Post Treatment)

| | II-1 | II-2 |
|---|---|---|
| PFOA | <0.0004 | <0.0004 |
| PFOS | <0.0004 | <0.0004 |
| PFHxS | <0.0004 | <0.0004 |

# Example 2. Contaminant/Waste Destruction

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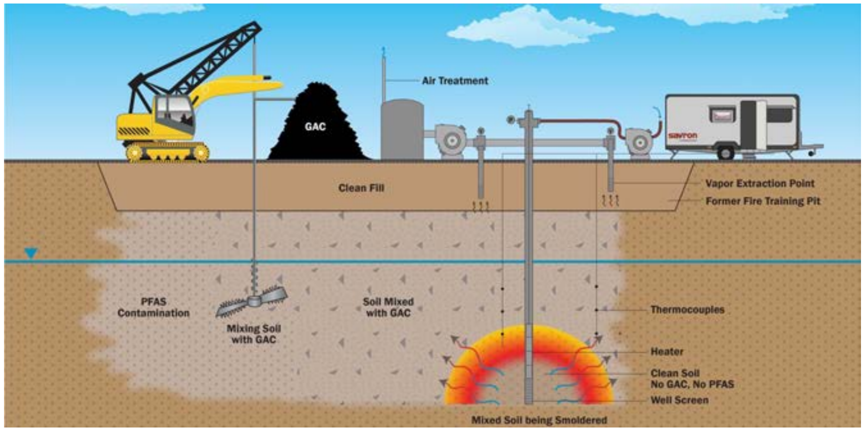
- GAC > 40 g/kg in soil achieved combustion at temperatures that destroy PFAS
- PFAS treated to non-detectable levels in soils, sand and ash
- >80% of the PFAS as HF, shows complete decomposition is possible
- Low amounts of some decomposition products may form; capture and re-treat
- Fast smoldering front velocity allows practicable application at larger scales (full scale experience using smoldering to destroy other hydrocarbons)
- Ex situ and in situ applications



# Example 3: Informed Decision Making

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- Geosyntec teaming partners: UC Berkeley, Oregon State University, Colorado School of Mines, SERDP
- Title: “Lines of Evidence to Assess the Effectiveness of PFAS Remedial Technologies”
- Objectives
  - Produce guidelines, best practices, and metrics for DoD site managers and contractors to evaluate PFAS treatment technologies
  - Provide accurate, more complete information to inform treatment expectations
  - Inform reviews of technology effectiveness, knowledge gaps, and priorities for further testing
  - Accelerate the development of promising technologies for PFAS remediation

https://www.serdp-estcp.org/Program-Areas/Environmental-Restoration/ER18-1663

# Example 3: Informed Decision Making

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- Decrease in target PFAS concentrations
- Decrease in PFAS precursors (e.g., TOP assay, QTOF, PIGE)
- Factors that affect treatment are identified
- Treatment kinetics and mechanism(s) identified or appear plausible
- Treatment intermediates or byproducts (PFAS or non-PFAS) identified and quantified
- Study design employs best practices (e.g., controls)
- Study design represents environmentally-relevant conditions (e.g., concentrations in soil and GW, geochemistry, matrices)
- Supported by peer-reviewed literature
- Total organic fluorine measurement/reduction (should methodology become available)
- Reductions in risk/toxicity/bioavailability

# Example 4: Informed Decision Making

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- Geosyntec teaming partners: Colorado School of Mines, SERDP
- Title: "Ecological Risk Assessments for AFFF Impacted Sites"
- Goals
  - Quantitative guidance for ecological risk assessments
  - Based on modeling using empirical bioaccumulation measures
  - Detailed review of mammalian and avian toxicity; aquatic life toxicity
- Despite unknowns and uncertainties, ecological risk assessments can be done

# Example 5: Better Tools for Decision Making

- Geosyntec teaming partners: Oregon State University, AECOM, CDM Smith, Jacobs, SERDP
- Title: "Assessing and Mitigating Bias in PFAS Levels during Groundwater and Surface Water Sampling"
- Objectives
  - Myth busting sampling protocols
  - Developing science-based PFAS sampling guidance

# Conclusions

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- PFAS challenges ahead
  - Different nature and scale than prior contaminants
- Solutions of past not sufficient to address problems of the future
- Role of environmental engineering community in addressing PFAS challenges
  - Build on past successes and lessons learned
  - Bridge among scientists, other engineers, decisions makers, and communities to assess options, weigh trade-offs and design pragmatic solutions
- Key opportunities
  - Translating research into practice through collaborative partnerships between industry, academia and communities is key
  - Partnerships with other hubs for research and innovation lead to optimal problem solving and earlier adoption of technologies by practitioners

# Lessons Learned from PFAS

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- Application of holistic systems thinking
- Use of life-cycle analysis and similar tools

# Questions

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