# Ending PFAS

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# What We Do

Aquagga provides PFAS destruction equipment and services for the **environmental remediation** & **industrial wastewater treatment** industries**.**

Benefits include:

- ➔ Safe & clean disposal of PFAS-rich wastes
- ➔ Reduction of future liability
- ➔ Reduction of overall project costs
- ➔ Compliance with emerging regulations
- ➔ Prevention of future contamination

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# Sources of PFAS

Examples:

- ➔ **Industrial PFAS production and use**
- ➔ **AFFF (Fire Fighting foams)**
- ➔ Brands such as Teflon, Scotchgard, Rain-X
- ➔ Gore Tex and other waterproofing coatings
- ➔ Oil & gas activities

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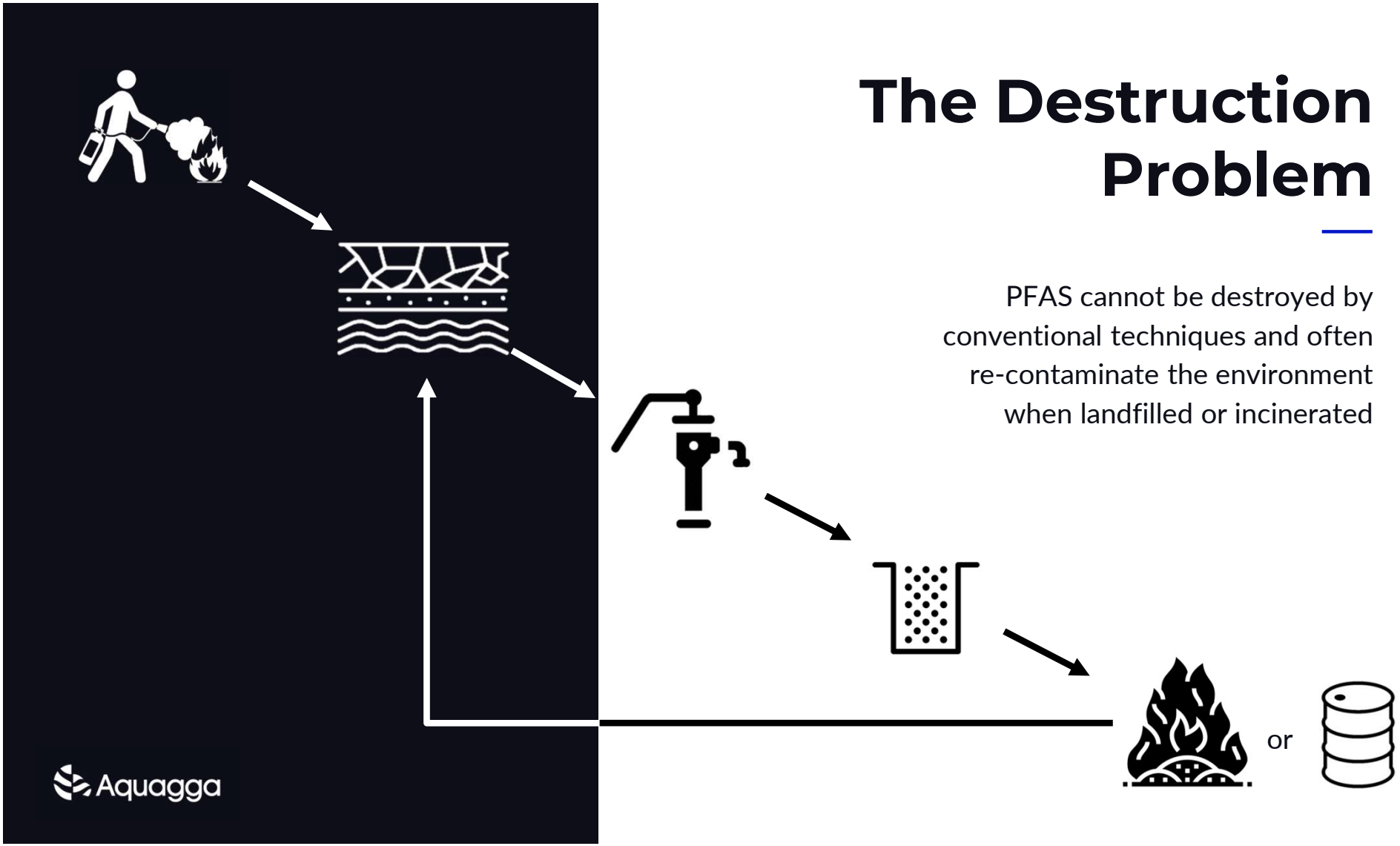
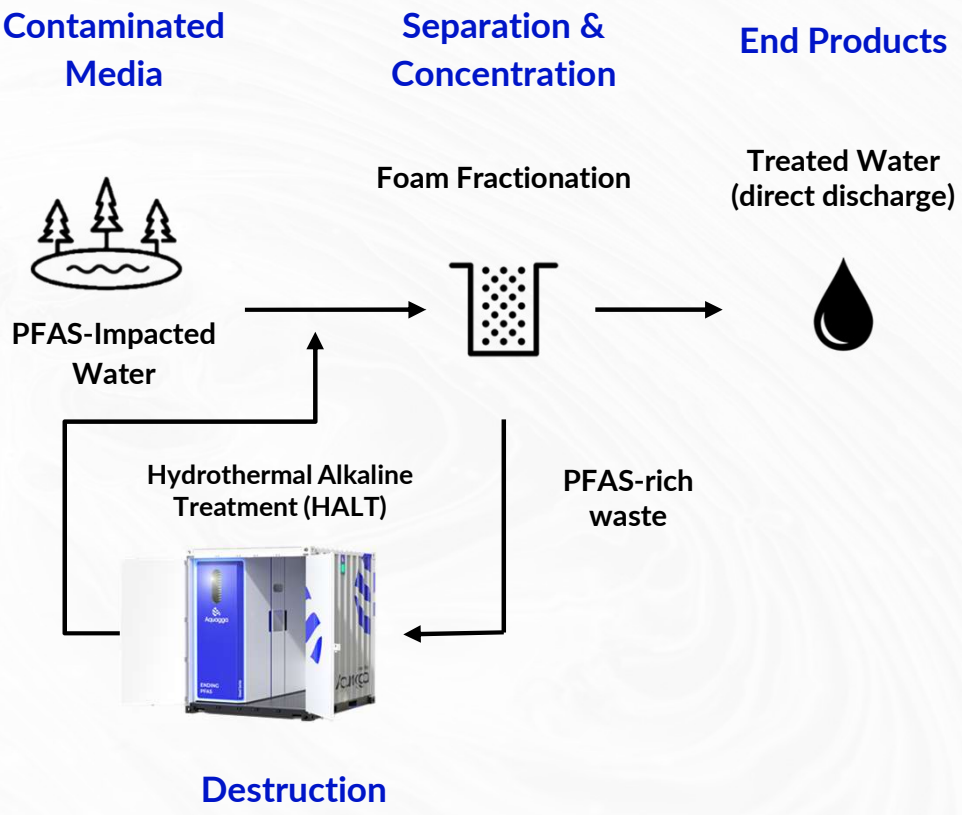
# The Destruction Problem

PFAS cannot be destroyed by conventional techniques and often re-contaminate the environment when landfilled or incinerated



# Integrating PFAS Destruction Technology

- Example: Foam Fractionation (FF) with HALT
  - Use FF to remove PFAS from contaminated water and produce concentrated liquid waste stream
  - Use HALT to reduce PFAS levels in concentrate by ~99.99%
  - Blend HALT effluent into FF influent to capture residual PFAS
  - **Closed-loop PFAS treatment and destruction solution**

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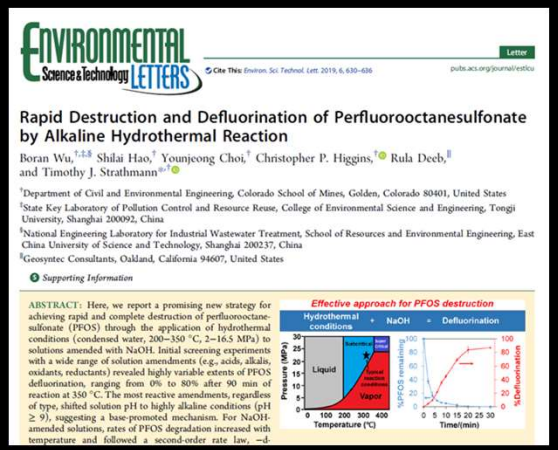
# How It Works

***Hydrothermal Alkaline Treatment*** completely destroys ***all PFAS compounds*** under subcritical water conditions through ***high-pH-driven*** (base catalyzed) defluorination reactions



Environmental Science & Technology Letters

Letter

Rapid Destruction and Defluorination of Perfluorooctanesulfonate by Alkaline Hydrothermal Reaction

Boran Wu,[†,‡,§] Shilai Hao,[†] Younjeong Choi,[†] Christopher P. Higgins,[†] Rula Deeb,[∥] and Timothy J. Strathmann[*,†]

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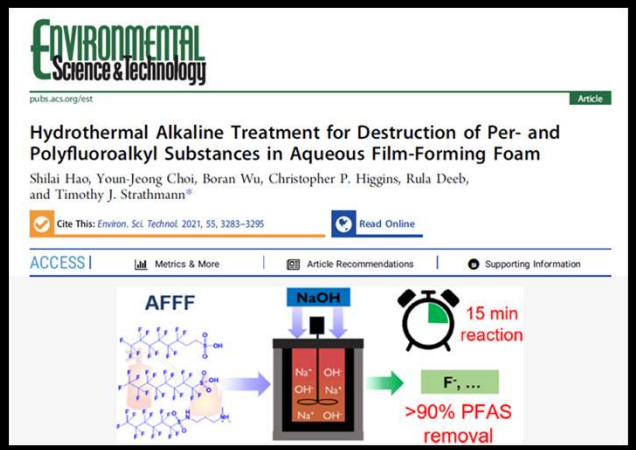
Supporting Information

ABSTRACT: Here, we report a promising new strategy for achieving rapid and complete destruction of perfluorooctanesulfonate (PFOS) through the application of hydrothermal conditions (condensed water, 200–350 °C, 2–16.5 MPa) to solutions amended with NaOH. Initial screening experiments with a wide range of solution amendments (e.g., acids, alkalis, oxidants, reductants) revealed highly variable extents of PFOS defluorination, ranging from 0% to 80% after 90 min of reaction at 350 °C. The most reactive amendments, regardless of type, shifted solution pH to highly alkaline conditions (pH ≥ 9), suggesting a base-promoted mechanism. For NaOH-amended solutions, rates of PFOS degradation increased with temperature and followed a second-order rate law, −d-

Effective approach for PFOS destruction

Hydrothermal conditions + NaOH → Defluorination



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Article

Hydrothermal Alkaline Treatment for Destruction of Per- and Polyfluoroalkyl Substances in Aqueous Film-Forming Foam

Shilai Hao, Youn-Jeong Choi, Boran Wu, Christopher P. Higgins, Rula Deeb, and Timothy J. Strathmann*

Cite This: Environ. Sci. Technol. 2021, 55, 3283−3295

Read Online

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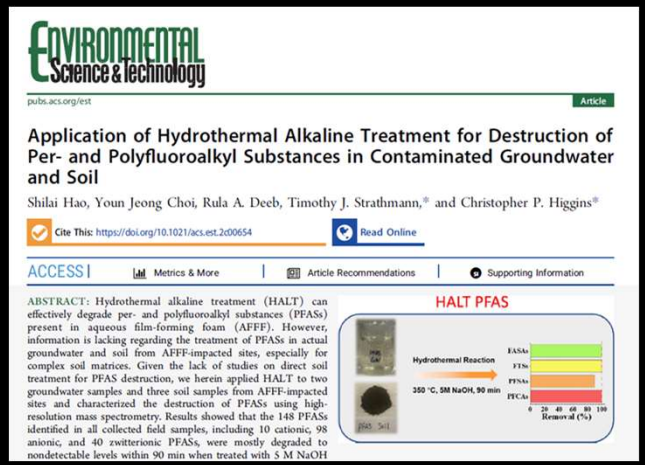

Environmental Science & Technology

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Article

Application of Hydrothermal Alkaline Treatment for Destruction of Per- and Polyfluoroalkyl Substances in Contaminated Groundwater and Soil

Shilai Hao, Youn Jeong Choi, Rula A. Deeb, Timothy J. Strathmann,* and Christopher P. Higgins*

Cite This: https://doi.org/10.1021/acs.est.2c00654

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ABSTRACT: Hydrothermal alkaline treatment (HALT) can effectively degrade per- and polyfluoroalkyl substances (PFASs) present in aqueous film-forming foam (AFFF). However, information is lacking regarding the treatment of PFASs in actual groundwater and soil from AFFF-impacted sites, especially for complex soil matrices. Given the lack of studies on direct soil treatment for PFAS destruction, we herein applied HALT to two groundwater samples and three soil samples from AFFF-impacted sites and characterized the destruction of PFASs using high-resolution mass spectrometry. Results showed that the 148 PFASs identified in all collected field samples, including 10 cationic, 98 anionic, and 40 zwitterionic PFASs, were mostly degraded to nondetectable levels within 90 min when treated with 5 M NaOH

HALT PFAS

# Patented Technology

PFAS-rich Wastewater In → Clean Water & Safe Salts Out

***A "Pressure Cooker on Steroids" for PFAS Destruction***

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# Aquagga's PFAS Destruction Systems

## Pilot Series

- Bench testing or feasibility studies
- **1 - 2.5 gph** of concentrate disposal
- **3 - 5 gallons** per sample for testing

## Steed Series

- Available for projects in 2023
- **10 - 20 gph** of concentrate disposal
- Couples with **25 to 50 gpm** foam fractionation system
- 480V Three Phase (124 kWh/$m^3$)

## Stampede Series

- Coming in 2024
- **50-150 gph** of concentrate disposal
- Couples with **100 to 1,000 gpm** concentration technologies
- 480V Three Phase (124 kWh/$m^3$)

# Example Project - FAI Fire Training Pit

- Customer problem - **AFFF-impacted surface water in lined holding pond at Fairbanks International Airport**
  - Total PFAS concentrations: 2 to 6 ppm
  - Co-contaminated with arsenic and hydrocarbons (DRO & RRO)
  - 40,000 gallons of liquid to treat
  - Liquid contained in a lined & capped holding pond

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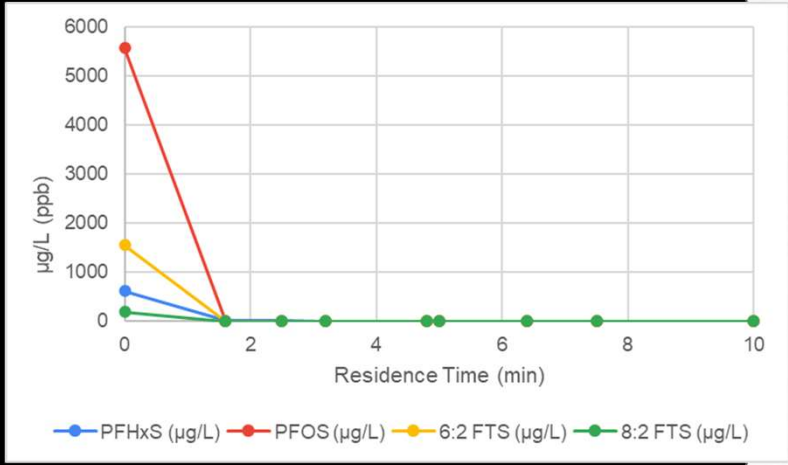


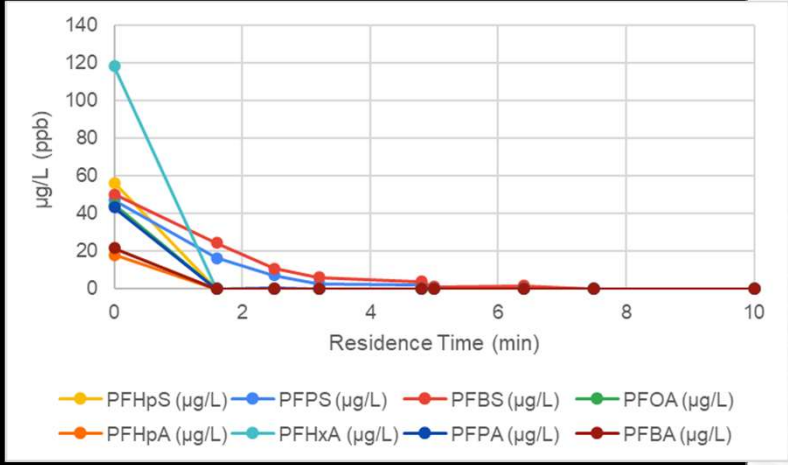


**Pinkard et al., 2023. Chemosphere 314.*

# Example Project - FAI Fire Training Pit

- >99.9% total PFAS reduction within 10 minutes of processing through continuous HALT system
  - PFOS reduction by >99.99%
  - PFHxS reduction by 99.77%
  - PFBS reduction by 99.67%
  - PFOA reduction by 99.997%
  - PFHxA reduction by 99.97%
  - PFBA reduction by 99.94%
- System performance characterized as function of residence time in the HALT system
- **Current effort - field deployment to Fairbanks in 2023 for FAA-funded pilot demonstration**

# Example Project - FAI Fire Training Pit

- June 2023 - foam fractionation of FTP water
- Bench testing results:
  - ~97% total PFAS removal
  - >99.998% PFOS + PFOA removal
  - **<7.32 ppt PFOA & <16.9 ppt PFOS**
  - Proprietary, non-toxic surfactant used to boost foaming performance
- 20x to 50x volume reduction

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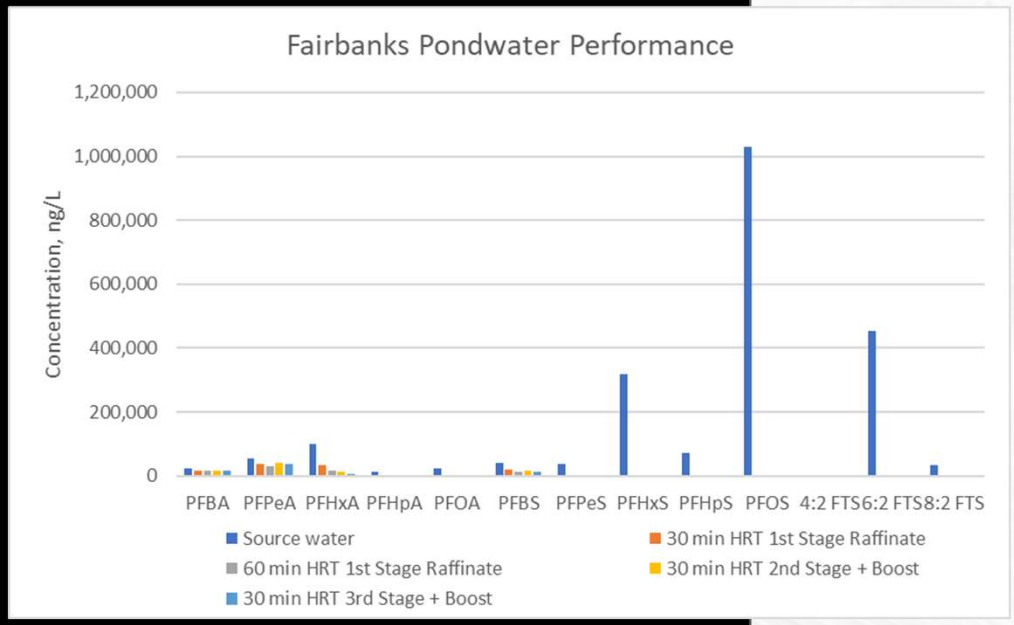
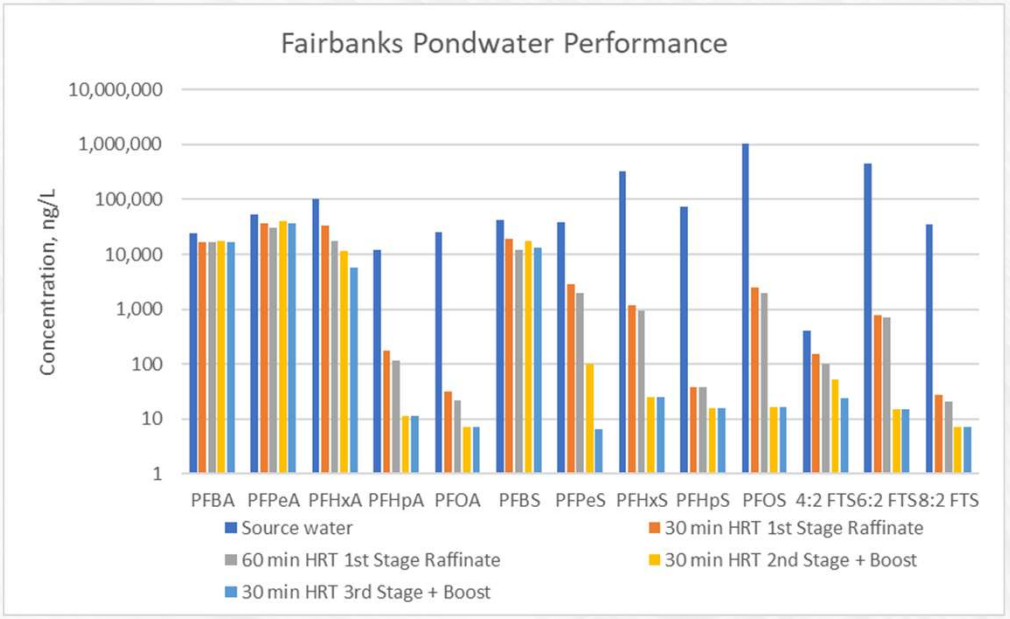
Montrose Environmental Group

# Example Project - FAI Fire Training Pit

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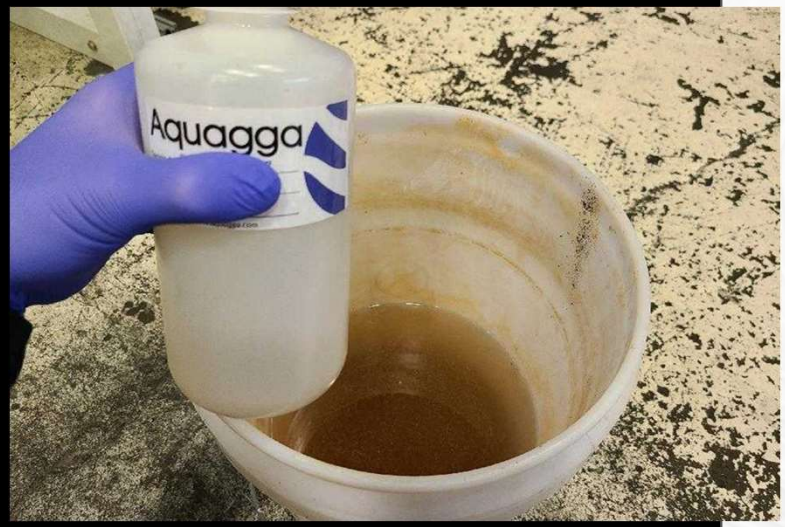
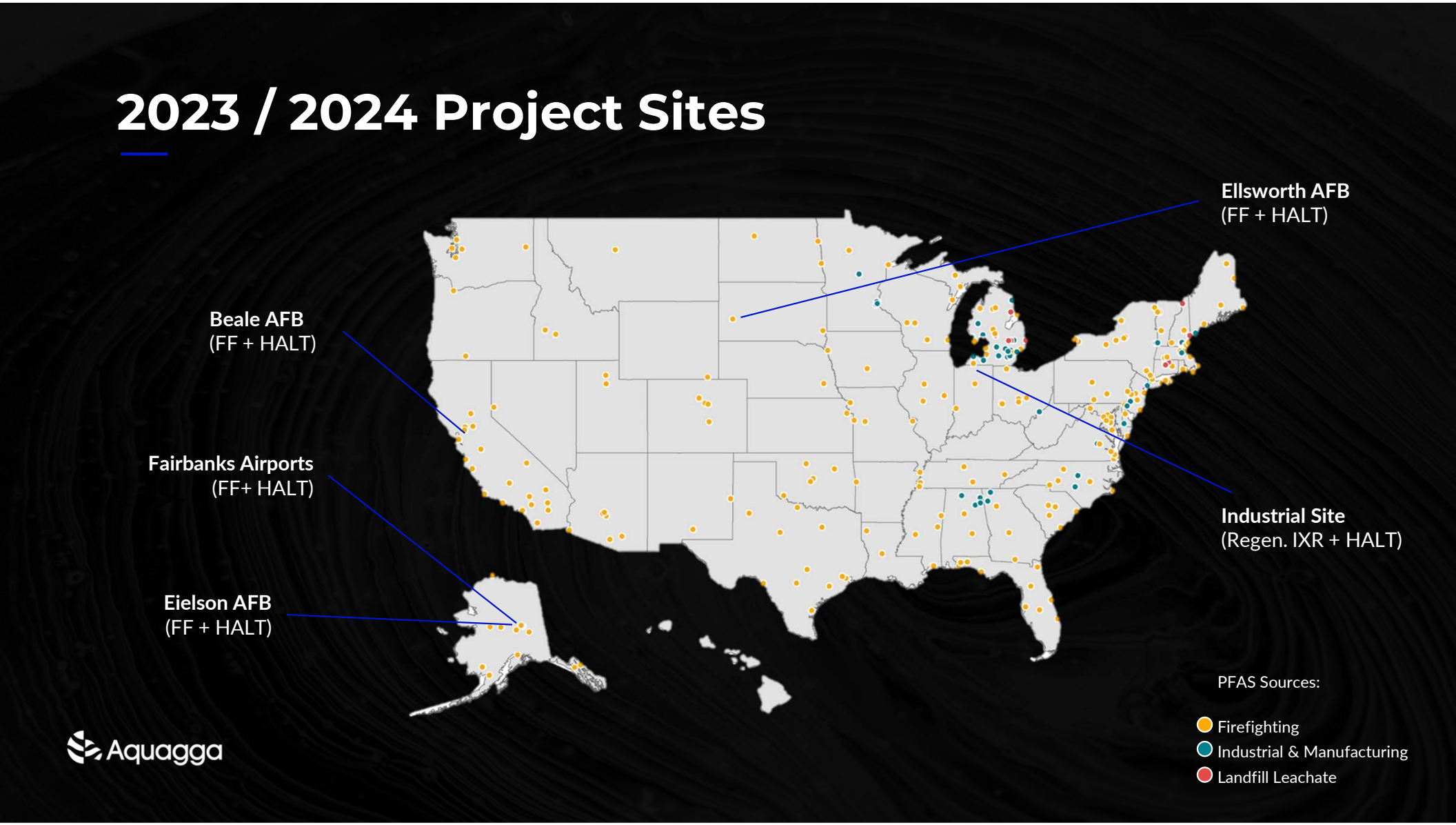



# Example Project - FAI Fire Training Pit

| Analyte | Foamate (ppb) | HALT Effluent (ppb) | Destruction % |
|---|---|---|---|
| **PFOS** | **36,400** | **10.9** | **99.97%** |
| PFHpS | 522 | 0.199 | 99.96% |
| PFHxS | 6,260 | 3.34 | 99.95% |
| PFPeS | 1,160 | 1.09 | 99.91% |
| PFBS | 552 | 1.58 | 99.71% |
| **PFOA** | **484** | **0.047** | **99.99%** |
| PFHpA | 334 | ND | >99.993% |
| PFHxA | 2,540 | ND | >99.999% |
| PFPeA | 196 | ND | >99.98% |
| 6:2 FTS | 8,800 | ND | >99.999% |
| **Total PFAS** | **58,280** | **17.16** | **99.97%** |

- September 2023 - On-site HALT of foam concentrate

# 2023 / 2024 Project Sites

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# Applications for HALT

| Feedstock | ✓ = tested<br>◎ = currently testing |
|---|---|
| Regeneration brine | ✓ |
| Foam fractionate | ✓ |
| AFFF stockpiles | ✓ |
| Fire training pit water | ✓ |
| RO / NF reject | ✓ |
| Landfill leachate | ✓ |
| Coagulated slurries | ✓ |
| Distillation brine | ◎ |

# Key Takeaways

- **The most ideal PFAS destruction technologies are ‘heavy lifters’**
  - Eliminate the most PFAS by mass. **HALT can destroy 100’s to 1,000’s of mg/L of PFAS in a single pass**
  - Effective on all PFAS regardless of structure or chain length (HALT can treat **all PFAS**)
  - Should not be thought of as a way to achieve discharge targets or treat water to health advisory levels (HALs). HALT will reduce PFAS levels to 10’s to 100’s of ng/L
  - Separation of PFAS from HALT effluent facilitates an overall treatment solution, reaching target discharge levels

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# Let’s keep the flow going...

*Contact us to schedule a Zoom call or a tour at our HQ in Tacoma, WA*

*alex@aquagga.com*

# Frequently Asked Questions

- ***What are some practical considerations of integrating Aquagga's HALT systems at a project site?***
  - Electrical connections are standard 480V, 3-phase connections
  - Standard hose connections used to interface with holding tanks of various sizes
  - 10 ft. shipping container, moveable with forklift
  - Can batch and treat concentrated liquids in a centralized location
  - No emissions controls required
  - Aquagga operators deployed for pilot demonstrations
  - Installed systems are remotely monitored and controlled
  - 24/7 technical support for system operators

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# Frequently Asked Questions

- ***What happens to co-contaminants? Do any compounds cause processing challenges?***
  - Any halogenated compounds are destroyed very effectively under HALT conditions (*e.g.*, PFAS, chlorinated solvents)
  - Organic compounds are gasified or converted to stable monomers
  - Heavy metals are not removed
  - High levels of TDS or TOC do not significantly affect PFAS destruction efficacy or cause processing challenges
  - Feedstocks with very high levels of Ca, Mg, or Si may require water softening

# Frequently Asked Questions

- ***Can you provide rough cost estimates for full-scale project deployments?***
  - Project costs depend on:
    - Mobilization distance and complexity
    - Volumes to treat
    - Length of deployment
    - Complexity of feedstock and specific PFAS present
  - Once installed, HALT costs $0.65 to $1.10 per gallon to operate at-scale, inclusive of:
    - Chemical usage
    - Electricity consumption
    - Mobilization
    - Equipment depreciation.

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