Per- and Polyfluoroalkyl Substances Field Pilot Study at Operable Unit 1 Hill Air Force Base, Utah

A Presentation Prepared By:

Brice

Toni Mehraban, PE
Brice Engineering, LLC

Toni.Mehraban@BriceEng.com
385.253.0684

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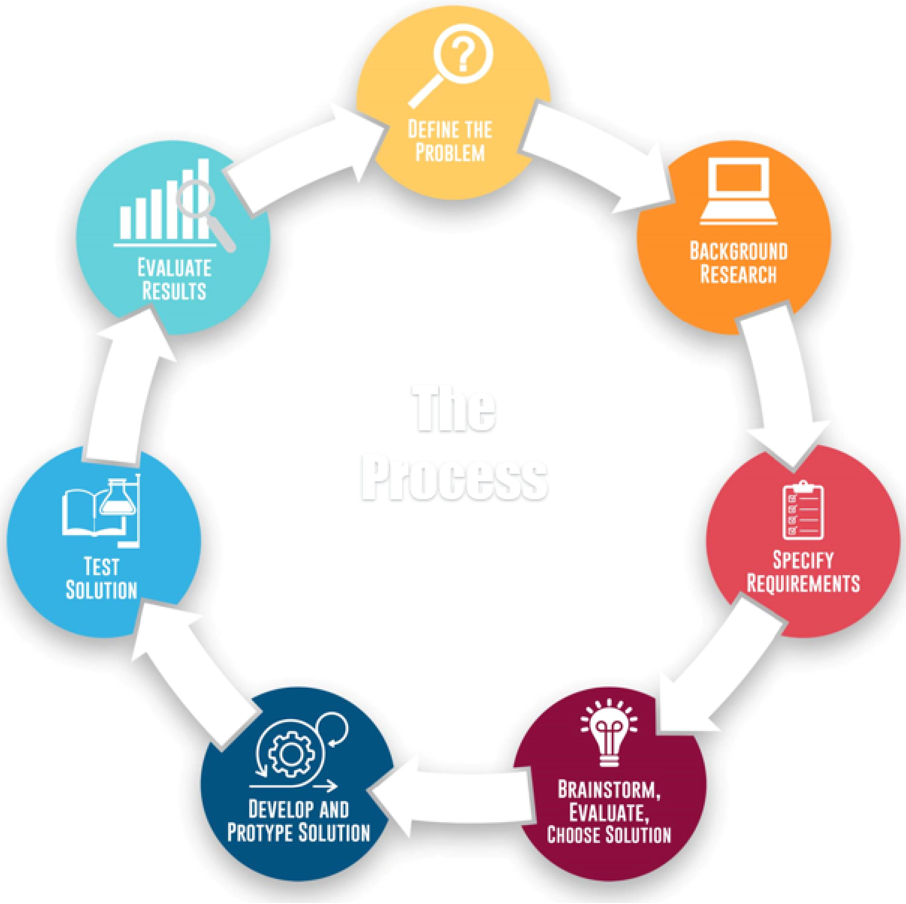
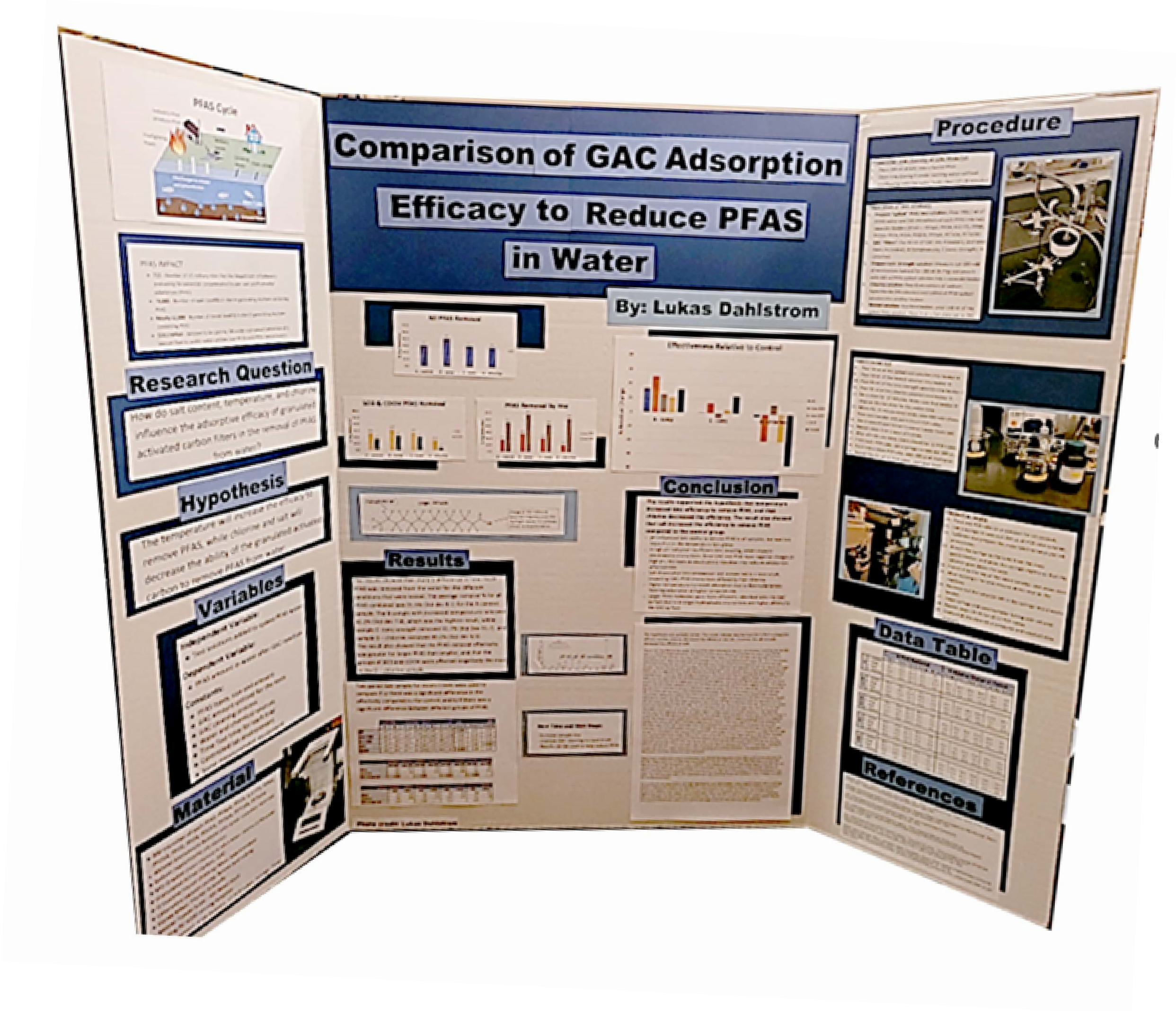
Scientific/Engineering Method

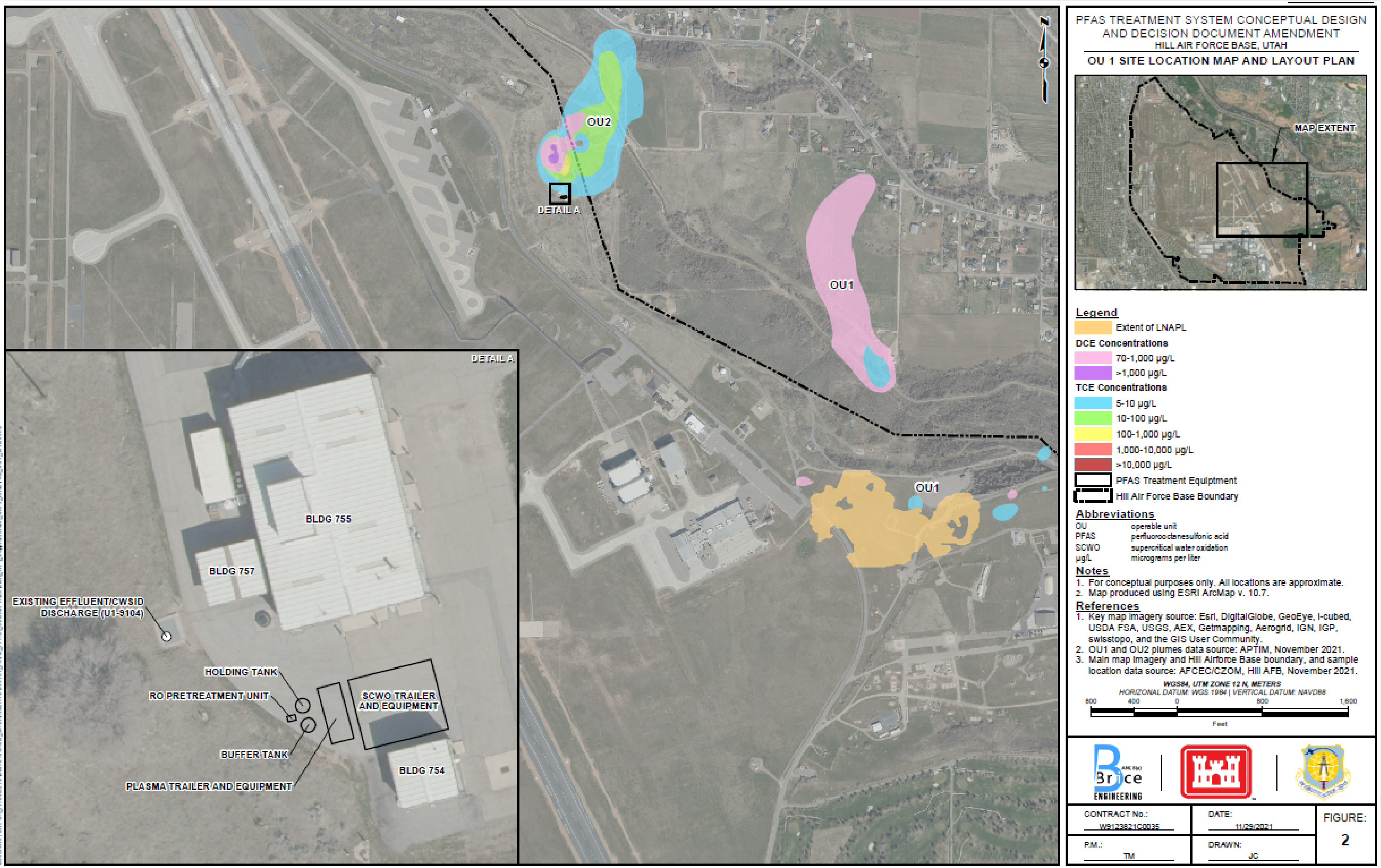




STEM Fair project photo used with permission from Y. Dahlstrom, 4/29/24

Current Understanding of PFAS at Hill AFB

Define the Problem



Treatment Technologies Considered

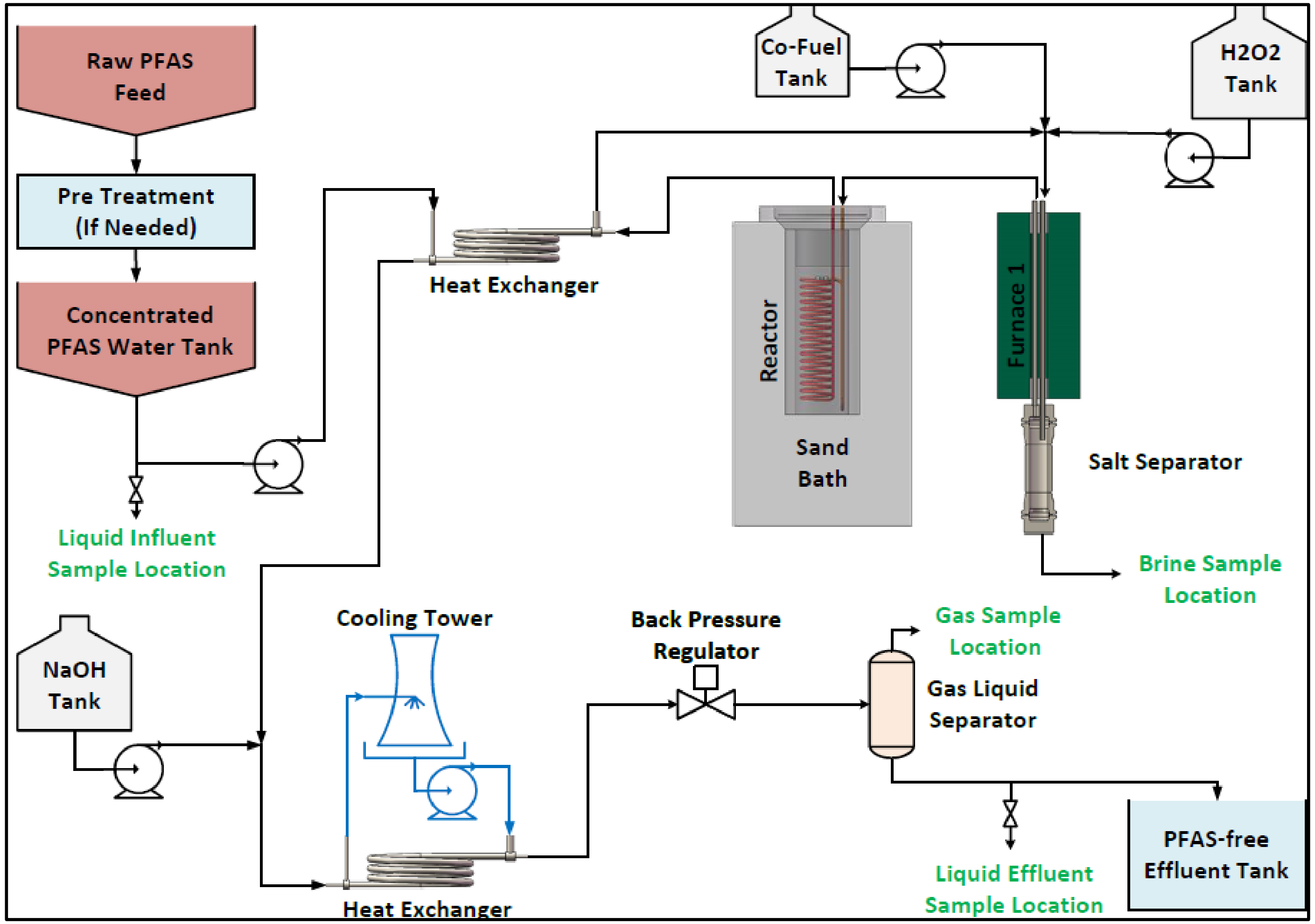
Background Research

Brainstorm, Evaluate, Choose Solution

Technology Considered	Field Implemented	Limited Application and Developing	Destructive Technology	Advantages	Limitations
Sorption (GAC/IXR)	✓			● PFAS removal well documented ● Throughput is high	● Not a destructive technology ● Waste management considerations for spent media
High Pressure Membranes (RO)	✓			● Can be used as a concentration step ● Throughput is high	● Not a destructive technology ● Consider downstream treatment
Super Critical Water Oxidation (SCWO)		✓	✓	● Complete destruction of PFAS ● Residence time short ● Not inhibited by organic co-contaminants ● Proven treatment of other recalcitrant chemicals	● Aggressive operating conditions necessitates specialized materials and equipment ● High energy input ● Salt precipitation inherent with SCWO requires special design considerations
Electrical Discharge Plasma		✓	✓	● Ability to treat larger flow rates ● Little to no requirements for chemical additions ● No interference from co-contaminants	● Reduced and/or longer removal times for some short-chain PFAS ● Unknown treatment of other organic compounds
Electrochemical Oxidation		✓	✓	● Low energy costs ● Operation at ambient temperatures ● No requirements for chemical oxidants	● Potential generation of toxic byproducts ● Efficiency losses due to build up on anodes ● High cost of electrode ● Potential volatilization of contaminants
Hydrothermal Alkaline Treatment (HALT)		✓	✓	● Complete destruction of PFAS ● Formation of stable fluorine byproducts	● Potential system degradation due to high temperatures and chemical requirements ● High energy input ● High temperature and pH effluent conditions

Overview of SCWO

- Water is pretreated/concentrated, if needed
- Water is heated to supercritical temperature (705˚F) and pressure (221.1 bar) and then oxygenated with H_2O_2 or air
- A neutralizing agent (sodium hydroxide [NaOH]) is added to remove hydrofluoric acid in the effluent
- The effluent is cooled and generated gas is separated from the liquid
- Liquid effluent is treated through GAC and/or IXR for metals removal
- Effluent streams are discharged

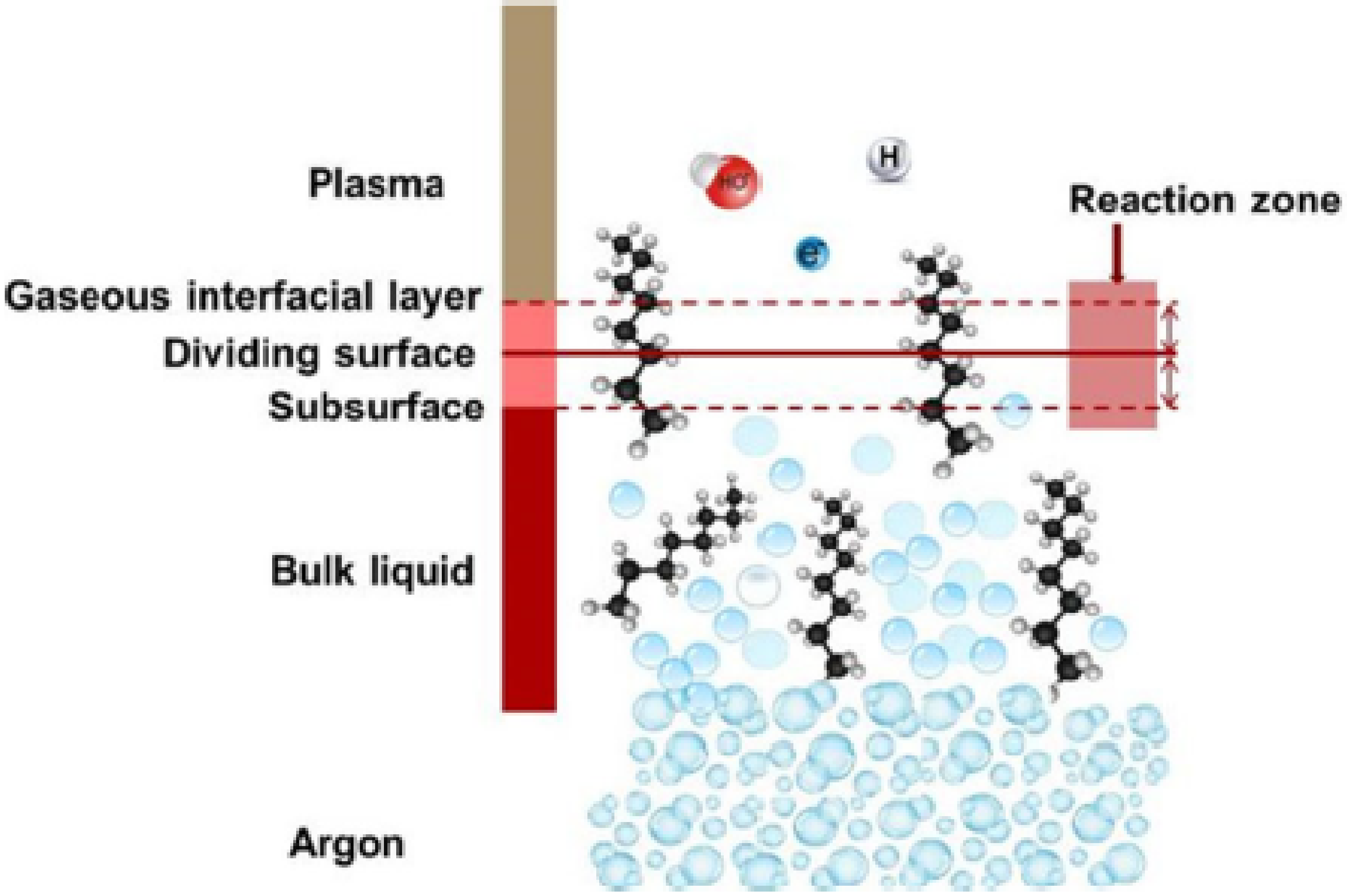


Background Research

Brainstorm, Evaluate, Choose Solution

Overview of Electrical Discharge Plasma

- Water is pretreated/concentrated, if needed
- Gas diffusers pump argon gas bubbles from the bottom of the reactor through water column
- Surfactant is added, if needed
- PFAS preferentially adsorb to the bubbles and are transported to the liquid surface, creating a layer of PFAS concentrated water
- High voltage electrodes discharge plasma to the liquid surface
- Effluent streams are discharged
- Flow can also be recirculated



Background Research

Brainstorm, Evaluate, Choose Solution

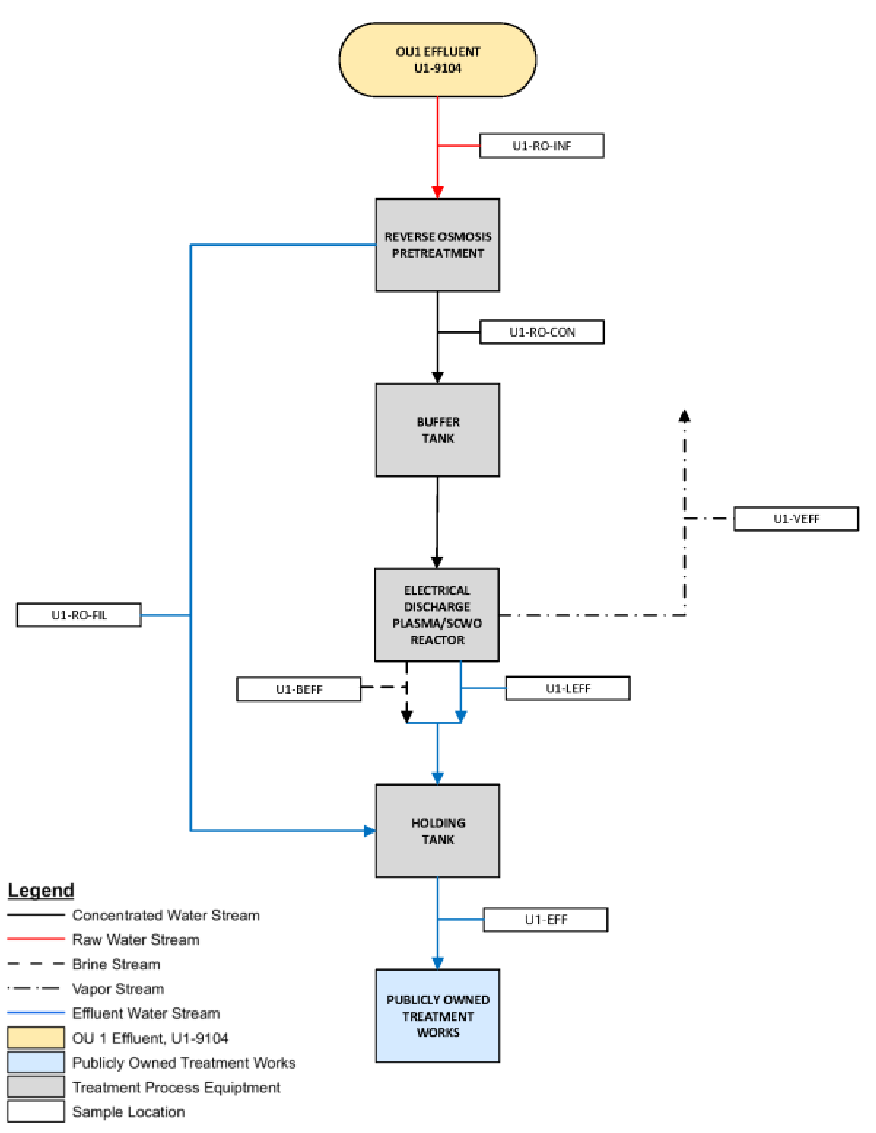
Sampling and Analytical Design

Liquid influent and brine/liquid effluent:

- PFAS
- AOF
- VOCs
- Alkalinity
- TOC
- Anions, cations, metals (+hexavalent chromium, tungsten, and molybdenum)
- Field parameters
- Physical parameters

Vapor effluent:

- PFAS
- VOCs



Specify Requirements

Develop and Prototype Solution

Summary of SCWO Implementation

Procedure:

Battelle/Revive conducted their *first* PFAS Annihilator mobile outdoor field demonstration at Hill AFB in November 2023 processing 300 gallons of RO concentrate. Operating time was adversely impacted by system plugging challenges.

Process Evaluation:

The salt separator dip tubes inside the three salt separator vessels had become disconnected during mobilization. This resulted in temperatures not sufficient to allow salts to precipitate in the salt separators for continuous treatment and instead precipitated in the downstream heat exchanger.

Corrective Action:

Design has been modified along with improved installation/fastening process and visual inspection upon delivery.

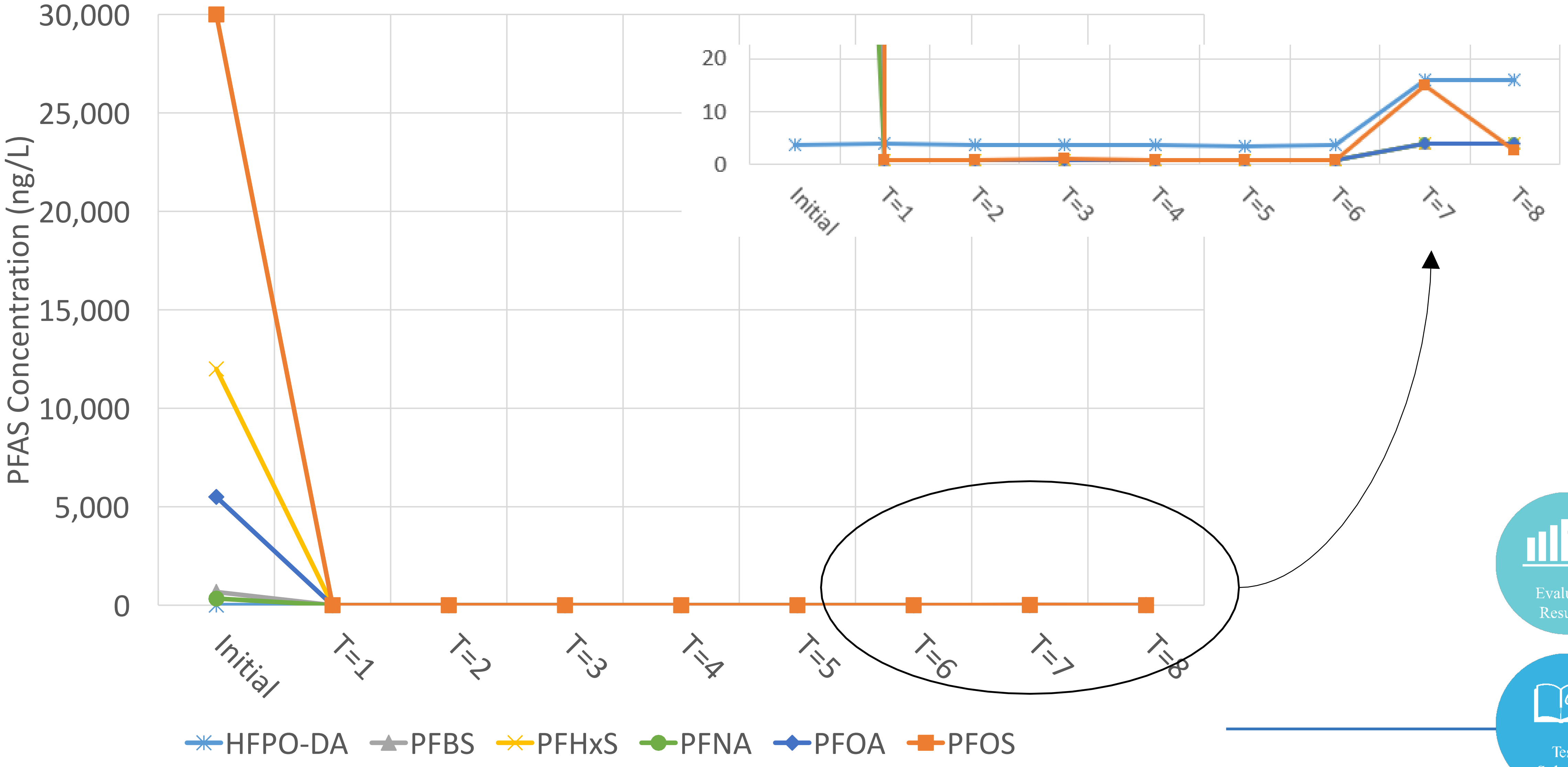
Next Steps:

1,000 gallons of raw OU 1 leachate has been provided to Revive to perform additional testing at their facility.

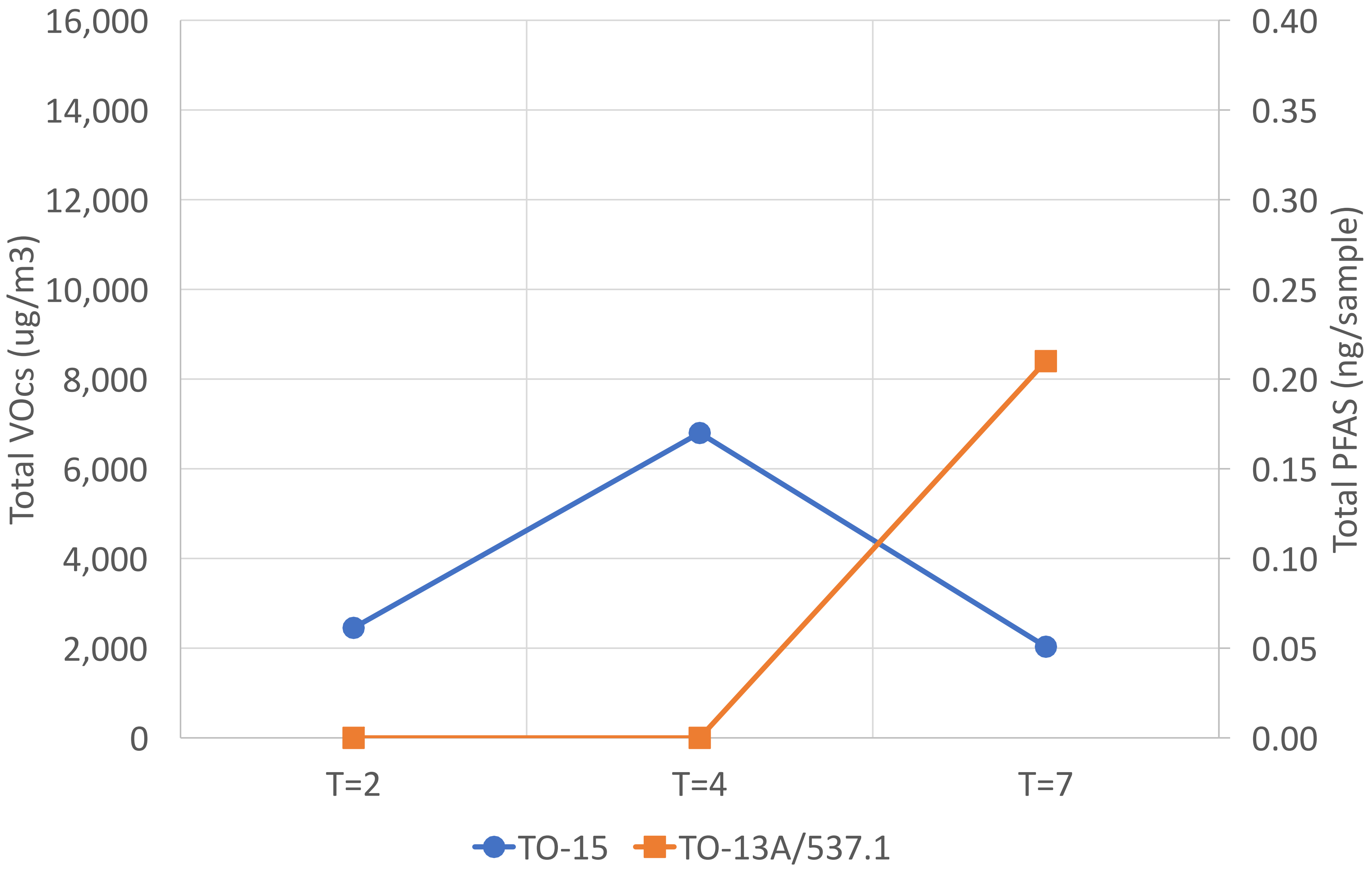
Evaluate Results

Test Solution

SCWO Results – PFAS in Liquid Effluent



SCWO Results – PFAS and VOCs in Vapor Effluent



Summary of Plasma Implementation

Procedure:

DMAX conducted their mobile outdoor field demonstration at Hill AFB in November 2023 processing 700 gallons of RO concentrate and 500 gallons of raw leachate.

Process Evaluation:

Based on analytical data and elevated detections of PFAS in an equipment blank, DMAX concluded that cross-contamination from prior field trials of a hyper-concentrate (>100 mg/L) had occurred in which PFAS continued to desorb from the equipment surfaces recontaminating the effluent.

Corrective Action:

Decontamination procedures have been improved and selection of unit based on previous projects will be considered.

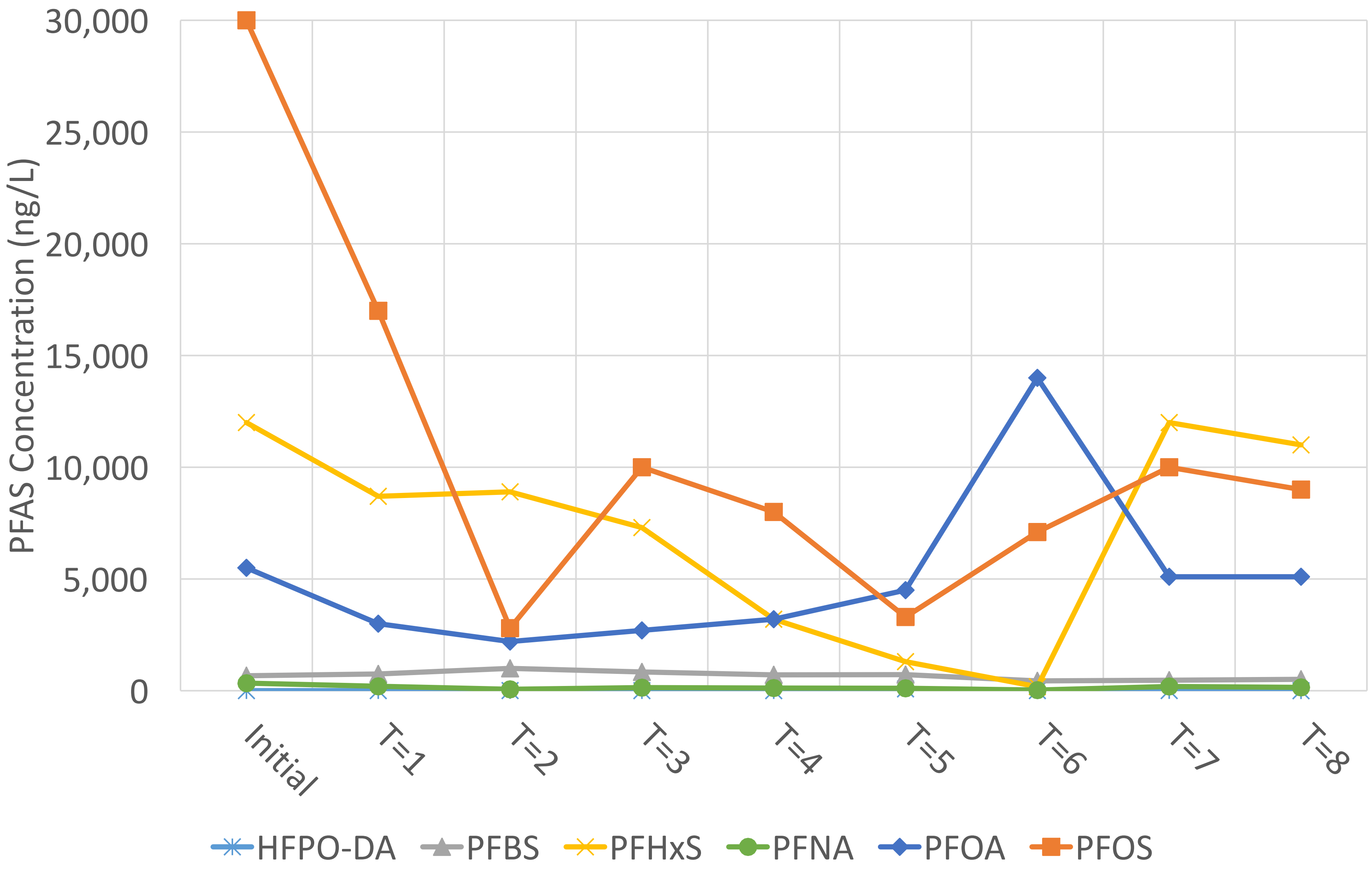
Next Steps:

1,000 gallons of raw OU 1 leachate will be provided to DMAX to perform additional testing at their facility.

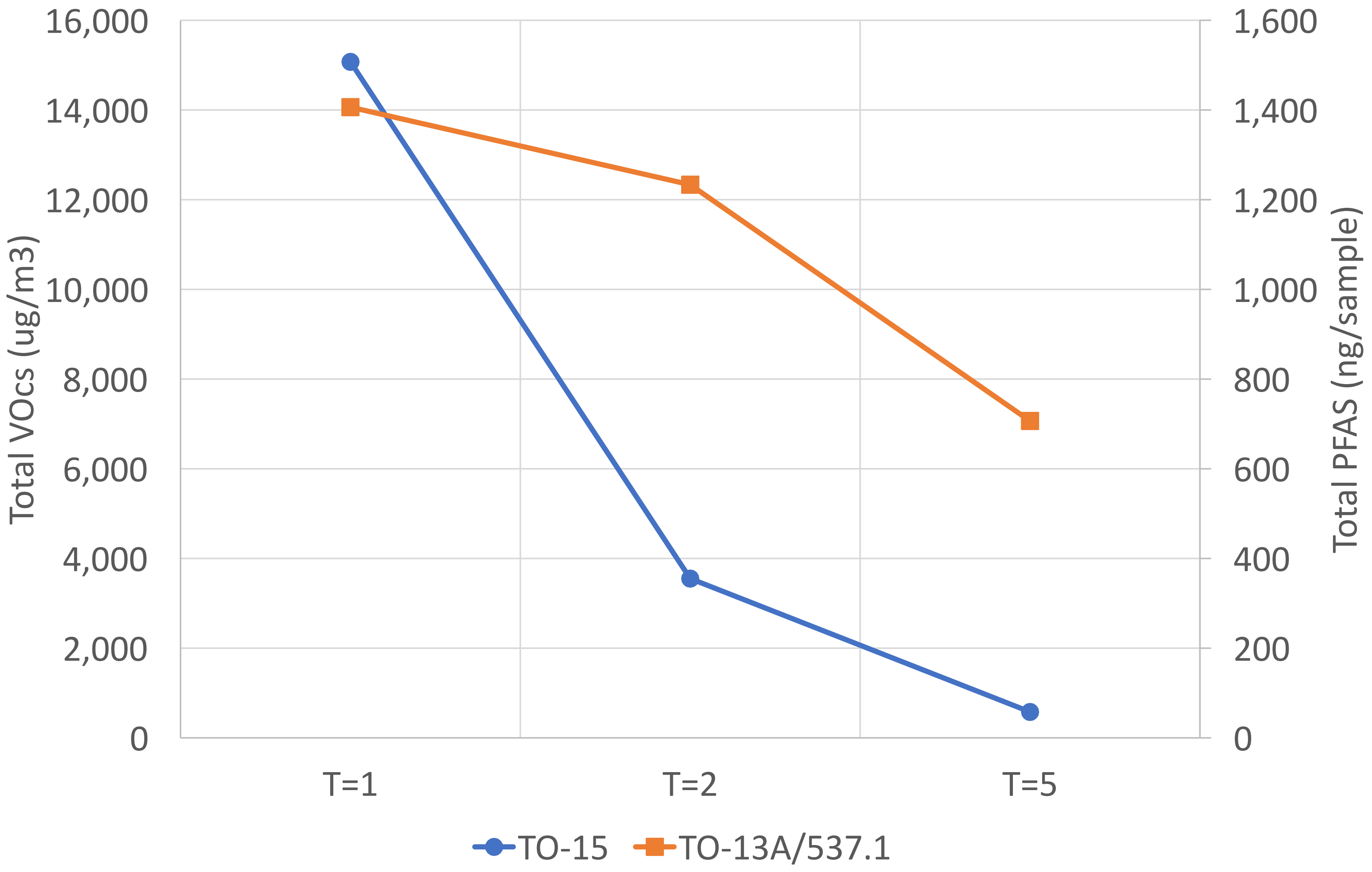
Evaluate Results

Test Solution

Plasma Results – PFAS in Liquid Effluent



Plasma Results – PFAS and VOCs in Vapor

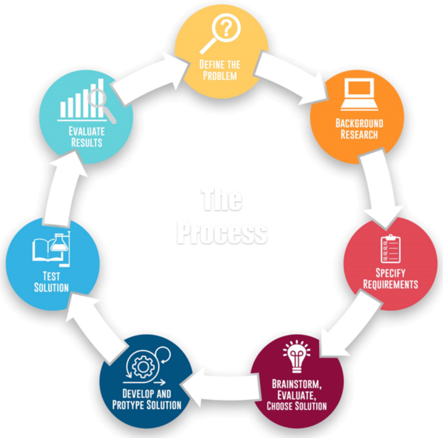


Preliminary Observations

Technology Implemented	Field Implementability	Effectiveness	Advantages	Limitations
Super Critical Water Oxidation (SCWO)	Inconclusive	✔	● Complete destruction of PFAS	● Brine and GAC/IXR media require offsite disposal ● Reactor plugging ● Complex equipment, operation, and chemical additions
Electrical Discharge Plasma	✔	Inconclusive	● Ability to treat larger flow rates ● Little to no requirements for chemical additions ● Simple equipment and operation	● Cross contamination issues makes it difficult to assess PFAS destruction

What Would I Do Different Next Time?

- Decontaminate treatment units and collect EB in advance
- Design pretreatment/concentration carefully with geochemistry of water and type of destructive technology for complementary treatment train
- Employ screening lab to make quicker decisions on effectiveness, possible parameter changes, issues, etc.
- Choose analytical methods carefully



Takeaways

- Need to implement destructive technologies in the field at different sites with different conditions in order to drive continuous improvement
- Destructive technologies are in a stage of rapid growth and optimization
- Although not required, combining a pre-concentration step in the overall treatment train decreases equipment, material, waste management, and energy requirements
- Intensive field setup and takedown might not always be practical for short implementations
- It takes a village and interdisciplinary teams are key to success
- There is no silver bullet (except in my driveway)

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