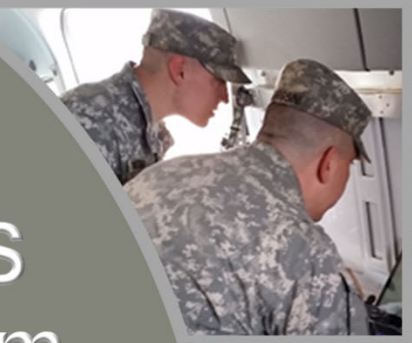
DETS to PETS – Development of the PFAS Effluent Treatment System





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ERDC Engineer Research and Development Center

Innovative solutions for a safer, better world

US Army Corps of Engineers®

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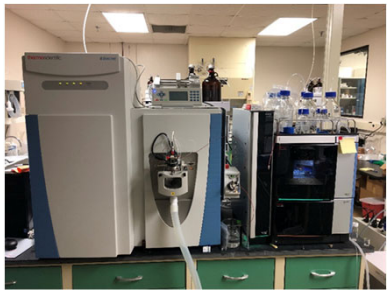
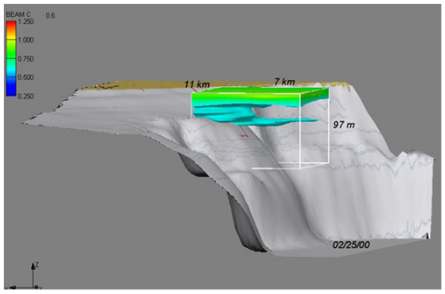
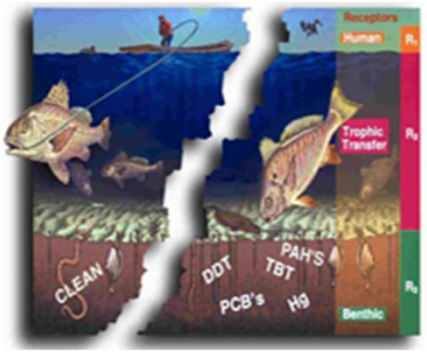
ERDC Overview

Over the last 30 years ERDC has developed unique capabilities and expertise to address environmental issues relating to advanced materials (nano, additive manufacturing, etc.) and emerging contaminants of concern (coal ash, depleted uranium, insensitive munitions, micro-plastics, PFAS, etc.). Capabilities include:

- Advanced analytics (water, soils/sediments, biological media)
- Fate and Transport (surface water, groundwater, soils, and sediments)
- Exposure and Effects (uptake, toxicity, trophic transfer, mode of action)
- **Treatment and Remediation (water, soils/sediments)**

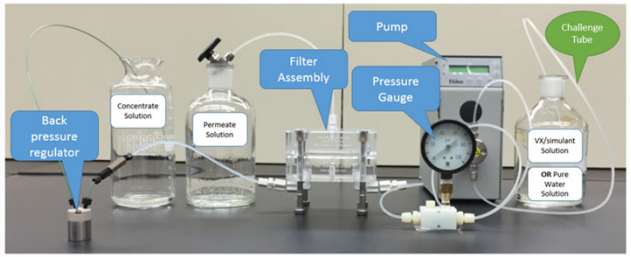






EL-Environmental Engineering Background:
Treatment Trains Customized for Site Chemistry

Experts in Cleanup Technologies



Innovative Technology R&D

- Solidification/stabilization
- Electrochemical treatment for contaminants
- Physical separations
- Advanced chemical oxidation and reduction
- Synthetic resin ion exchange
- Sorption studies (activated carbon/specialty resins)

Prototyping Facility

Pilot and Prototype Systems

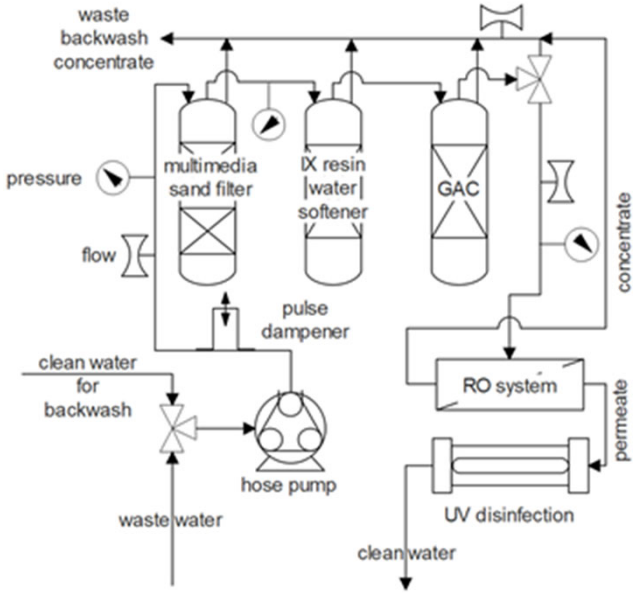
- Deployable platforms
- Custom Designs
- Benchmarking and Scaling
- Field scale assessment

Process Control & Instrumentation

Control Architecture: EZ Automation, EZ-Touch HMI/PLC

- Customizable interfaces
- Ladder logic controls
- Data recording
- Modular I/O

EL-Environmental Engineering Capabilities: In-house Pilot and Prototyping



We are interested in collaborating to develop the best solutions for clean water!

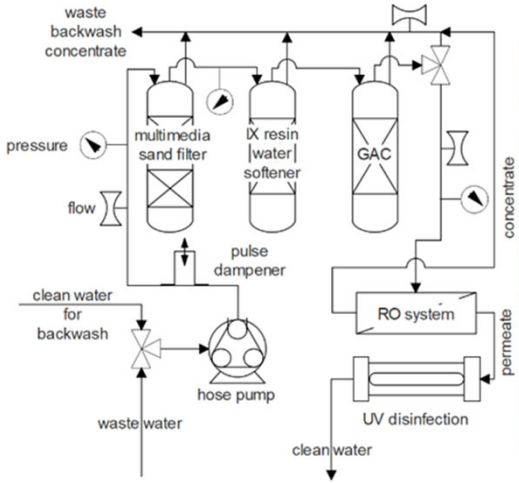
Ongoing work – Remediation / Treatment

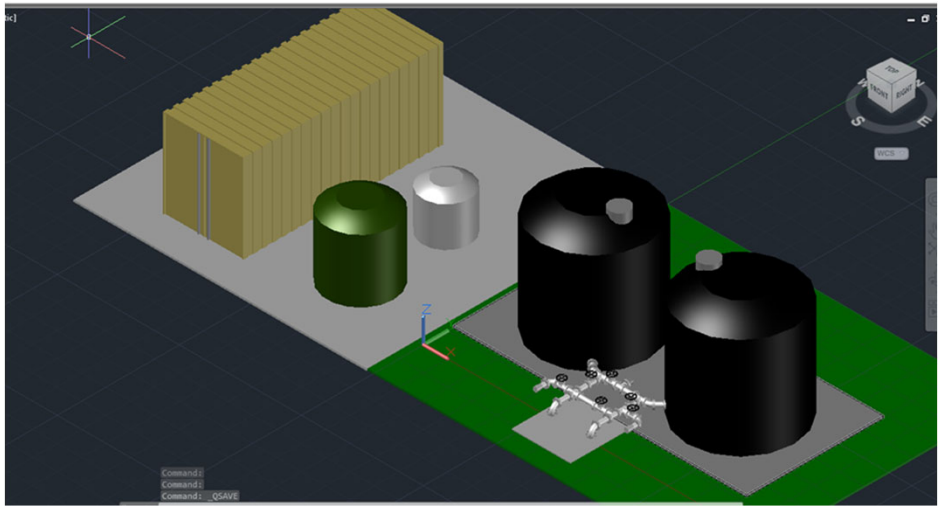
PFAS Treatment Systems

- Media filter treatment train
- Primary filtration/ GAC/ RO
- Mobile trailer 10-30 GPM
- Recovers over 90% of the influent water
- Treatment of concentrate approaches zero discharge
- goal will be to produce effluent with total PFAS measurements of 0.070 ppb or less

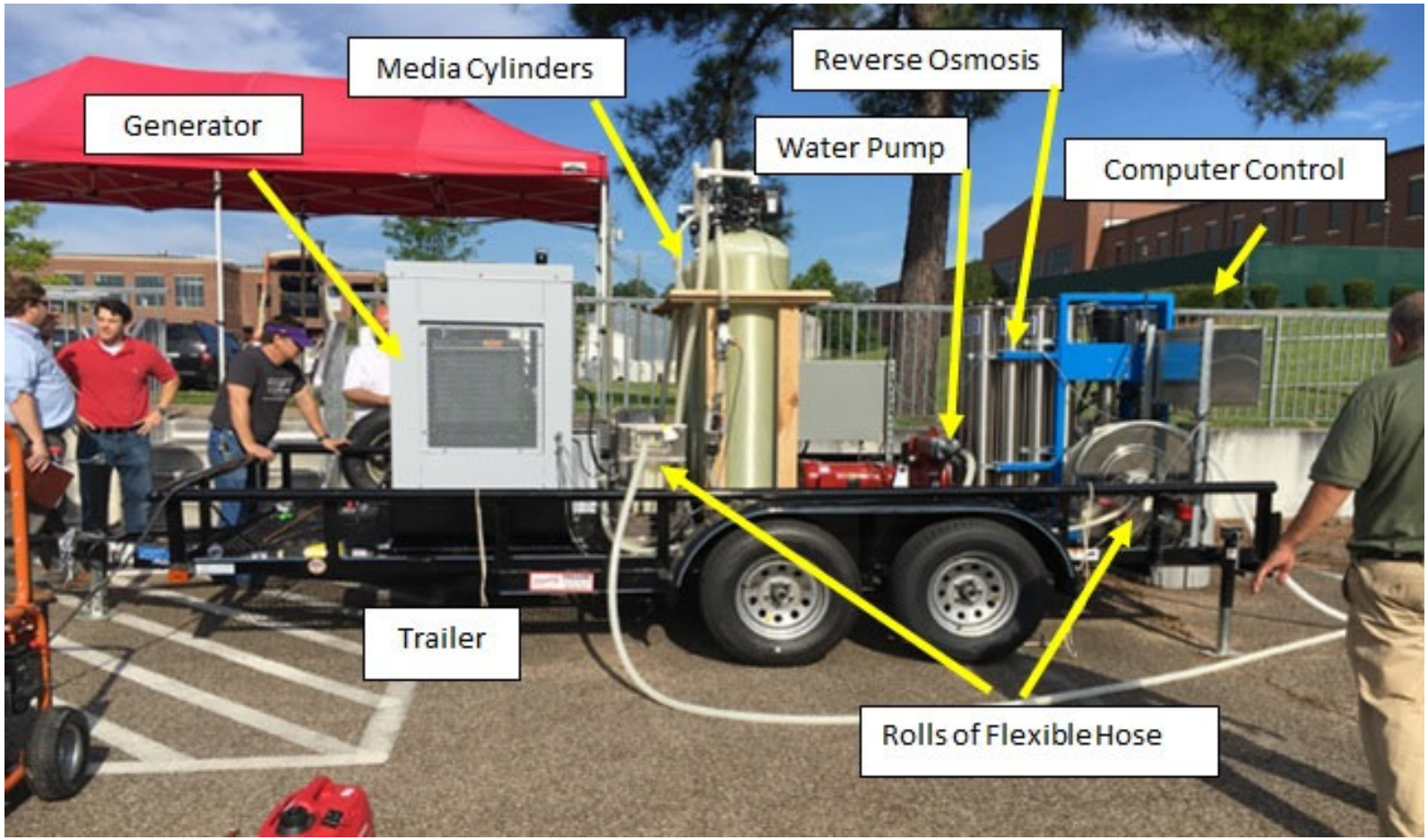
20’ Containerized Pilot Systems

- Deployable/ Ruggedized
- Primary filtration/ RO





Initial Concept: The Decontamination Effluent Treatment System (DETS)



DETS Treatment Train for Response to CBRN

- Sediment – **Settling (tank or blivet) & sand filter**
- Surfactant – **Granular Activated Carbon (GAC)**
- Bleach –**GAC**
- Oils/Greases/Misc. Organic Compounds – **Incidental removal, GAC, Reverse Osmosis (RO)**
- Chemicals – **Incidental removal, GAC, RO**
- Radioisotopes – **Incidental removal, Sand, RO (especially Cesium [Cs])**

Alpha Version of Mobile Treatment System

Our pilot reactor capable of treating aqueous effluent from decontamination of 200 people and 10 large vehicles per day for 3 to 5 days.

Our system treated a simulated effluent with soap, bleach, clay and cesium. The removal was >99 percent of each constituent.

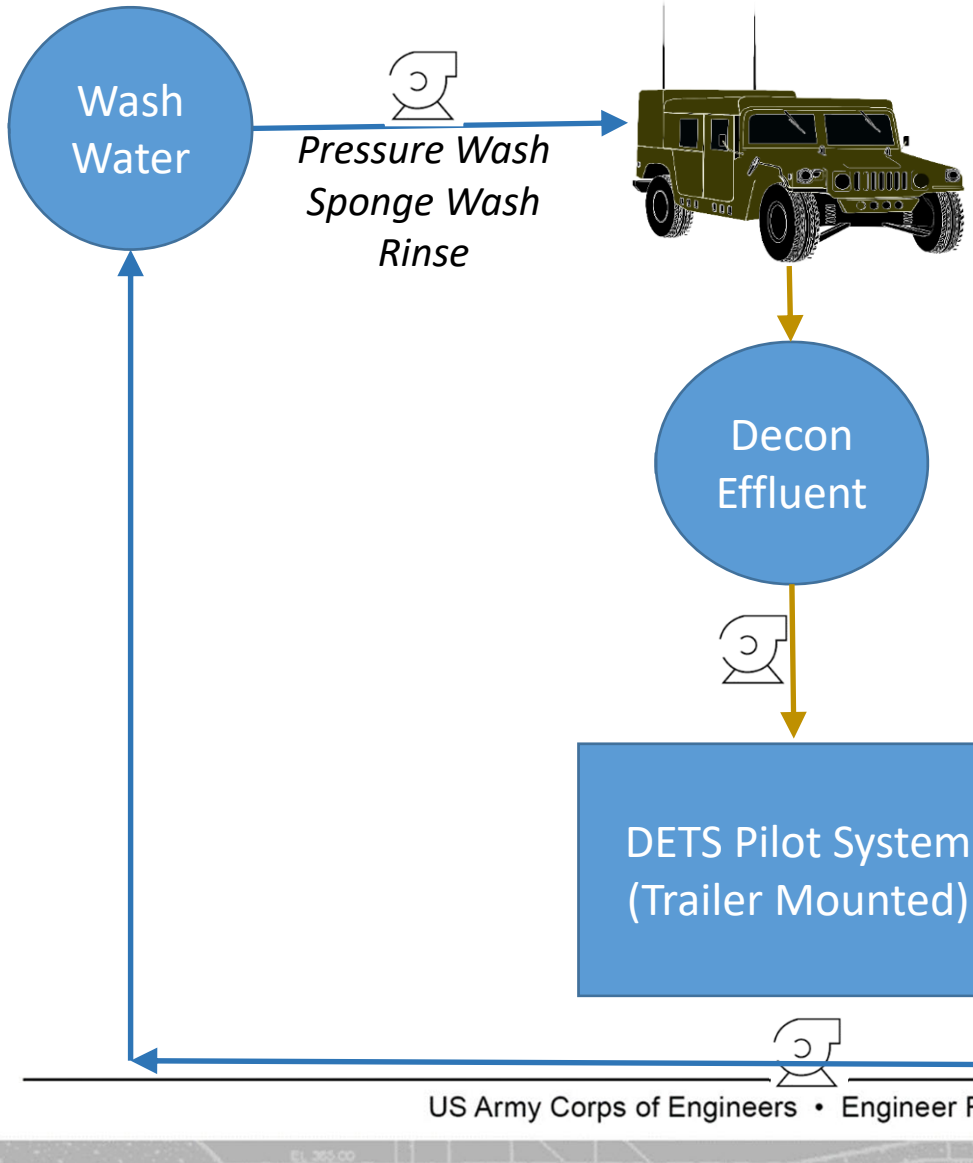
Process control and instrumentation

- Control architecture: EZAutomation EZ-Touch HMI/PLC
  - Customizable and programmable interface with ladder logic control
  - Data recording
  - Modular I/O
  - Pressure sensitive touch screen – compatible with heavy gloves

Power Supply

- Kubota Diesel 9875 Watt Generator
- 240 V, 40 amp
- 60 gallon subbase fuel tank and a two-wire auto start control.
- Sound enclosure keeps noise at 68 dB(A) at 7 m (23 ft), which is helpful for communications.
- The system is also designed to be suitable for operation of sensitive electronic equipment.
- Fuel consumption varies from 0.41 to 0.84 gal/hr
- The system can also simply be plugged into a 240 V, 60 Hz, single phase, 40 amp source.

TRL 5 or Greater



Details

- 27 June 2017
- 6 hours of total activity
- DETS operation 2 hours
- 10 large military vehicles & 20 cars, trucks, minivans were washed w/ soapy water & rinsed.
- 1200 gallons collected and spiked with Malathion, cesium, and bleach. Target concentrations were 10 mg/L.
- Contaminated water treated with the DETS
- Observers from JPM-P, Army MSCoE, JPdM A&RS, ECBC, DTRA, & USEPA

Results

Constituent	Analytical Method	Influent Concentration	Effluent Concentration	%Removal
Turbidity	USEPA Method 180.1	>4200 NTU	1.825 ± 1.145 mg/L	100.0%
Hardness	Summation of Ca^{2+} and Mg^{2+} concentrations as measured by ion chromatography	82.36 ± 40.79 mg/L	0 mg/L	100.0%
Total Chlorine	Standard Method 4500-Cl G	0.26 ± 0.07 mg/L	0 mg/L	100.0%
Surfactants	Spectrophoto-metric method as given in Kloos (2015)	1.422 ± 0.359 mg/L	0.019 ± 0.017 mg/L	98.7%
Total Organic Carbon	USEPA 5310B	58.23 ± 29.7 mg/L	1.18 ± 0.84 mg/L	98.0%
Malathion	Phosphorus balance	26.71 ± 12.16 mg/L	0.08 ± 0.05 mg/L	99.7%
Malathion	USEPA 8141A	24.7 mg/L	0.000097 mg/L	100.0%
Cesium	USEPA 6020A	2.97 ± 4.21 mg/L	0 mg/L	100.0%

All measurements indicate that the DETS is highly effective treating constituents found in decontamination wash water (98% removal or greater).

Costs & Flow Rate

Unit	Cost	Comments
Reverse osmosis unit with pump & Prefilter Cleaning units for scale and organics Sand Filter Media Unit Carbon Filter Media Unit Water Softener Media Unit UV sterilization unit (not used in these studies)	$13,621.44	Price is for all the units described
Kubota Generator	$9922.45	
Bredel Pumps with mounting equipment and Hoses	$13,283.09	We purchased 2, but only 1 was used. Cost is for 1 unit.
Flanges	$1,066.00	
Hose Reels	8,939.92	
Trailer Trailer Upgrades	$5000.00 $1500.00	We determined up-grades were need after the initial demonstra-tion
EZ Touch Control Unit with associated soft-ware	$1800.00	
Pressure gauges	$1000.00	Estimated
Wiring	$500.00	Estimated
Total	$56,632.90	

Flow Rate

- Battalion Sized Event involving 200 people and 10 large vehicles
- Assume treatment time per day of 12 hours
- Adapted from planning factors of operational DECON (Army G3/5/7 Decontamination Planning factors)
- 10 gpm

Costs

- Table to the left summarizes costs of elements of the system.
- The equipment costs were less than $60,000.
- Keeping costs low allows for a unit to be disposed of in its entirety if it gets highly contaminated during treatment.
- Enhancement of monitoring equipment is the greatest estimated additional cost.

Adapting DETS to PETS for PFAS

Pilot System Construction and Application

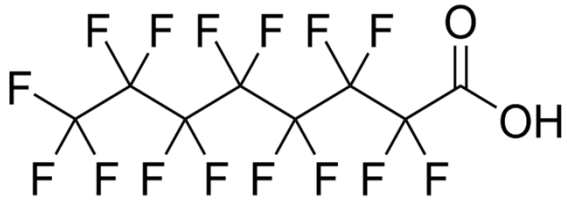
- PFAS Treatment Systems
  - Media filter treatment train
  - Primary filtration/ GAC/ RO
  - Mobile trailer 10-30 GPM
  - Recovers over 90% of the influent water
  - Treatment of concentrate approaches zero discharge
  - goal will be to produce effluent with total PFAS measurements of 0.070 ppb or less

74,000 gallons (2sites) with C6 AFFF

Adapting DETS to PETS for PFAS

Pilot System Construction and Application

PFOS



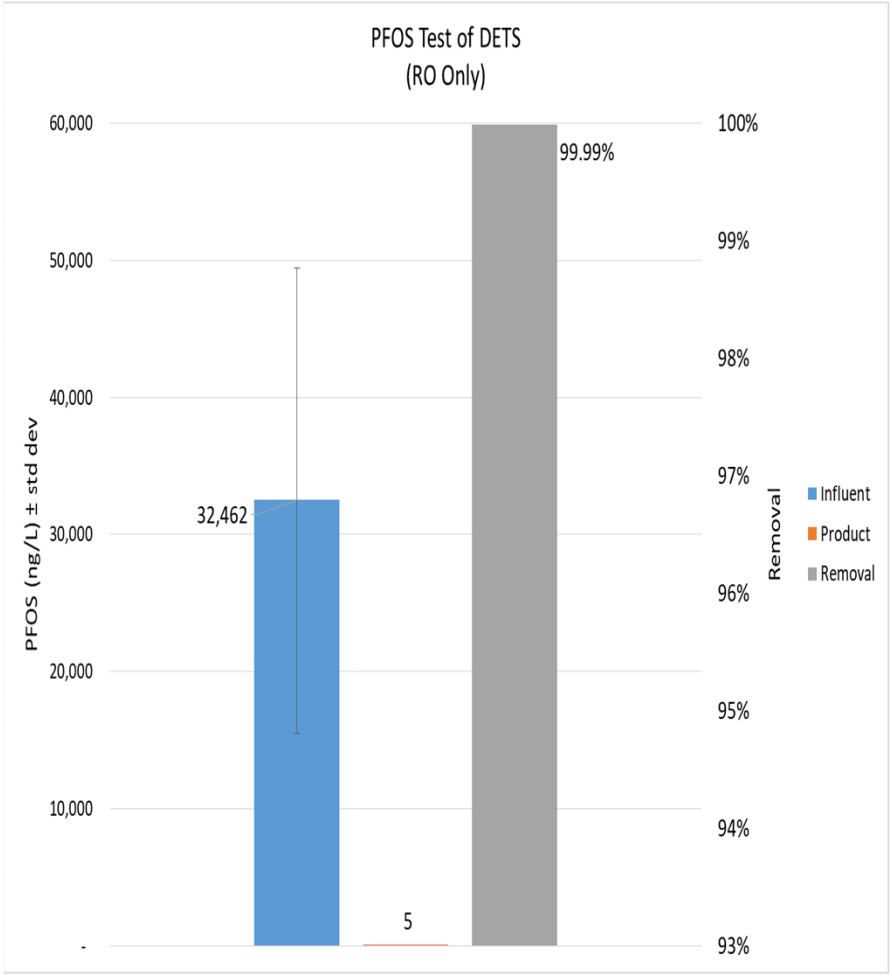
PFOA

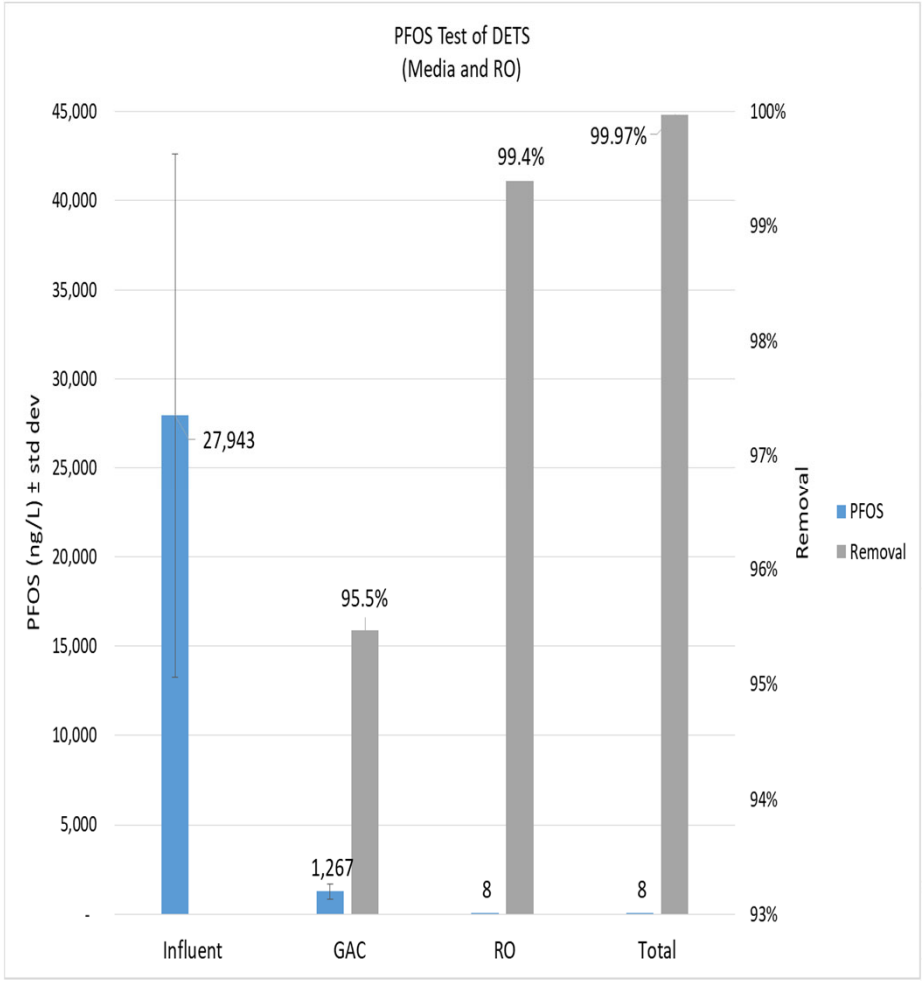
- Found in Aqueous Firefighting Foams (AFFF)
- Very challenging to degrade, particularly PFOS.
- EPA Drinking Water Health Advisory: 0.070 ug/L

Site Specific Mobile Platform

- PFAS is a problematic contaminant for US Military Installations with firefighting training and maintenance areas.
- **There are sites and processes that have relatively small quantities (<250,000 gal) of PFAS**
  - **Collection basins**
  - **Equipment flushing/cleaning**
  - **Investigative Derived Waste**
- A mobile treatment system could be useful for addressing these.

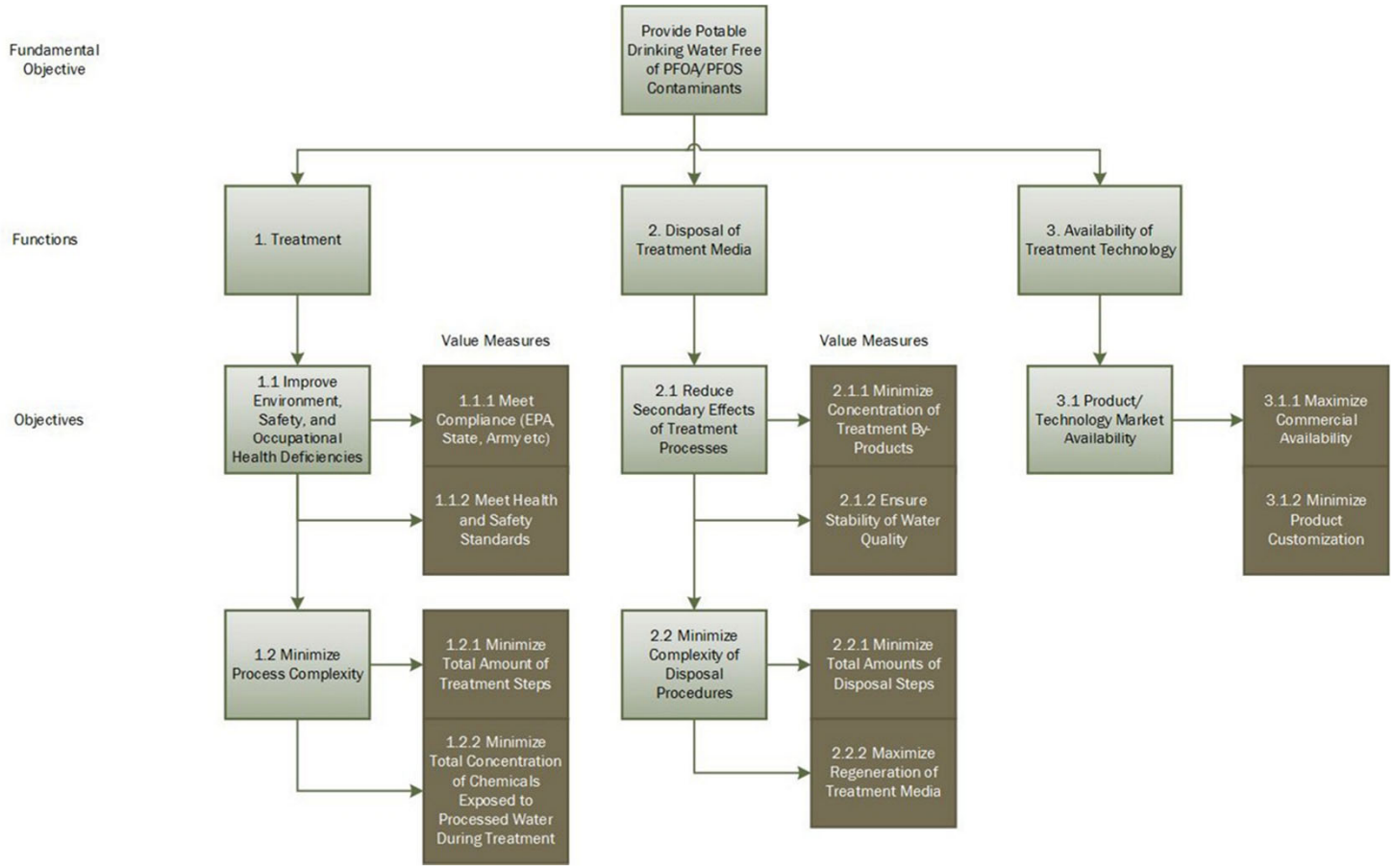
Results of DETS Treatment of PFAS





- RO very effective at removal PFOS. >99.99% removal
- Final concentrations (5 & 8 ppt) less than drinking water advisory (70 ppt) and minimum reporting level (40 ppt) (EPA, 2016).
- Media treatments also very effective at PFOS removal

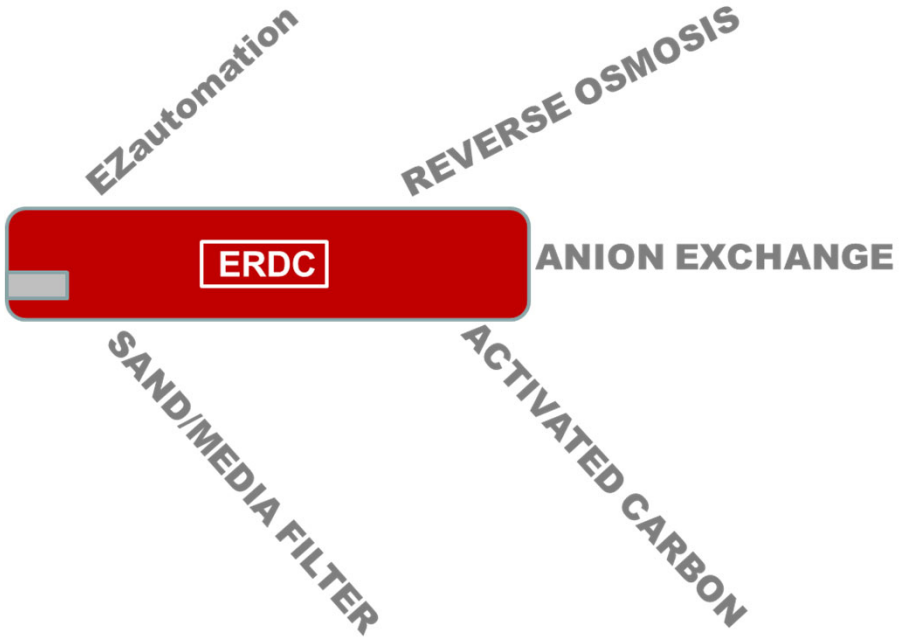
6.2 to 6.4 and Beyond: From DETS to PETS



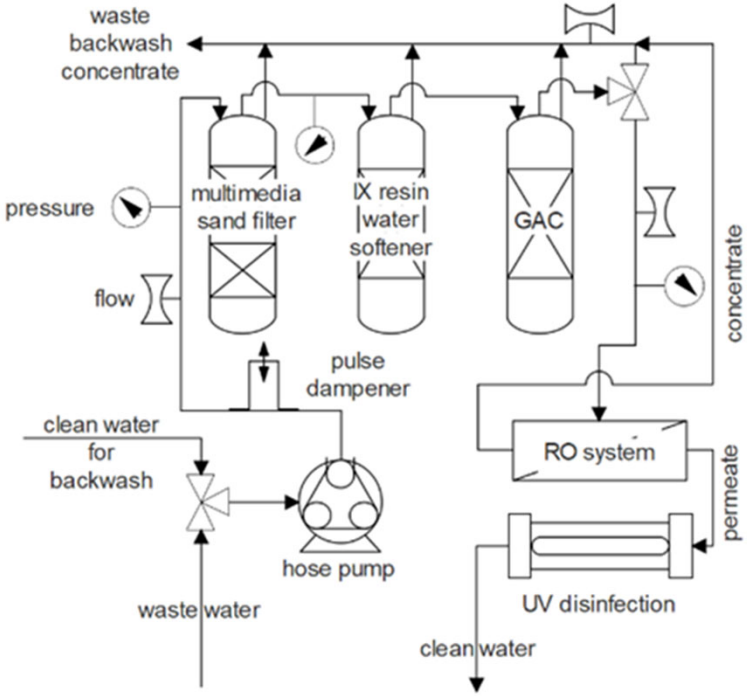
Value Hierarchy for PFOA/PFOS Treatment Technologies

Ongoing Work: Swiss Army Knife Approach

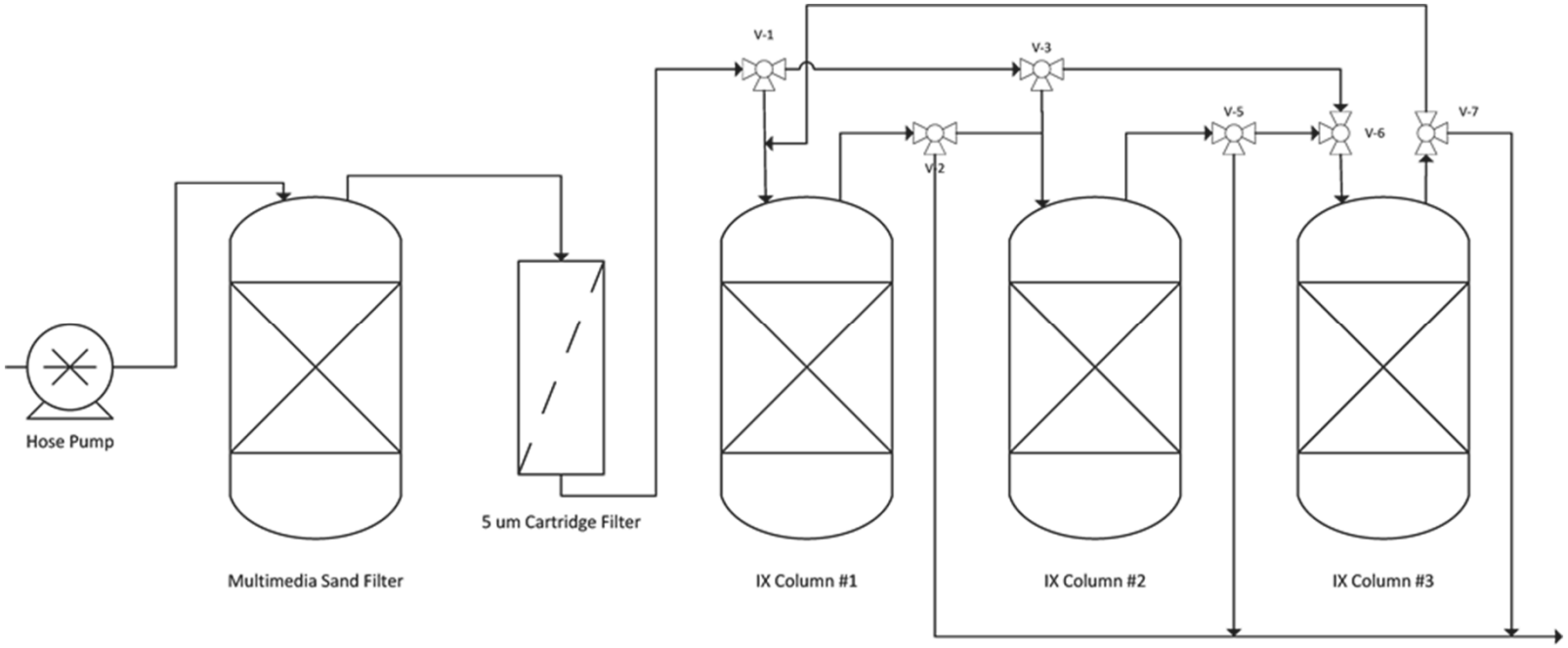
- Myriad of chemical configurations
- Diverse interactions with environment and site chemistry
- Competing organics and ions
- **(GAC)** filtration for short-chain PFAS
- **(RO)** membranes for short-chain PFAS
- **(IX)** exchange resins look promising



Initial Treatment Train



PFAS Treatment Train

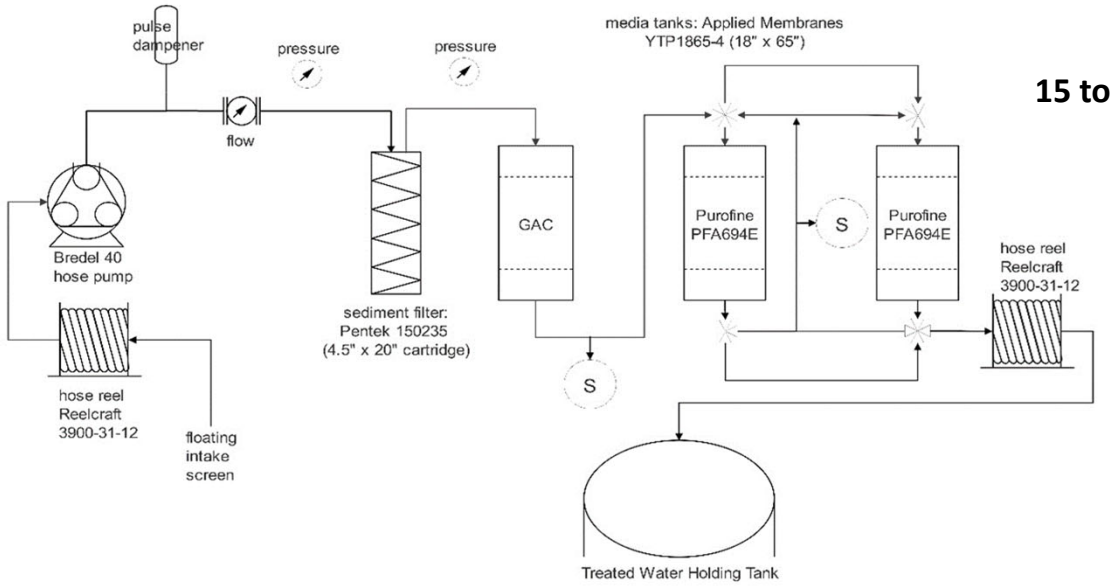


Primary Filtration

Lead-lag Process

Ongoing work – Ion Exchange Resins

2 column profiles For IX media

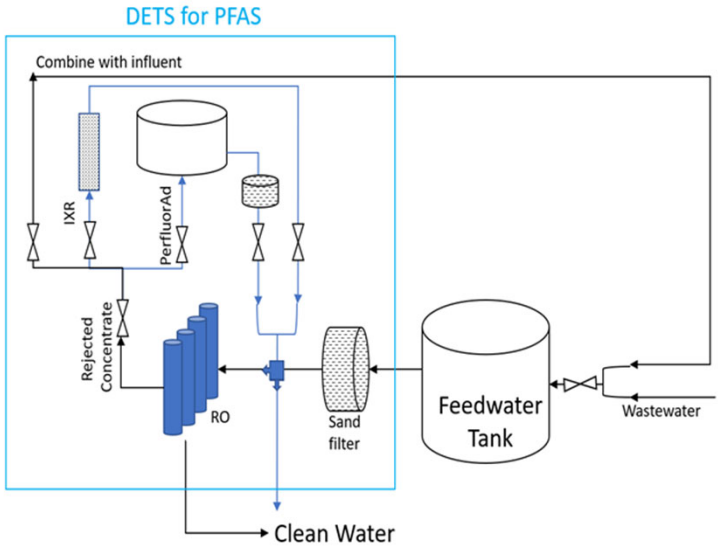


15 to 20 gpm

5 gpm

Ongoing work – Reverse Osmosis/ Flocculation

- **PerfluorAd is a Material that can flocculate PFAS in solution.**
- **Goal, retreat the concentrate to reduce residual to >5%**

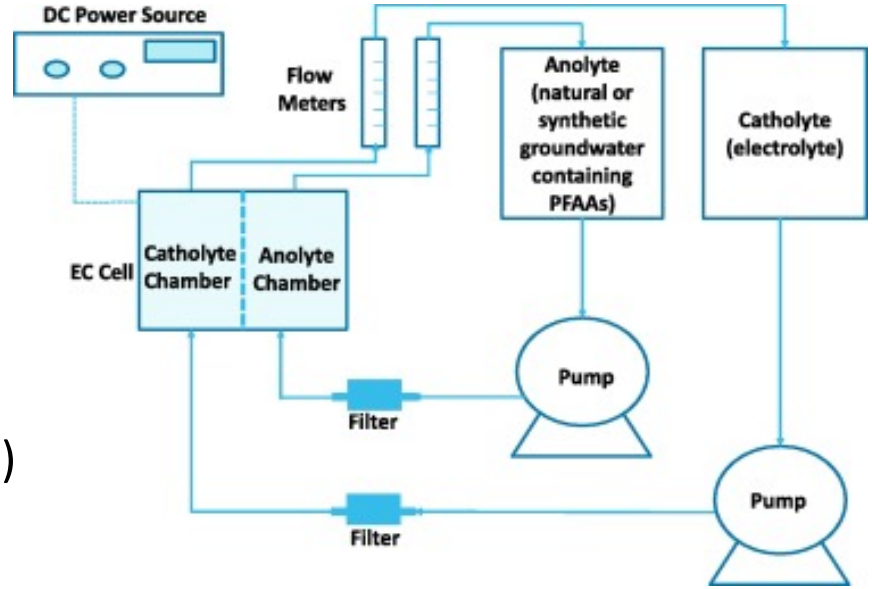


Expected concentrate residuals after RO treatment of 100,000 gallons (378,000 L) assuming 80% recovery with concentrate treatment passes. This is then related to estimated cost savings assuming incineration at $3.80/gallon (Medina et al. In Press)

Number of concentrate treatment passes	RO Effluent Volume (gallons)	Rejected Concentrate (gallons)	Estimated cost reduction of PFAS contaminated water disposal (incineration).
0	80,000	20,000	$304,000
1	96,000	4,000	$364,800
2	99,200	800	$376,960
3	99,840	160	$379,392

Next Steps: Destruction by BDD?

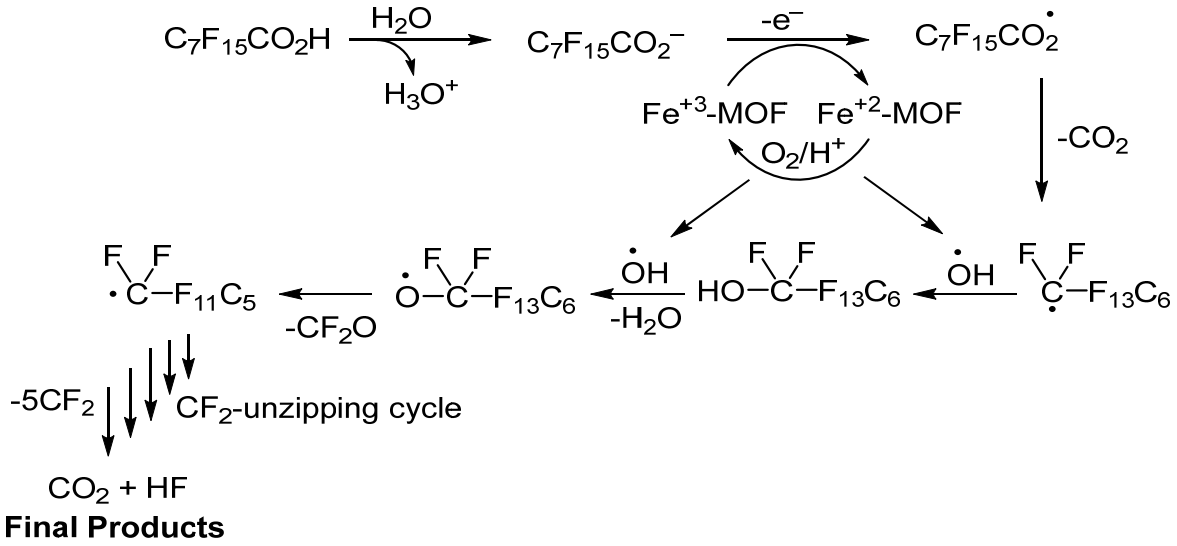
- Tertiary Treatment: GAC, IX, RO remove ~90%
- All treatment options **require a subsequent destruction step e.g. incineration**
- C-F bond is short/strong
- Fluorine atom is the strongest inorganic oxidant known (it will retain its electrons)
- Reduction potential 3.6V



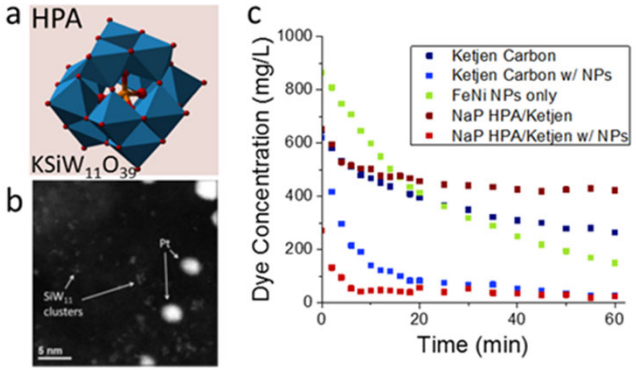
Anodic oxidation by BDD
Schaefer et al 2015

Engineering: Electrocatalytic Degradation for On-site destruction

Proposed Mechanism BBD



Energy use and off-gases
Of concern



HPA-carbon composites are Catalytically active toward model organic water contaminants

Innovative Solutions for a Safer, Better World

We are interested in collaborating to develop the best solutions for clean water!

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