

PFAS

PER- AND POLY-FLUOROALKYL SUBSTANCES

*Developing a new treatment
technology for destroying PFAS
(DE-FLUORO™)*

Dr Rick Parkman

Monday 18 May 2020

ENSOr 2020 Online Workshop

Presentation Overview

- Overview of Activities to Date
- Discovery Science
- Summary of Initial Bench-Scale Electrochemical Oxidation Treatment Results
- Building and Developing the EO Reactors
- Preliminary Results
- Summary and Next Steps

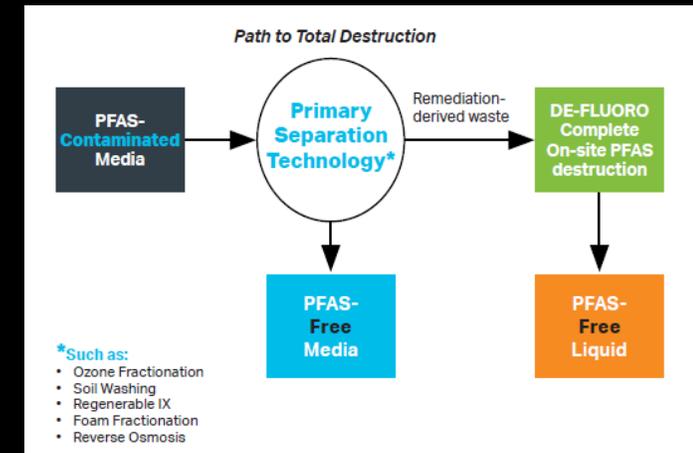
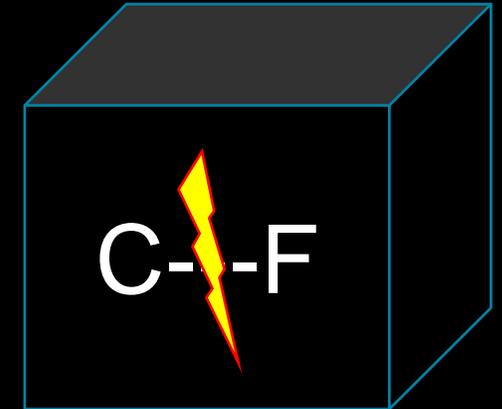
Co-authors and acknowledgements (AECOM US and ANZ EBL, US WBL, Ventures and partners)

- *Rachael Casson, Director of International PFAS Program*
- *Dr Shangtao Liang, Scientist/ Treatability Studies*
- *Dr Jack Q. Huang - University of Georgia*



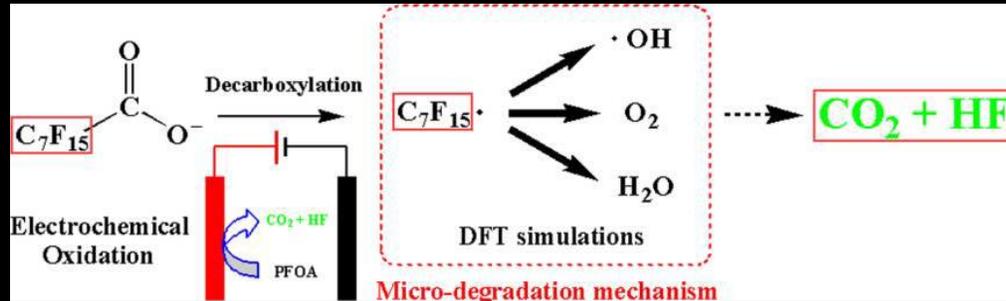
Introducing DE-FLUORO™ - PFAS Destruction Technology

- A **destructive** PFAS treatment technology
- **DE-FLUORO™**: **D**egradation via **E**lectrochemical oxidation of per- and poly**fluoro**alkyl substances
- Utilizes a proprietary, high durability and low cost electrode that can be used in different sizes, forms and shapes for different applications
- Initial applications focus on coupling with other treatment technologies that do not destroy PFAS but have processes that generate PFAS concentrated liquid waste
- It reduces environmental liability of transporting PFAS impacted waste off-site

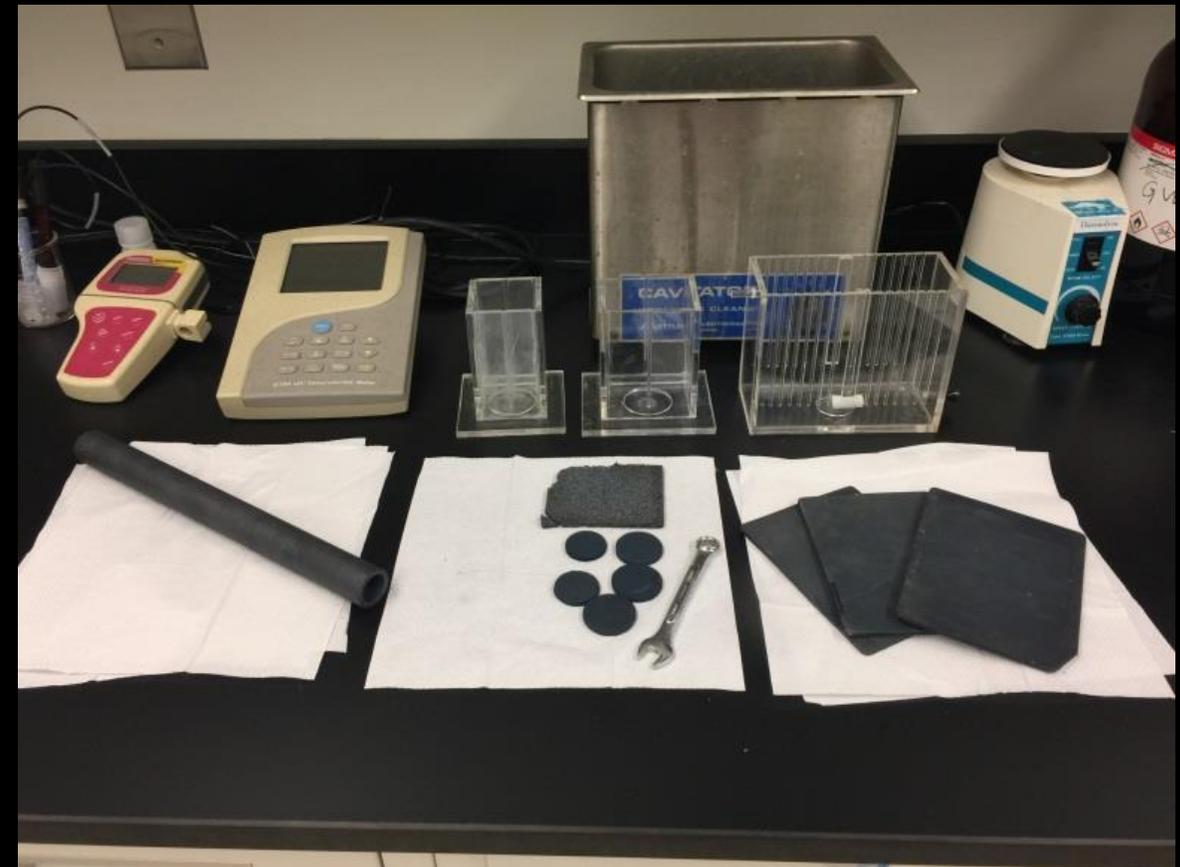


Coupling Approach

Treatment Science (Proof of Concept)



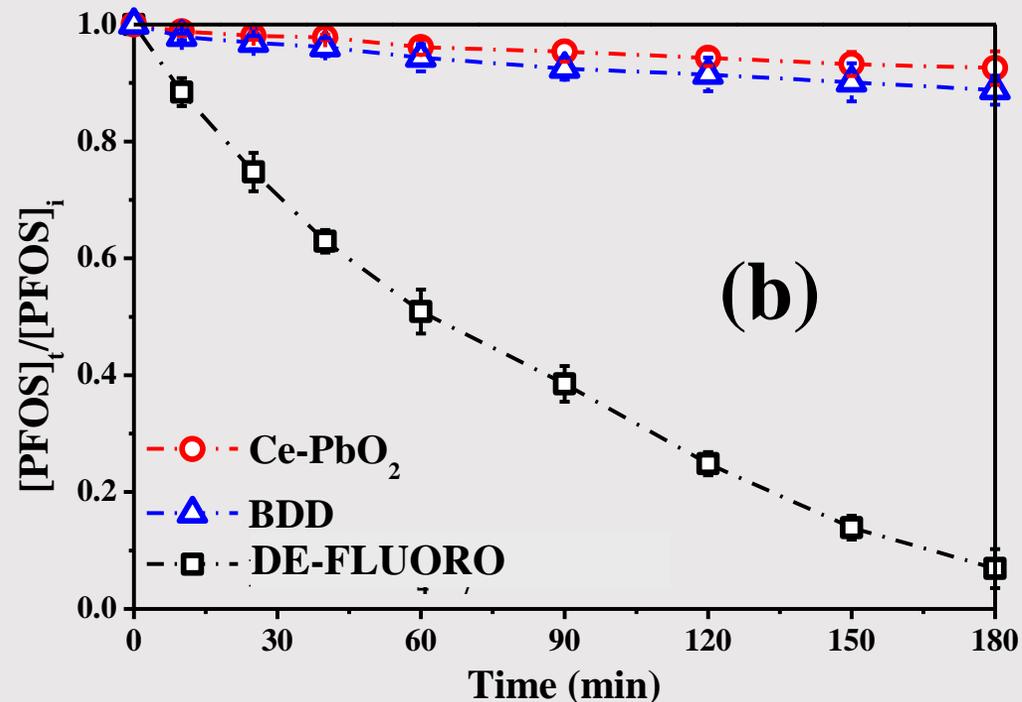
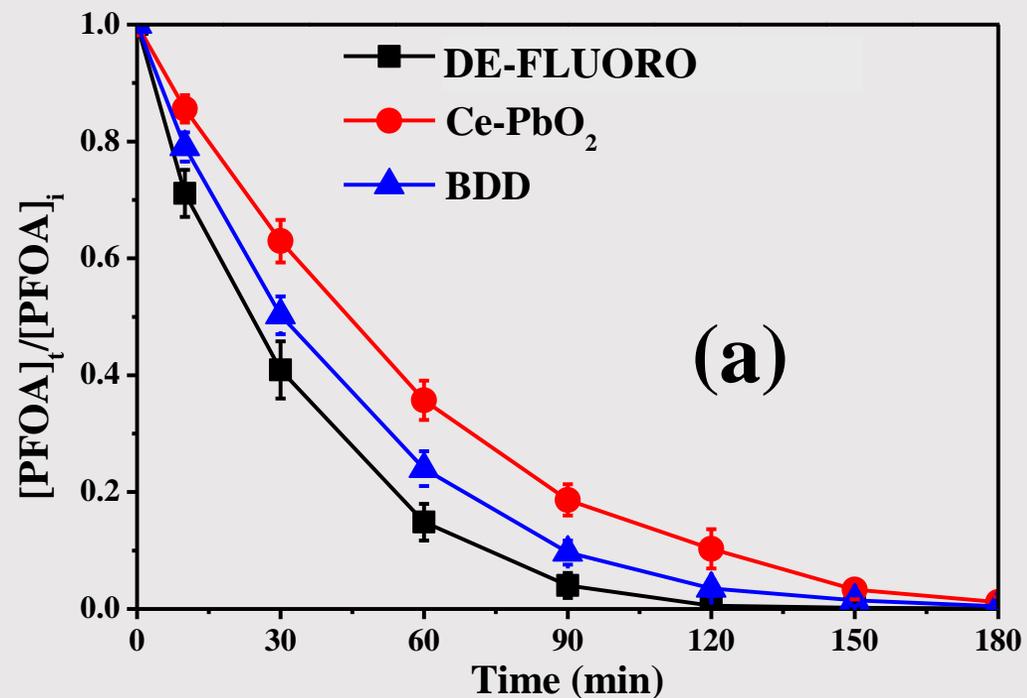
- EO is a proven technology that defluorinates and mineralizes short-chain and long-chain PFAS
- Several publications (technology well understood including mechanisms and kinetics of reactions)
- Measured electrode durability and compared oxidation potential against other electrode materials
- Tested against other electrode materials (Ce-PbO₂ and BDD) – spiked PFOS and PFOA



Publications

- Niu, Junfeng, et al. "Electrochemical oxidation of perfluorinated compounds in water" **Chemosphere** 146 (2016) 526-538
- Lin, Hui, et al. "Efficient sorption and removal of perfluoroalkyl acids (PFAAs) from aqueous solution by metal hydroxides generated in situ by electrocoagulation." **Environmental Science & Technology** 49.17 (2015): 10562-10569.
- Lin, Hui, et al. "Highly efficient and mild electrochemical mineralization of long-chain perfluorocarboxylic acids (C₉-C₁₀) by Ti/SnO₂-Sb-Ce, Ti/SnO₂-Sb/Ce-PbO₂, and Ti/BDD electrodes." **Environmental Science & Technology** 47.22 (2013): 13039-13046.
- Niu, Junfeng, et al. "Theoretical and experimental insights into the electrochemical mineralization mechanism of perfluorooctanoic acid." **Environmental Science & Technology** 47.24 (2013): 14341-14349
- Niu, Junfeng, et al. "Electrochemical mineralization of perfluorocarboxylic acids (PFCAs) by Ce-doped modified porous nanocrystalline PbO₂ film electrode." **Environmental Science & Technology** 46.18 (2012): 10191-10198.
- Lin, Hui, et al. "Electrochemical degradation of perfluorooctanoic acid (PFOA) by Ti/SnO₂-Sb, Ti/SnO₂-Sb/PbO₂ and Ti/SnO₂-Sb/MnO₂ anodes." **Water Research** 46.7 (2012): 2281-2289.

Bench Scale Results: DE-FLUORO™ destruction of PFAS (Spiked Water)



Electrode	PFOA $t_{1/2}$ (min)	PFOS $t_{1/2}$ (min)
Ce-PbO ₂	34.7	NA
BDD	25.7	NA
DE-FLUORO™ Electrode	20.3	52.6

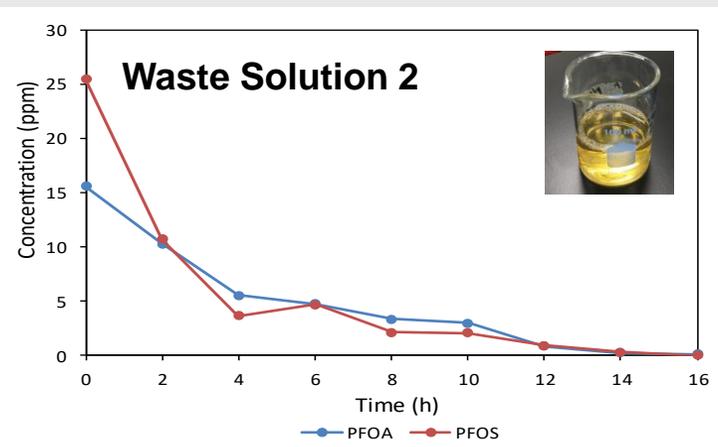
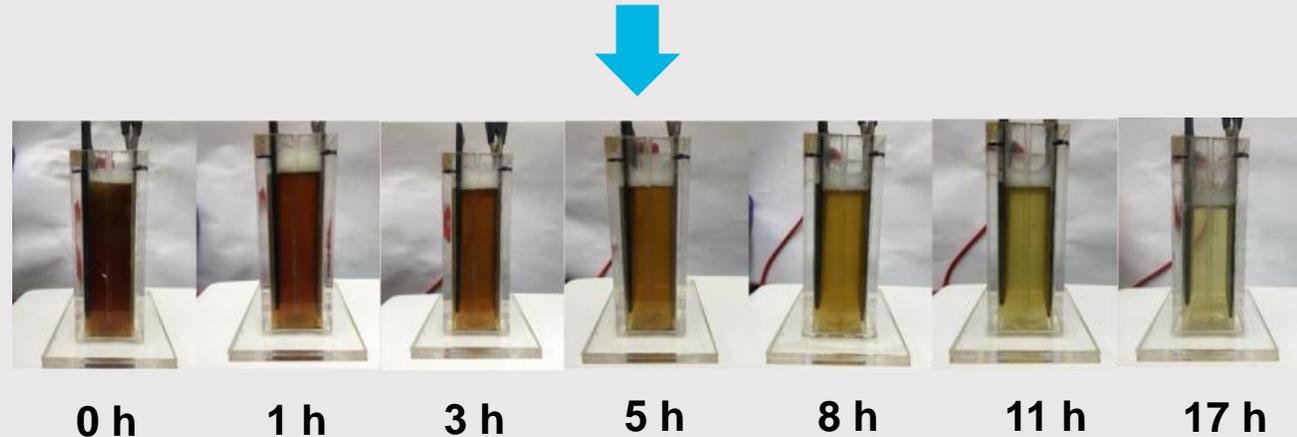
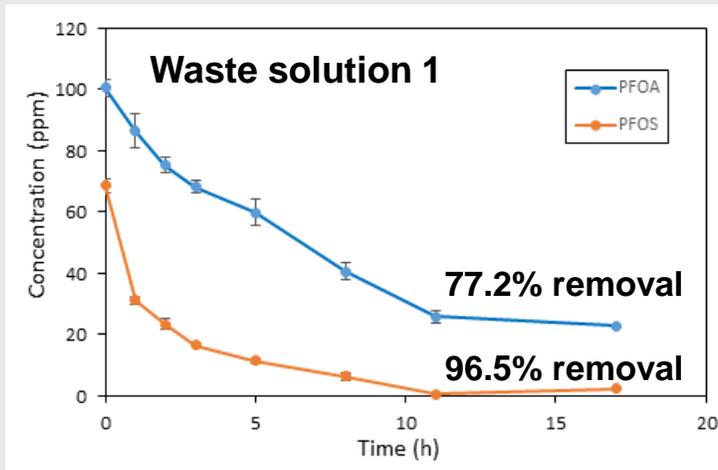
Test conditions

- 0.5 mM PFOA (a) 0.1 mM PFOS (b)
- 5 mA/cm², 20 mM NaClO₄ as electrolyte
- 200 mL solution, 50 cm² electrode surface

**Methods and systems for electrochemical oxidation of polyfluoroalkyl and perfluoroalkyl contaminants. 2016, US provisional patent application 62377120

DE-FLUORO™ (Bench Trial) treatment of ion exchange resin regeneration waste

TOC (ppm)	Conductivity (µs/cm)	PFOA (ppm)	PFOS (ppm)	PFHxS (ppm)	PFHxA (ppm)	PFHpA (ppm)	PFPeA (ppm)	PFBS (ppm)
7861	2939	100.5	68.6	55.1	18.7	10.2	5.3	1.9



	Fluoride (ppm)	Chloride (ppm)
T0	1	3534
17-H sample	836	2874

Test conditions

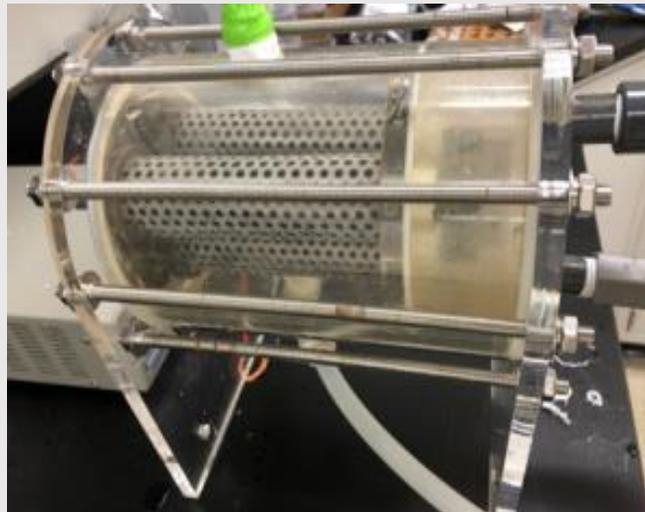
- Current density: 10 mA/cm²
- Cell voltage: 7.0 V
- pH: 12.0 (initial), 9.0 (final)

DE-FLUORO™ Development Models

Model 1 (Nemo)



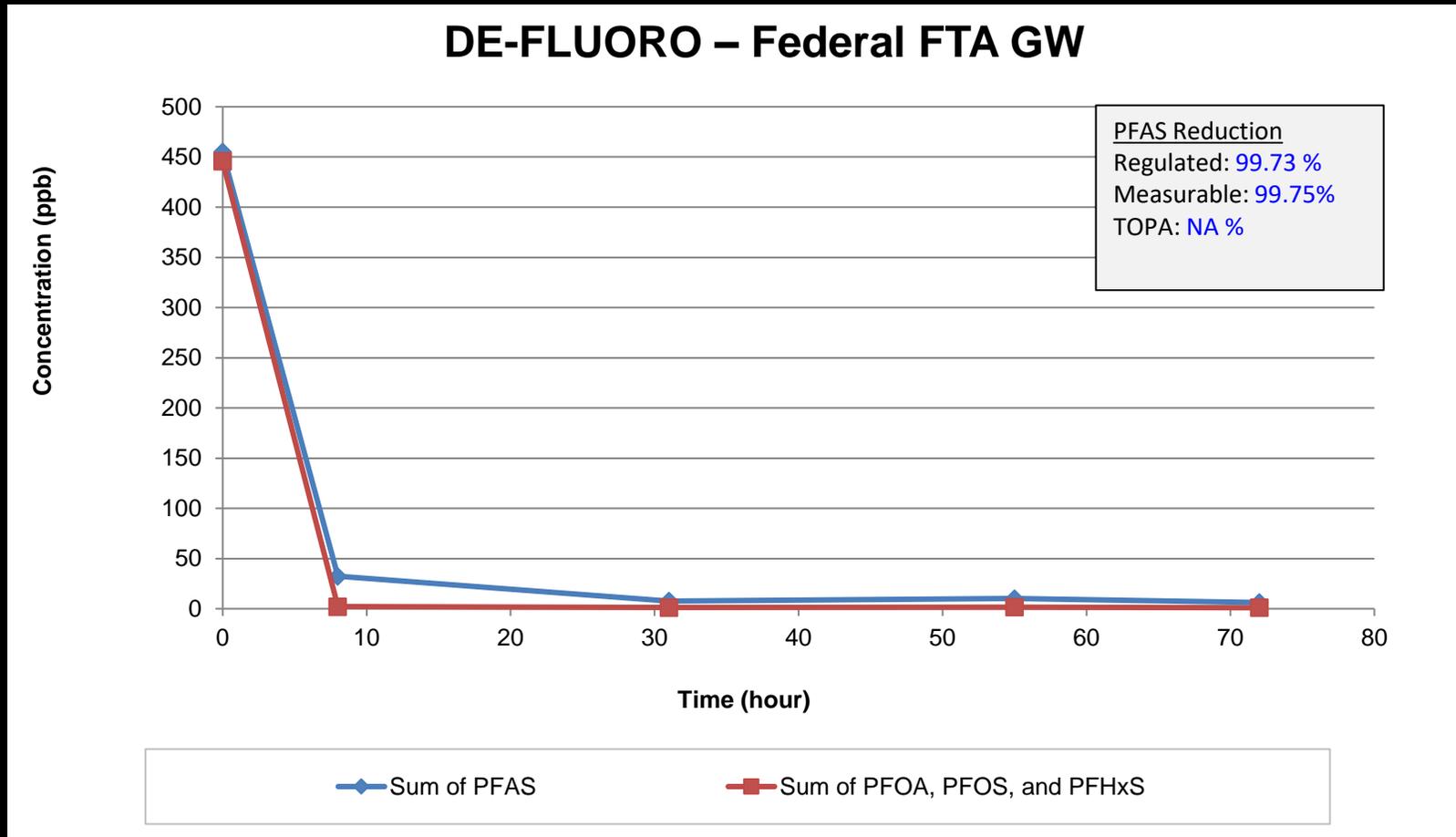
Model 2 (Jaws)



DE-FLUORO™ Demonstration Solutions/ Summary of Results

Trial #	Client	Sample Description	Initial total PFAS concentration (ug/L)	Mass Reduction
1	Government	Source area groundwater	455	99.7%
2	Chemical Manufacturer	Industrial wastewater	411	99.5%
3	Remediation Contractor	Remediation derived wastewater	13,600	99.2%
4	Aviation	Remediation derived wastewater	1,590	90.7%
5	Government	Source area groundwater	27.3	83.8%
6	O&G	Spent C6 AFFF solution	4,620	83.3%
7	Remediation Contractor	IX R – soft wash recipe	2,370	63.6%
8	O&G	AFFF Concentrate / Product	6,380,000	60 %

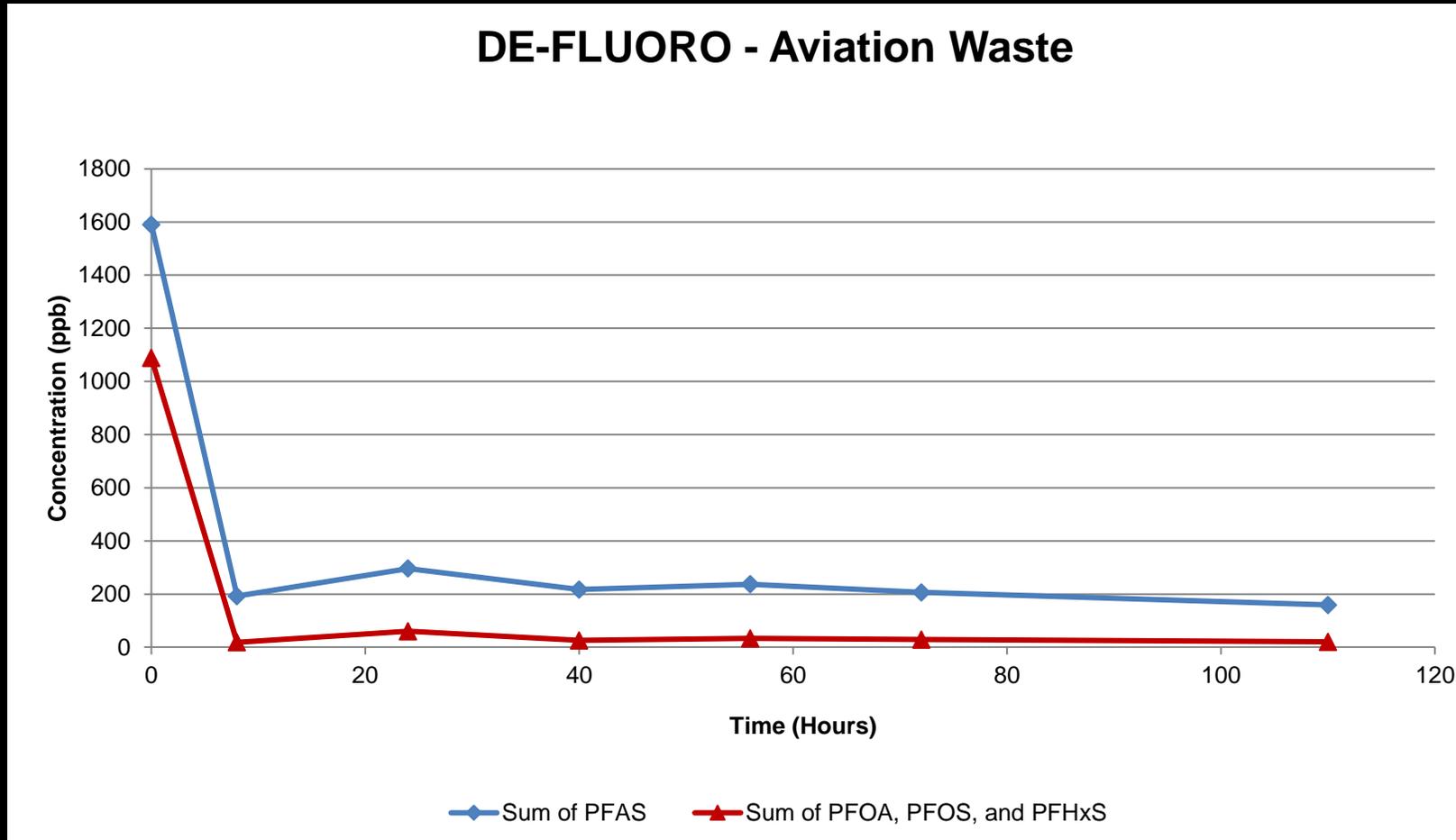
Government FTA groundwater



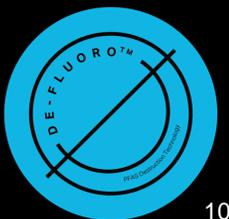
- More than 99% of regulated PFAS reduction by DE-FLUORO in under 8 hours
- More than 99% of total measurable PFAS reduction by DE-FLUORO in approximately 30 hours



Aviation Remedial Derived Waste

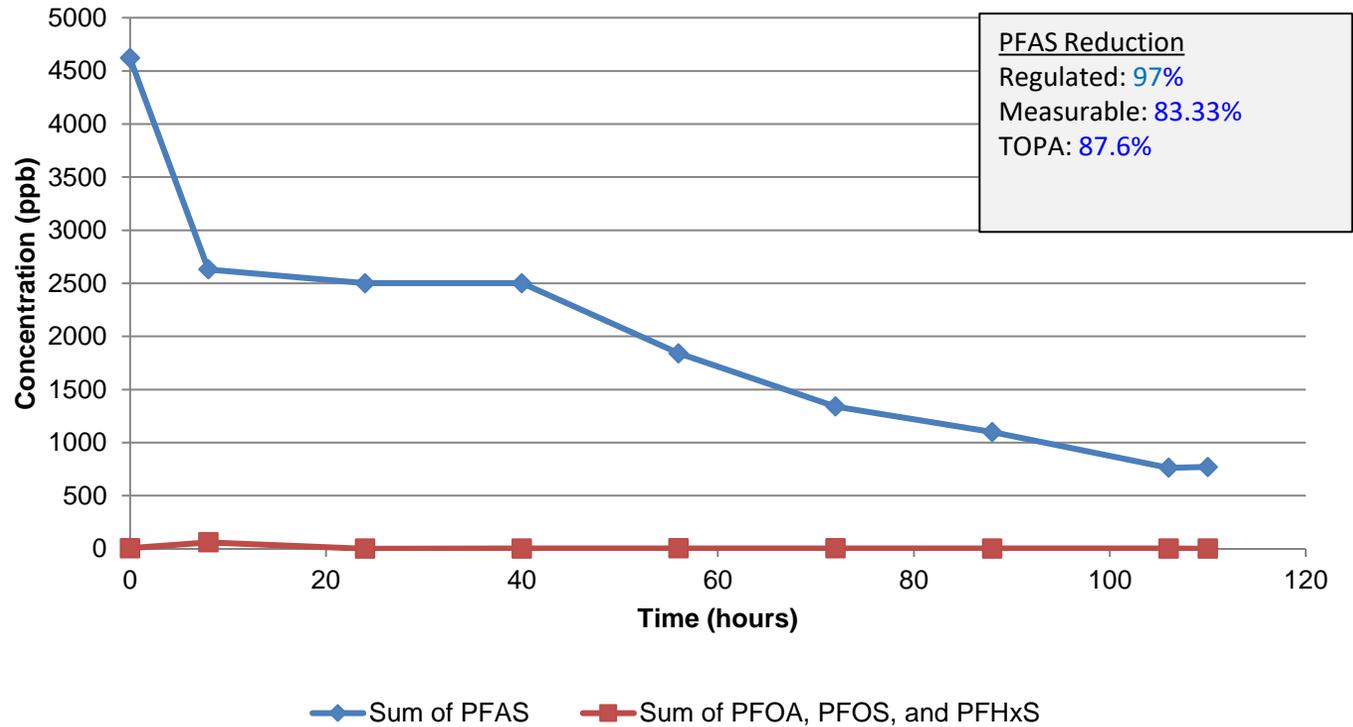


- More than 98% of regulated PFAS reduction by DE-FLUORO in under 10 hours
- More than 90% of total measurable PFAS reduction by DE-FLUORO in approximately 110 hours



O&G Spent AFFF Solution

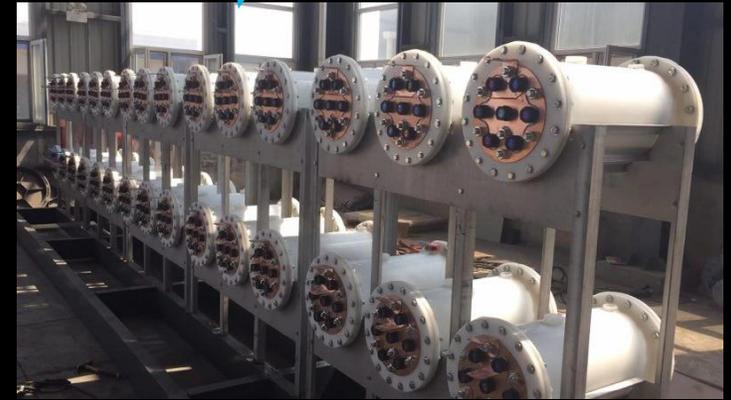
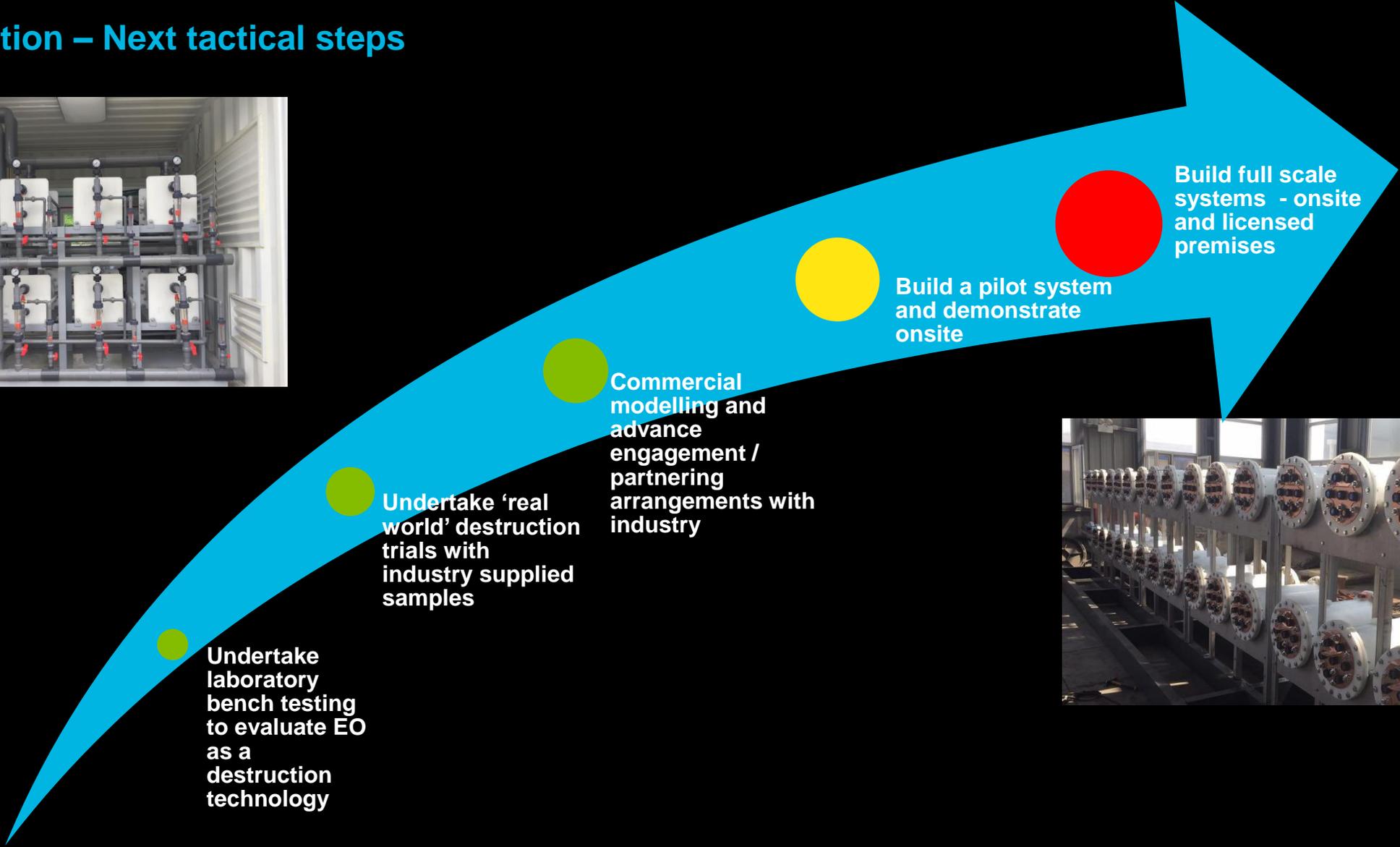
DE-FLUORO - Spent AFFF Solution



- Unique sample - little to no regulated PFAS within the sample
- More than 83% of total measurable PFAS reduction by DE-FLUORO in approximately 110 hours



Direction – Next tactical steps



DE-FLUORO™ – Treatment Systems and Electrodes



Bench Scale Unit ~ 4 L/m

Membrane Electrodes

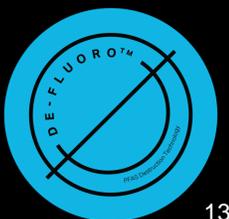
- Flow-through mode
- Large Surface Area
- Stable and long life
- Scalable and commercially available



Mobile Pilot Scale System ~ 20 L/m



Full Scale Treatment Plant ~ 1700 L/m



Key Takeaways

1. **DE-FLUORO™ WORKS** – treats and destroys PFAS (including short to long chain PFAAs and precursors)
2. Can be standalone or coupled treatment technology
3. Can destroy PFAS on-site
4. Comparison to other technologies indicates this is cost effective / competitive



**2018 EBJ Business
Achievement Awards**

TECHNOLOGY MERIT: PFAS

AECOM (Chelmsford MA) for developing an on-site technology that destroys per- and poly-fluoroalkyl substances (PFAS) compounds in

Thank you for listening

Please get in touch:

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