AECOM

PFAS IDENTIFY. RESOLVE.

DE-FLUORO™

DEMONSTRATION PROGRAM

DE-FLUORO™ Demonstration Program

AECOM has been developing a treatment technology (DE-FLUORO™) that will significantly reduce environmental liabilities associated with per- and poly-fluoroalkyl substances (PFAS). Our ultimate focus is to design a destructive PFAS treatment technology that is compact, highly efficient, economical and mobile.

At present, the industry is limited in PFAS treatments, having turned to conventional, commercially available water treatment technologies that do not destroy PFAS mass, and that require eventual off-site thermal treatment or disposal. This approach may result in a transfer of PFAS liability from one location (site water) to another (disposed treatment media). Using AECOM's proprietary electrodes for the process of electrochemical oxidation, DE-FLUORO™ breaks the carbon and fluorine bonds in PFAS and destroy these onsite - offering an alternative solution for onsite separation and offsite destruction options.

Purpose of DE-FLUORO™

PFAS have been widely used for commercial water- and stain-proofing, metals plating, food packaging, and as essential components to Aqueous Film Forming Foam (AFFF) used to fight liquid pool fires and in aviation fire training. These uses and disposal of commercially treated products into landfills have released PFAS into the environment, affecting many environmental media and appearing widely in drinking water supplies and wastewater effluent/biosolids. Due to their strong carbon-fluorine (C-F) covalent bond essential to PFAS, these chemicals are very difficult to break down or mineralize. They are resistant to chemical, biological, and thermal degradation, and the very nature of PFAS that makes them so ideal for their commercial application has rendered them persistent in the environment. The uniquely engineered properties of PFAS also mean that there is no one single effective treatment technology for this class of compounds.

To remove PFAS from liquids, remediation contractors currently employ mass transfer technologies for PFAS, such as granular activated carbon (GAC), ion exchange resin (IX-R) and reverse osmosis (RO). These concentrate PFAS onto a media, and the spent PFAS loaded media typically require off-site incineration or regeneration, producing regenerant wastes that require further management and treatment. To avoid such a scenario, DE-FLUORO™ was designed to couple electrochemical destruction of PFAS in AFFF and concentrated waste solutions that are generated by conventional filtration / separation technologies.

DE-FLUORO™ Technology Demonstration Program – Destruction Trials

DE-FLUORO™ has proven to be successful in destroying the dissolved PFAS mass within laboratory bench scale trials and the next step in the evolution of the technology was to undertake the Destruction Trials which compromised the treatment of eight 'real world' samples using electrochemistry.

The key objective of the Destruction Trials included the evaluation of the effectiveness and suitability of DE-FLUORO™ in the following areas:

- Treatment effectiveness on a diverse range of 'real world' samples with varying solution chemistry
- Suitability to operate as a stand-alone or coupling technology
- Commercial viability and scalability of the technology, including the ability to design and manufacture a compact, highly efficient, cost-effective mobile treatment unit for on-site and/or off-site PFAS destruction treatment.

Client Supplied Samples

Clients provided samples of eight different PFAS-impacted solutions from real-world operating environments for AECOM's DE-FLUORO™ Destruction Trials, including:

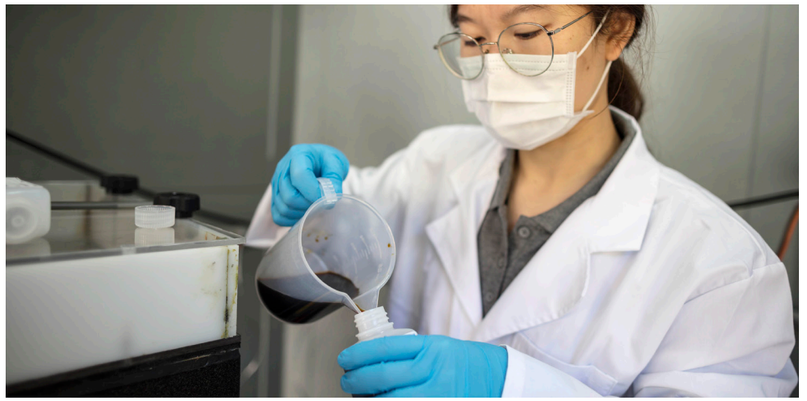
- C8 based Aqueous Film Forming Foam (AFFF) product concentrate
- Spent AFFF (C6 based) solution
- Two PFAS impacted groundwater samples from two different fire training grounds
- Groundwater from a comingled PFAS and chlorinated hydrocarbon plume
- Two PFAS-impacted waste solutions resulting from two different water remediation/treatments (IXR regeneration and ozone foam fractionation)
- PFAS-impacted waste solution resulting from soil remediation/treatment (soil washing).

The samples contained a broad range of PFAS concentrations, from extremely low (parts per billion [ppb]) to extremely high (parts per million [ppm]). The sum of PFAS concentrations in client supplied samples ranged from 27.3 ppb to 6,380,000 ppb (6,380 ppm). Concentrations of targeted Perfluorooctane sulfonic acid [PFOS], Perfluorooctanoic acid [PFOA] and Perfluorohexane sulfonic acid [PFHxS] in the samples ranged from 13.4 ppb to 5,837,000 ppb (5,837 ppm). [The Destruction Trials took place in Australia, where PFOS, PFOA, and PFHxS are referred to as 'regulated PFAS'; we acknowledge that regulations differ,consequently, AECOM performed a full PFAS analysis during the trial.]

Table 1 provides some detail on total and targeted PFAS concentrations in the samples provided by each sector for the DE-FLUORO™ Destruction Trials.

TABLE 1. TOTAL PFAS CONCENTRATIONS PRIOR DE-FLUORO™ TREATMENT

Trial #	Client Sector	Sample Description	Initial 'total' PFAS concentration (ppb)	Initial 'targeted' PFAS concentration (ppb)
1	New Zealand Government	Source area groundwater	27	13
2	Chemical Manufacturer	Industrial wastewater	354	310
3	Australian Government	Source area groundwater	455	445.8
4	Remediation Contractor	IX R – soft wash recipe	1,570	54.9
5	Aviation	Remediation derived wastewater	1,590	1,088
6	Oil & Gas	Spent C6 AFFF solution	4,620	6
7	Remediation Contractor	Remediation derived wastewater	10,700	6,572
8	Oil & Gas	3M AFFF Concentrate / Product	6,380,000	4,800,000



The samples contained a range of PFAS concentrations and signatures, including short and long-chain PFAS and a mix of precursors. Treating such a variety of samples allowed the Destruction Trials to challenge the operational boundaries of DE-FLUORO™ (Figure 1) and understand the versatility of this technology across potential different applications. Further details of the results from the Destruction Trials are outlined in Table 2 and Figures 2 to 5 on the following page.

FIGURE 1. PFAS COMPOUND SIGNATURES PRIOR TO DE-FLUORO™ TREATMENT

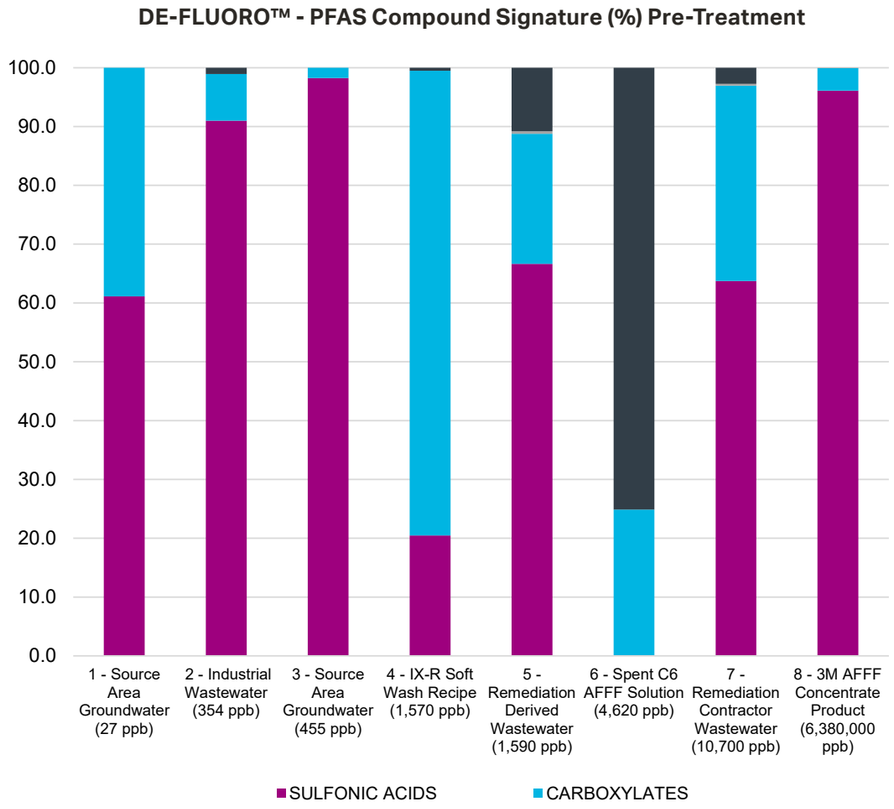


TABLE 2. SUMMARY OF DE-FLUORO™ TREATMENT RESULTS

Trial / Sample #	Client Sector	Sample Description	Initial total PFAS concentration (ppb)	% Mass Reduction (total PFAS) DE-FLUORO™	Initial 'targeted' PFAS concentration (ppb)	% Mass Reduction (targeted PFAS) DE-FLUORO™
1	New Zealand Government	Source area groundwater	27	84%	13	98%
2	Chemical Manufacturer	Industrial wastewater	354	100%	310	100%
3	Australian Government	Source area groundwater	455	99%	445	98%
4	Remediation Contractor	IX R – soft wash recipe	1,570	63.6%	54.9	100%
5	Aviation	Remediation derived wastewater	1,590	90%	1088	98%
6	Oil & Gas	Spent C6 AFFF solution	4,620	83%	6	71%
7	Remediation Contractor	Remediation derived wastewater	10,700	99%	6,572	100%
8	Oil & Gas	3M AFFF Concentrate / Product	6,380,000	57%	4,800,000	64%

FIGURE 2. TOTAL PFAS – CONCENTRATIONS PRE AND POST DE-FLUORO™ TREATMENT

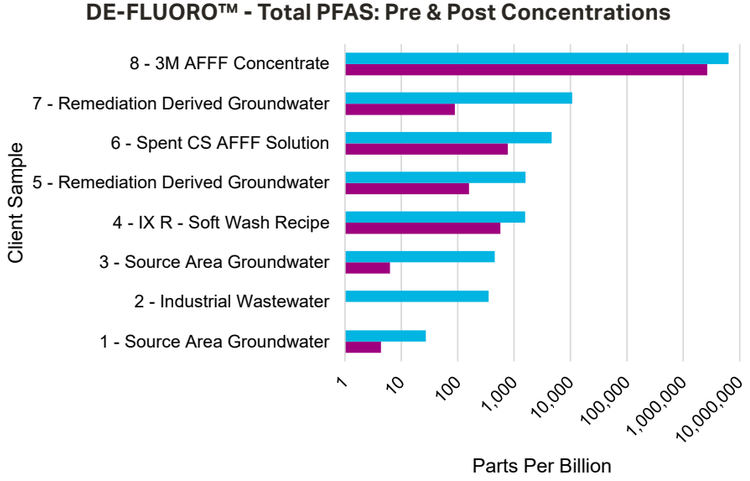
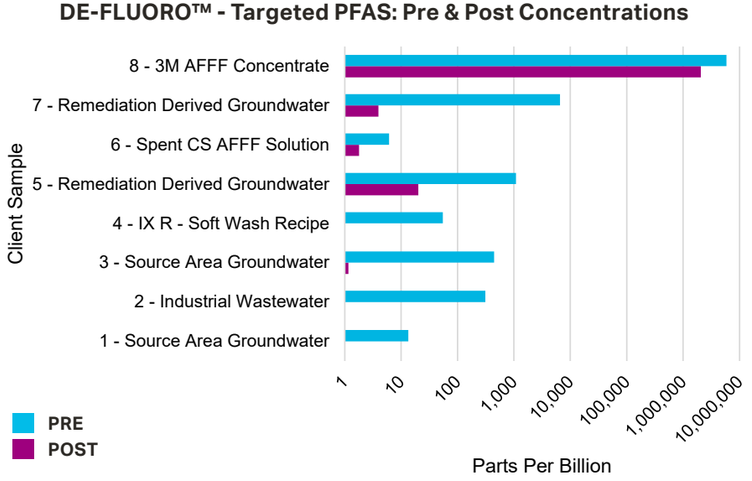


FIGURE 3. TARGETED PFAS – CONCENTRATIONS PRE AND POST DE-FLUORO™ TREATMENT



Detailed Analysis of Results

Figure 4 shows that the PFAS signatures of pre-treatment samples were dominated by sulfonic acids and long chained carboxylates, whereas PFAS signatures post-treatment were all dominated by short chained carboxylates. Exceptions to this trend included the 3M AFFF Concentrate sample, where the PFAS signature did not significantly change and the Spent C6 AFFF Solution which was dominated by intermediate fluorotelomers and, to a lesser degree, carboxylates in the post treatment solution.

Short chained carboxylate compounds were the most recalcitrant to treat using electrochemical oxidation as was evident by the slower kinetics of degradation and the signature of percent composition of PFAS compounds post-treatment. Figure 5 and Figure 6 summarize the degradation kinetics for the sum of measurable PFAS and targeted PFAS.

The 3M AFFF concentrate product was subject to the least PFAS % mass reduction by DE-FLUORO™, however the greatest reductions in PFAS concentrations were observed for this sample. AECOM notes that this is related to the extremely high pre-treatment concentrations of PFAS (6,380,000 parts per billion) and the limited treatment times for the trial.

Please note further data in relation to the degradation analytics associated with the Total and Regulated PFAS, as well as degradation rates in each of the individual PFAS compounds for each 'real world' sample is available in the detailed sample charts appended to this memorandum.

FIGURE 4. PFAS COMPOUND SIGNATURES PRE AND POST DE-FLUORO™ TREATMENT

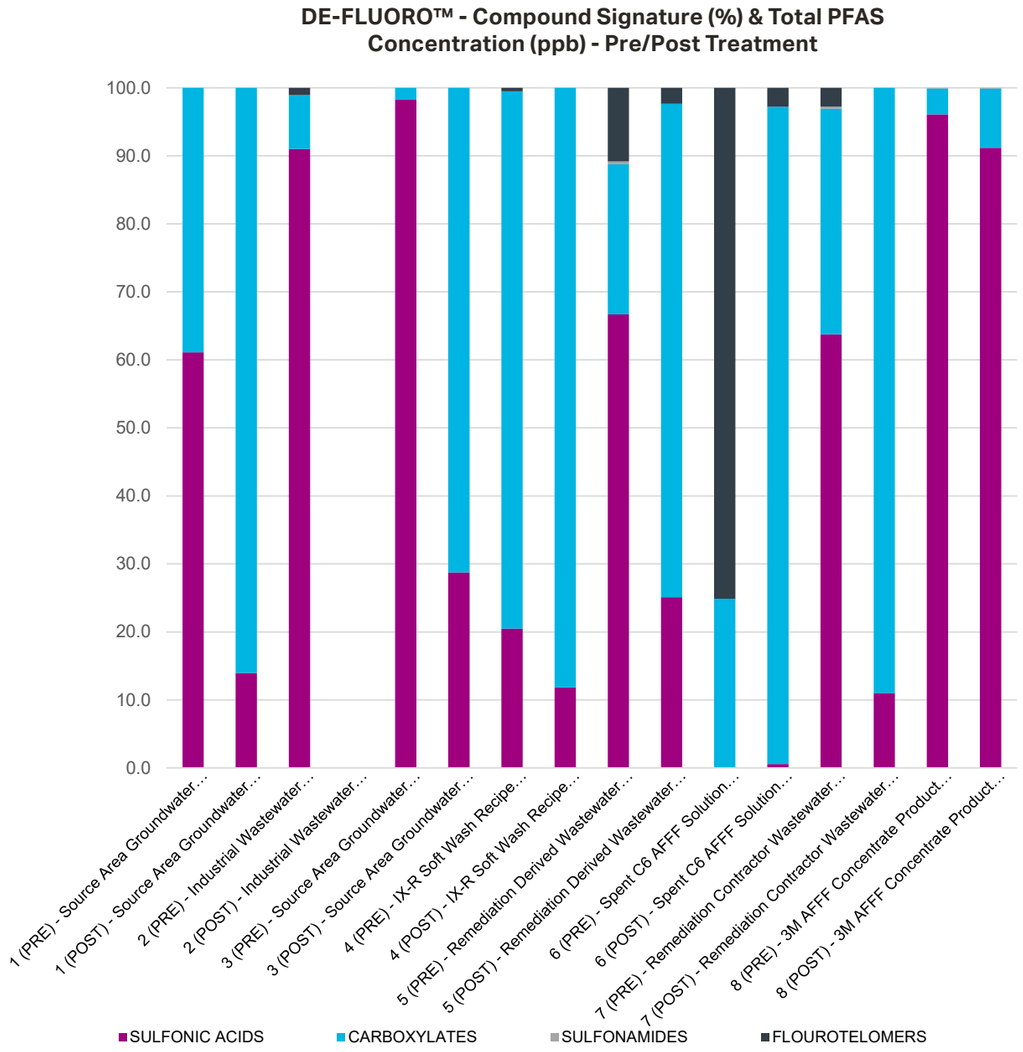


FIGURE 5. TOTAL PFAS MASS REDUCTION (%)

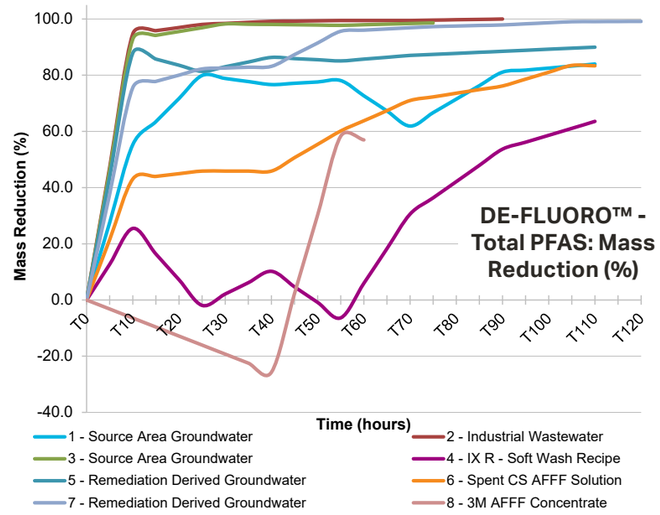
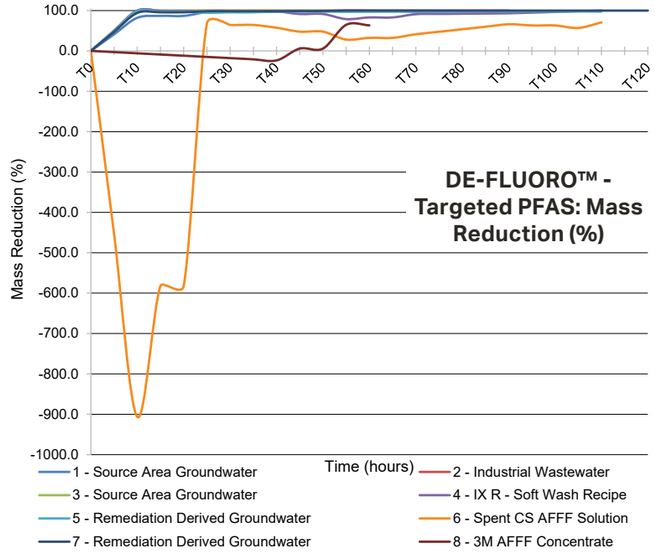


FIGURE 6. TARGETED PFAS (PFOS, PFOA AND PFHXS) MASS REDUCTION



Project Findings

The Destruction Trials data concluded that:

- DE-FLUORO™ destroyed between 90% to 100% of the total PFAS mass in most of the samples treated. The duration of each trial was limited due to schedule, and a longer residency time would likely have resulted in all samples achieving 100% destruction.
- DE-FLUORO™ destroyed between 98% to 100% of Targeted PFAS mass in all but two samples. Again, lesser effectiveness was attributed to the limited duration of each trial, and a longer residency time would likely have resulted in all samples achieving 100% destruction.
- DE-FLUORO™ treats both measurable and unmeasurable PFAS with a range of compound signatures.
- DE-FLUORO™ is not limited by PFAS concentration nor the presence of other contaminants (organic or inorganic).
- DE-FLUORO™ is a feasible PFAS destructive technology for 'real world' samples.

In addition, AECOM modelling indicates that greater reduction rates can be achieved by:

- Increasing the residency time / treatment duration (with the same sized reactor)
- Enhancing contact with electrodes by increasing the reactor size (e.g., in a field demonstration)
- Undertaking a sequential run of electrochemical reduction and electrochemical oxidation (i.e. reverse the polarity of the electrodes)
- Increasing mass transfer and the current density; the current density planned for future field demonstration systems will be scaled up by a factor of 40

AECOM's team continue to conduct efficiency trials to optimize DE-FLUORO™ treatment duration, benefits of reversing polarity, role of unmeasured fluorinated mass (via detailed chemical analysis), and other factors important to scaling up to a Destruction Pilot System.

DE-FLUORO™ Next Steps

The results of the Destruction Trials using DE-FLUORO™ are highly encouraging, for that reason AECOM is building two field scale mobile DE-FLUORO™ plants with large scale reactors/electrode arrays that will be available for on-site destruction pilots. We are seeking opportunities to partner with clients / contractors to further demonstrate the effectiveness of the DE-FLUORO™ technology in PFAS remediation through an on-site PFAS Field Demonstration which would include:

- Mobilizing a DE-FLUORO™ full Field Demonstration System to site
- Undertaking a 2- to 4-month on-site PFAS destruction program to confirm DE-FLUORO™ as a cost effective, on-site PFAS destruction solution
- Data analysis and interpretation of the findings, followed by design of a full scale DE-FLUORO™ PFAS destruction solution. Scaling up would only be recommended based on results the pilot program including a cost benefit analysis against other existing destruction technologies.

We welcome the opportunity to discuss the results of this program and the next steps in the evolution of DE-FLUORO™. We would also welcome the opportunity to provide a proposal to undertake a DE-FLUORO™ Pilot Program on your site.

To discuss in more detail, please contact:

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DE-FLU•RO™

About AECOM

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