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water technologies

Electrochemical Oxidation for the Elimination of PFAS from Contaminated Water

Arvia Water Technologies

- Leaders in electrochemical oxidation for industrial water treatment.
- One of the longest-established electrochemical water treatment companies in the market.
- Headquarters with laboratories and manufacturing in the UK.
- Office and laboratories in Shanghai, China and Gujarat, India.
- Sales office in U.S.
- Products deployed globally in various water treatment applications.

CERTIFIED CARBON NEUTRAL® company
CarbonNeutral.com

Industrial wastewater treatment

Persistent organic chemical removal

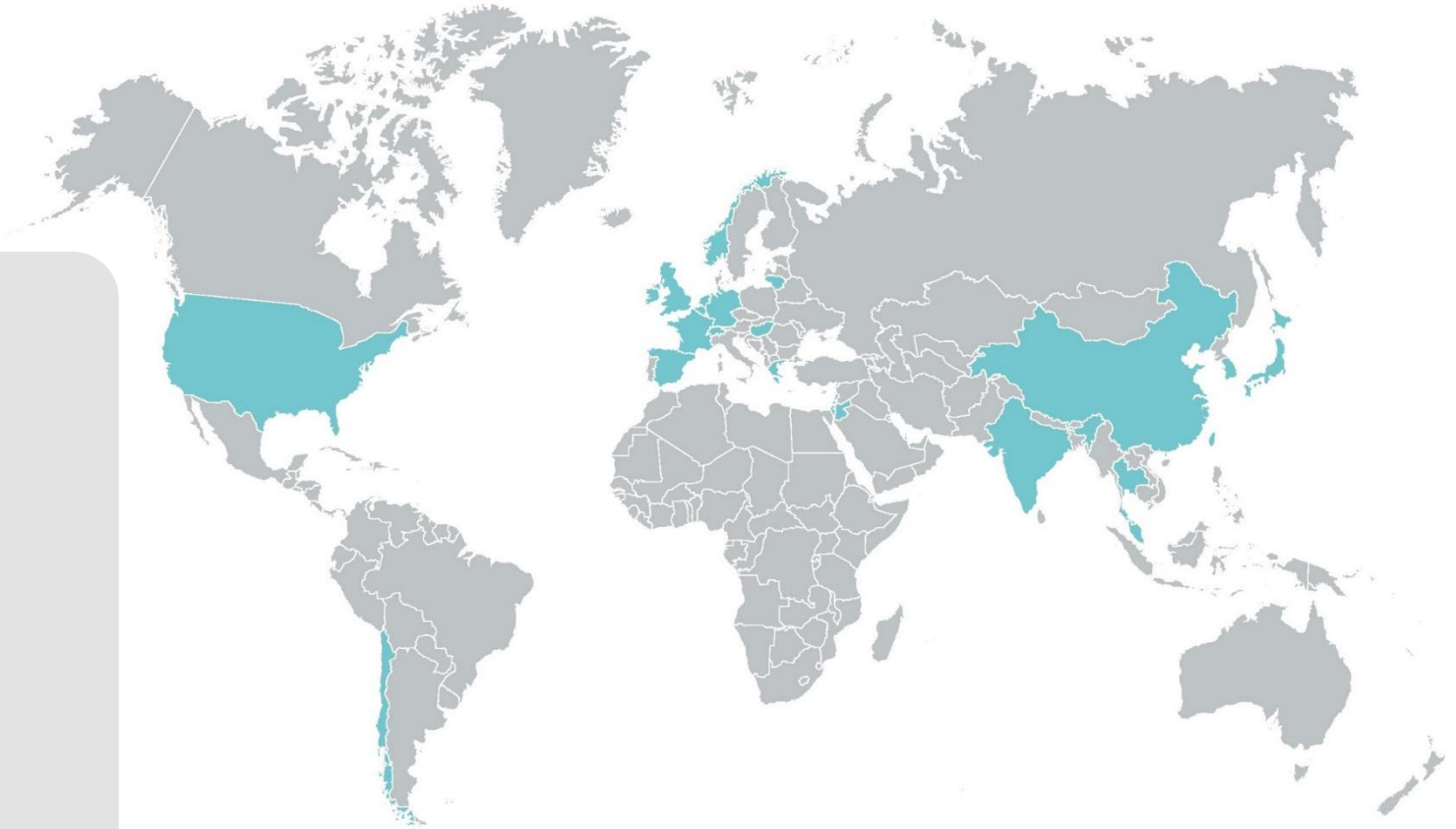
Water reuse

Scope 1, 2 & 3 Emission reduction

Worldwide Market Activity and Sectors

Sectors:

- Life Sciences
- Agrochemicals
- Speciality Chemicals
- Battery Recycling
- Waste Management
- Aquaculture
- Utilities



Nyex™ Treatment Applications

Recalcitrant COD:

- Reduction from 1000's mg/l to below 10 mg/l for reuse or Limit of Detection for discharge

Micropollutants / CECs:

- Removal, including pesticides and hazardous chemicals to Limit of Detection

PFAS:

- In-situ destruction of PFAS

Colour:

- Removal from raw water and process water, including dyes, tea/coffee wash and natural organic material (NOM/CDOM)

Arvia Technologies

Nyex Rosalox™

- Combines adsorption with electrochemical oxidation to remove pollutants to very low concentrations, e.g. APIs to PNEC values

Nyex Ellenox™

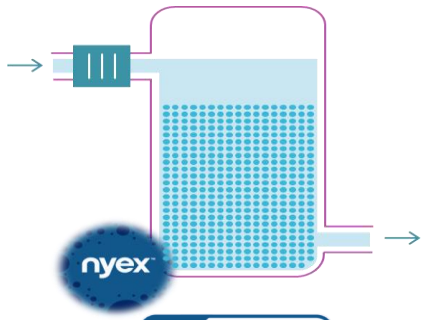
- Conventional electrochemical oxidation to remove bulk organics from industrial waste, landfill leachates.

Nyex Florenox™

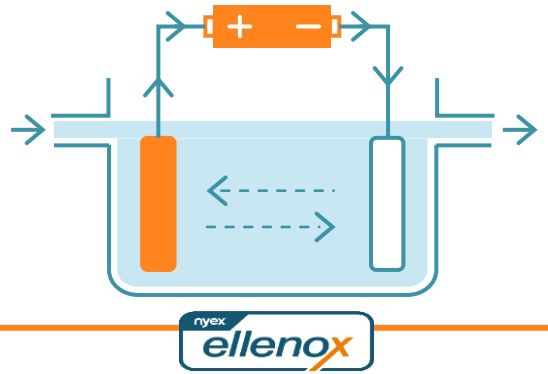
- Combines Nyex.3 granular media and electrochemical oxidation specifically designed for PFAS destruction.

PFAS Destruction

Adsorption and Oxidation



Electrochemical Oxidation



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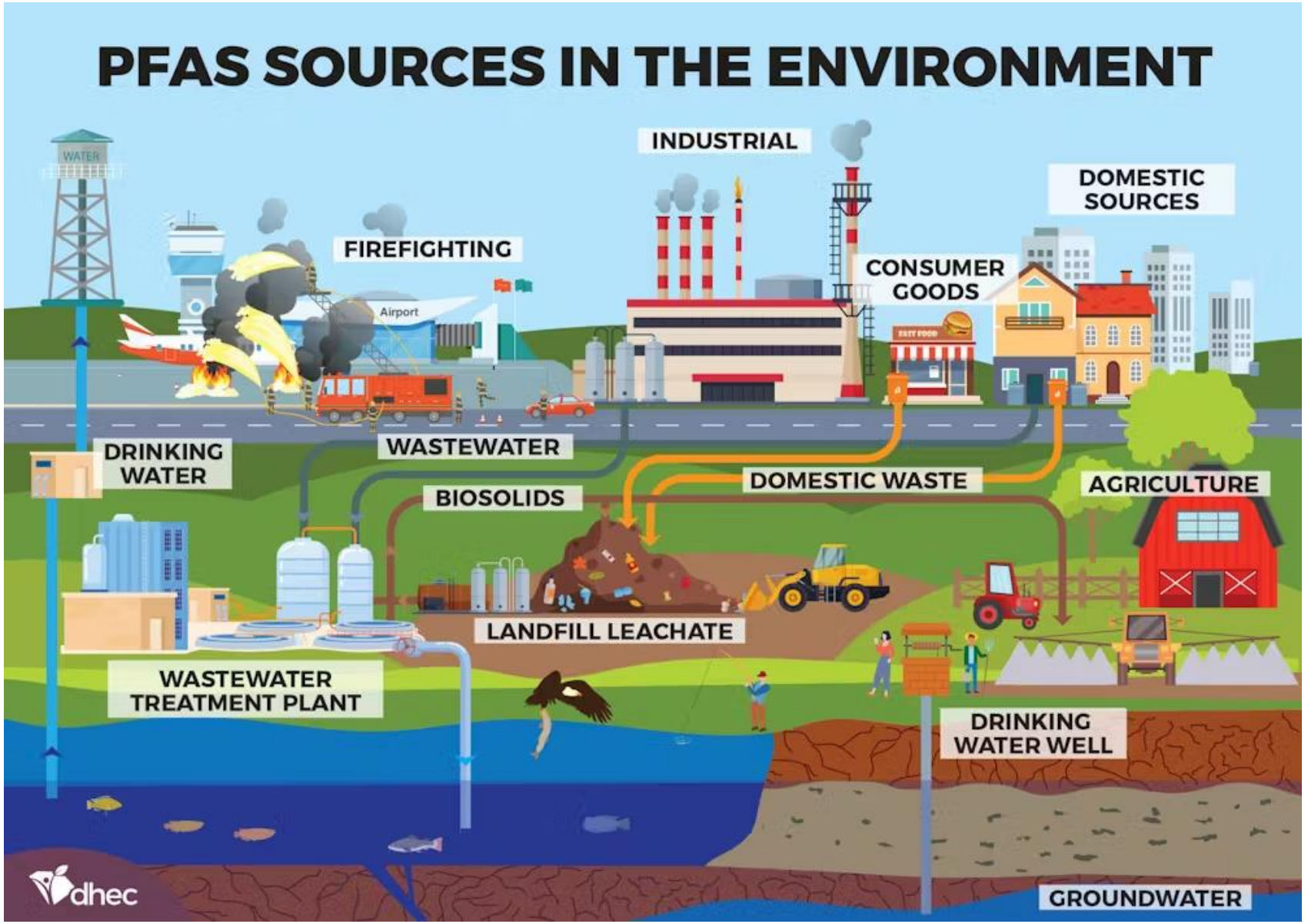
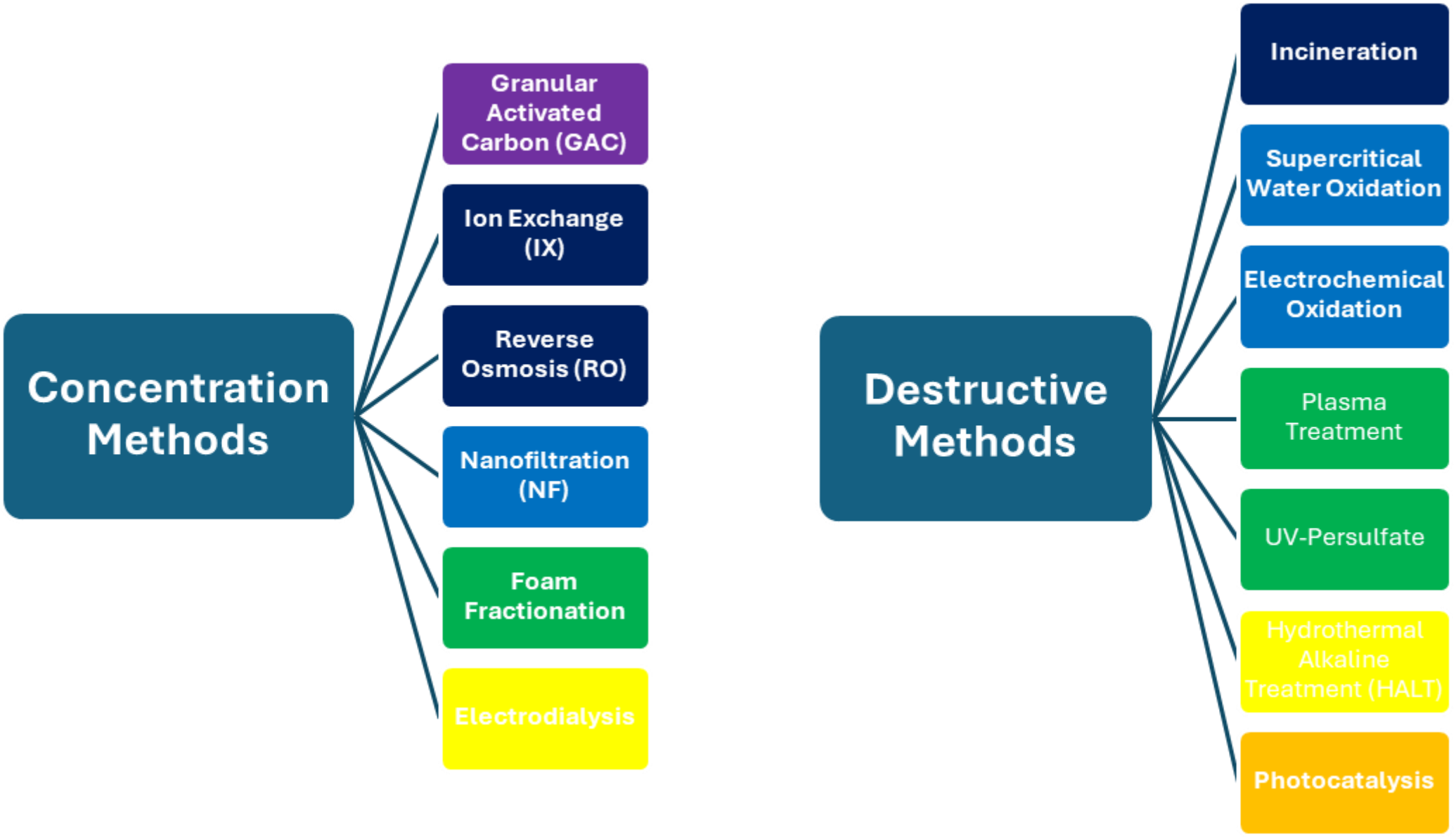
PFAS

Sources of PFAS Contaminants



Source: https://theconversation.com/pfas-forever-chemicals-are-getting-into-ocean-ecosystems-where-dolphins-fish-and-manatees-dine-we-traced-their-origins-216254

Current Treatment Techniques for PFAS



Destruction of PFAS – the challenges

- All destruction techniques are energy intensive to break the strong C-F bond
- Real wastes contain other organics that complicate treatment and analysis, e.g. landfill leachates, firefighting foams, land remediation (soil-washing).
- Fluorine is released as fluoride and, potentially, as volatile fluorocarbons, which need to be captured and managed
- Mass balance is required to identify all intermediates and end-products

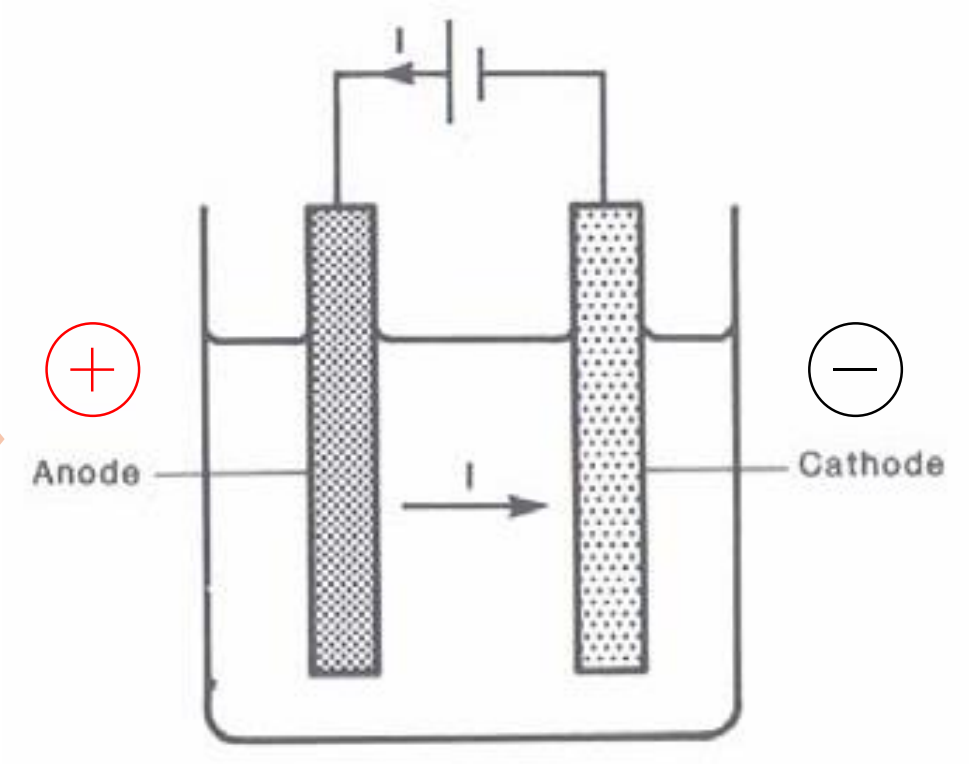
Destruction of PFAS – the challenges

- Bodies of water contain PFAS levels above regulatory demands, so large volumes need to be dealt with
- Regulatory requirements demand PFAS in ppt range, which is challenging analysis and typically takes weeks for results
- Cost to achieve ppt range will be significant ($17.5 trillion[1]) and therefore requires optimised design
- Any destruction technology needs to be readily scalable

[1] https://www.theguardian.com/environment/2025/jan/14/cost-clean-up-toxic-pfas-pollution-forever-chemicals

Electrooxidation – Basic Principle

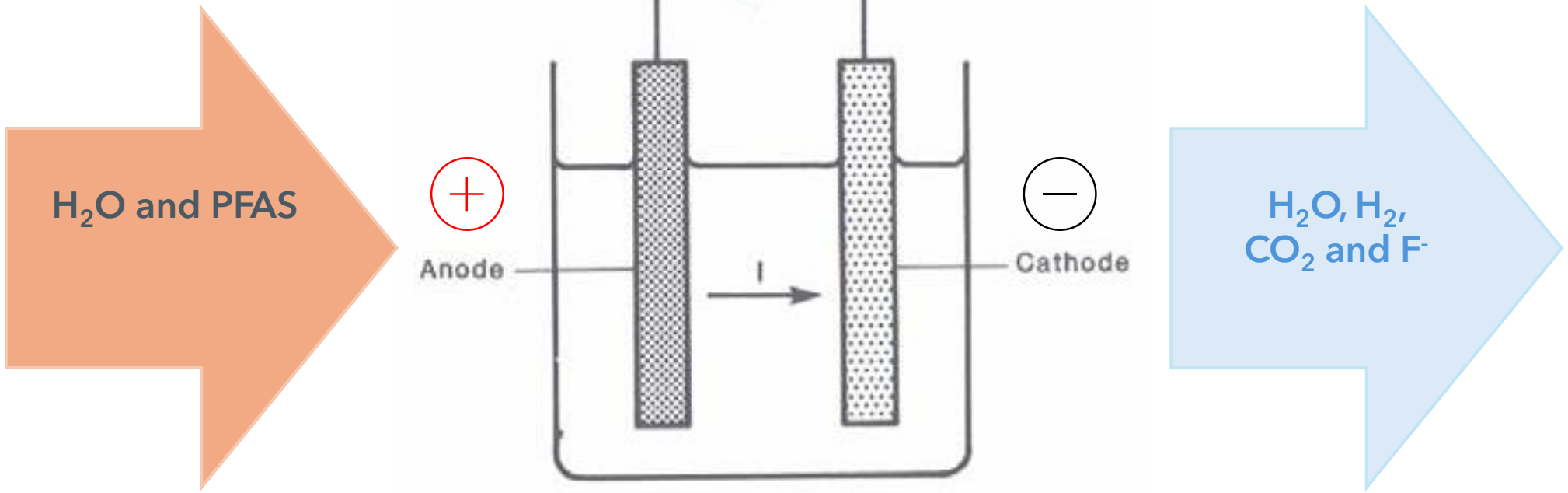
H_2O and PFAS



H_2O, H_2, CO_2 and F^-

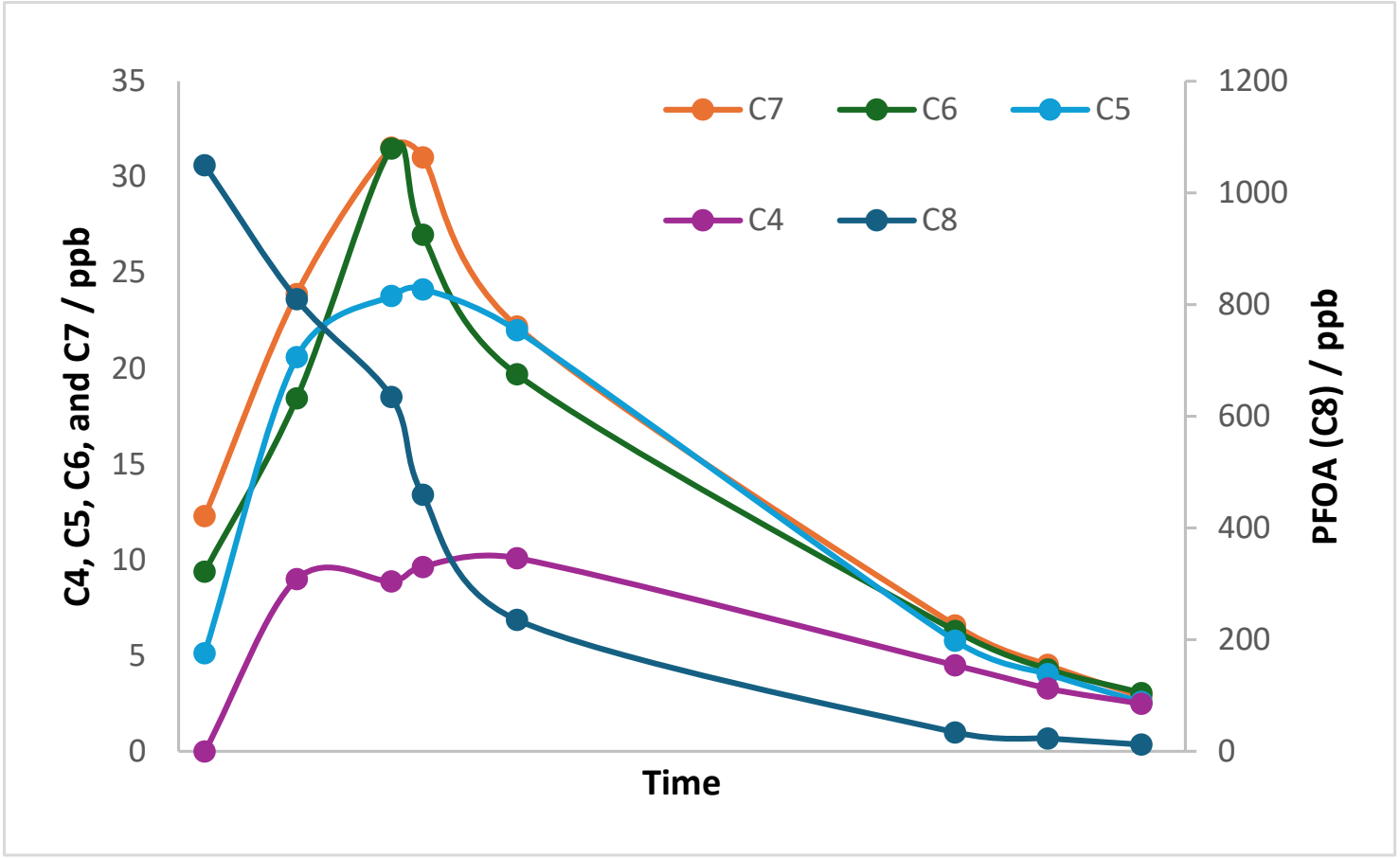
CHALLENGE 1: Conventional electrodes not effective

- There is a need for electrodes that predominantly produce hydroxyl radicals, very strong oxidative species:
- Nyex.3
- Boron Doped Diamond (BDD)
- Titanium suboxides



Nyex.3 Electrodes for PFAS Treatment

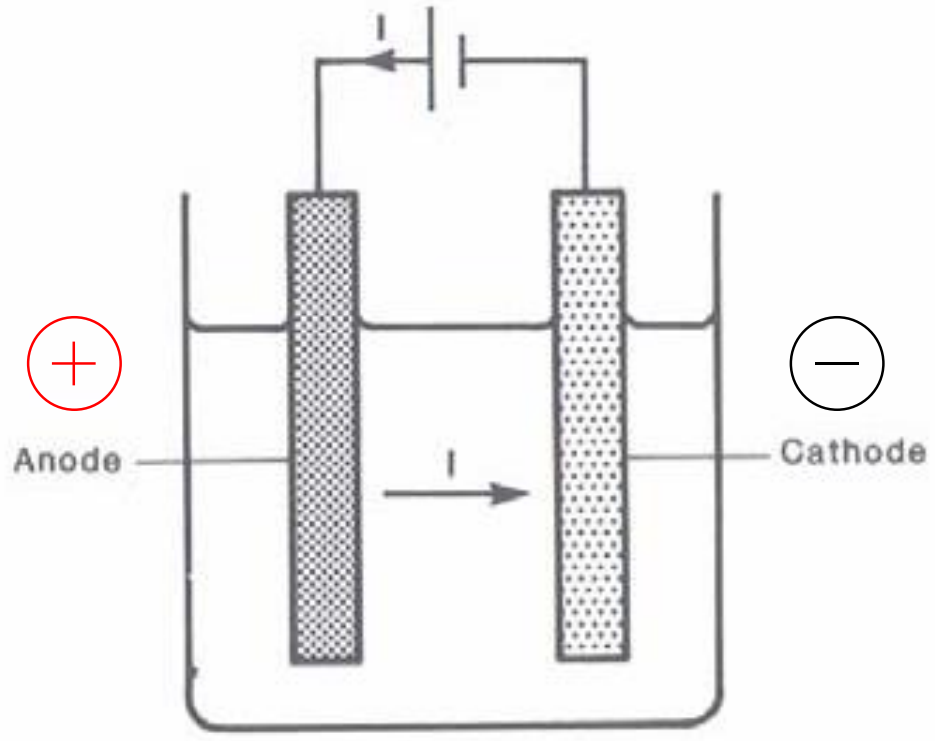
- Nyex.3 media generates powerful hydroxyl radicals
- Nyex.3 has been successfully tested against PFOA and PFOS
- Analyses show PFAS molecules are oxidised to shorter chains, which are then further treated



CHALLENGE 2: Fluoride is released during destruction of PFAS

- BDD manufacturers recommend not exceeding fluoride concentrations above 20 ppm, as it attacks the electrode substrate
- Nyex.3 can tolerate fluoride without loss of performance

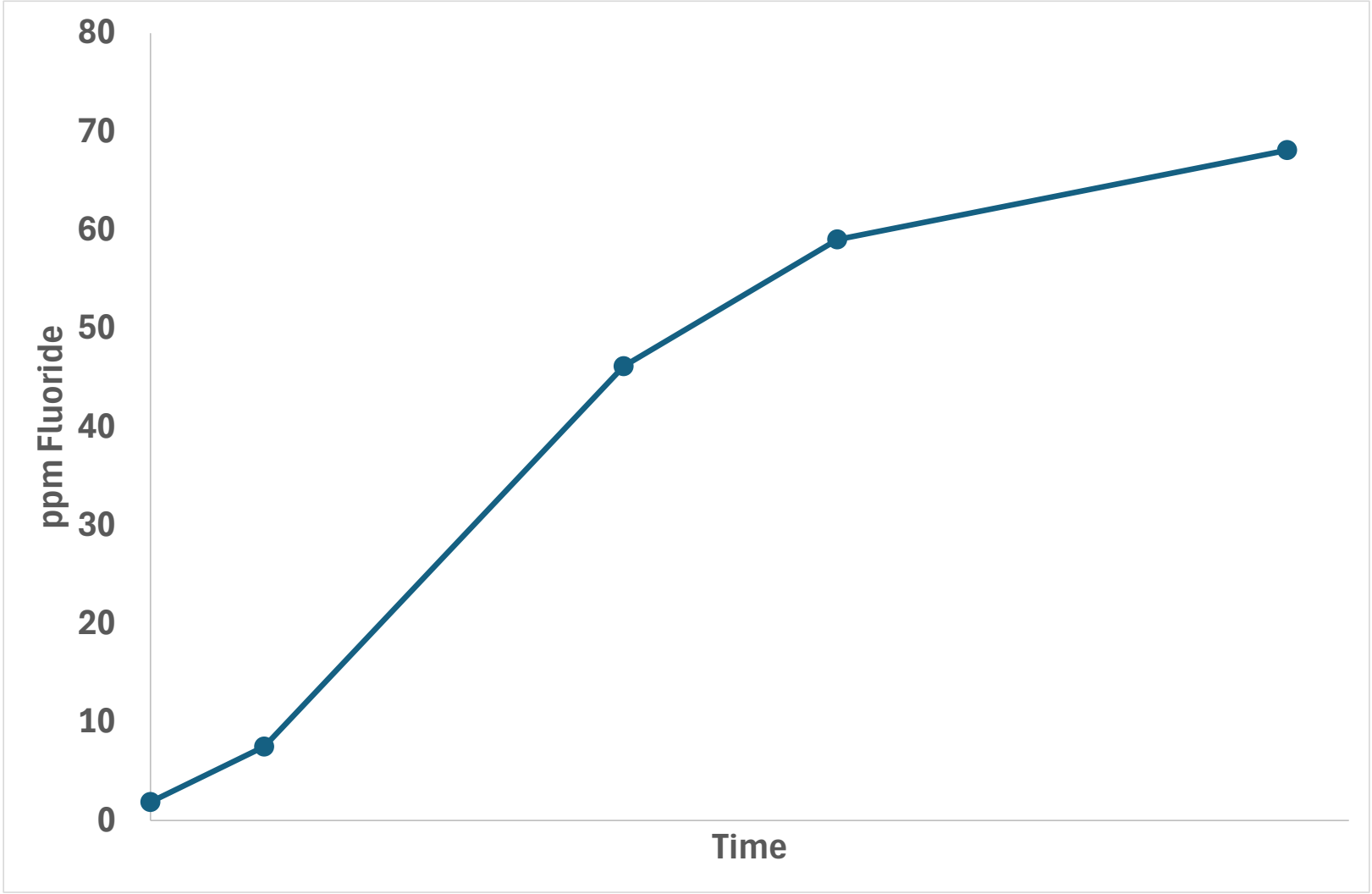
H_2O and PFAS



H_2O, H_2, CO_2 and F^-

Nyex.3 Electrodes tolerate fluoride

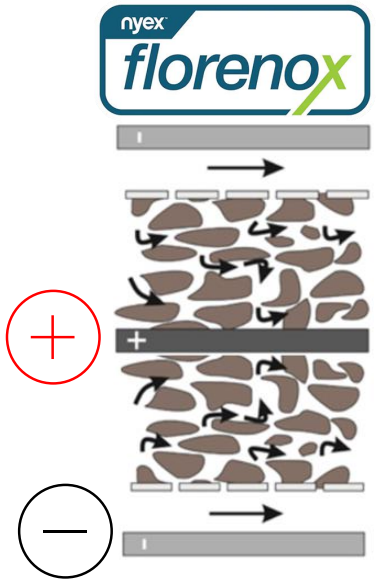
- 68 ppm fluoride released during treatment of 100 ppm PFOA solution
- Indicates destruction of all PFAS
- No loss of performance with Nyex.3, other electrodes may be damaged



CHALLENGE 3: Mass transfer of PFAS to electrode surface

Limiting current density proportional to concentration, but regulations require water to have no more than ppt PFAS

- Nyex.3 is a 3D electrode with high surface area which improves treatment at low concentrations compared to flat plate electrodes.
- Integration of electrochemical oxidation with a concentration technology to remove PFAS down to ppt levels



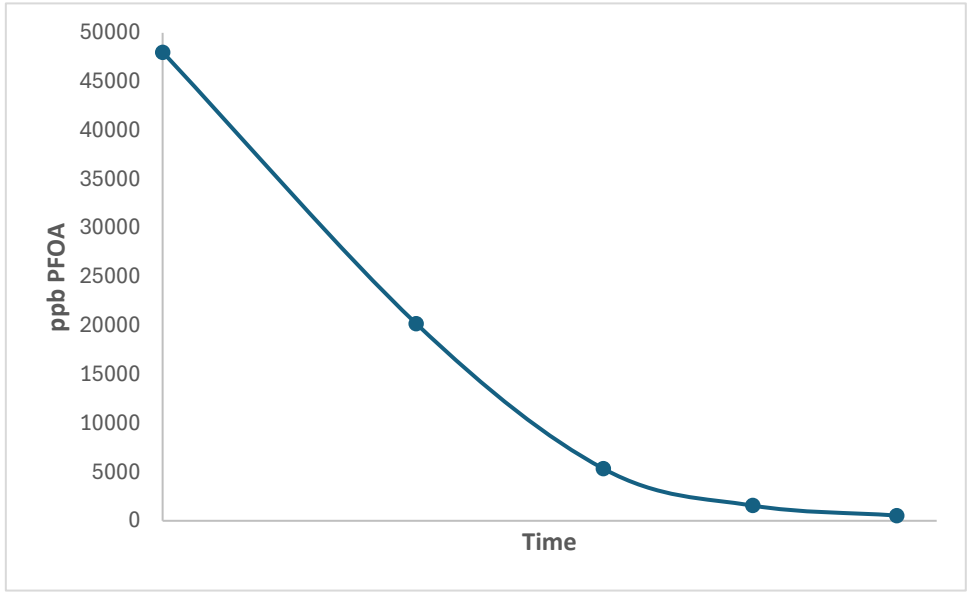
H_2O and PFAS (>ppm)

H_2O, H_2, CO_2 and F^-
PFAS (<ppm)

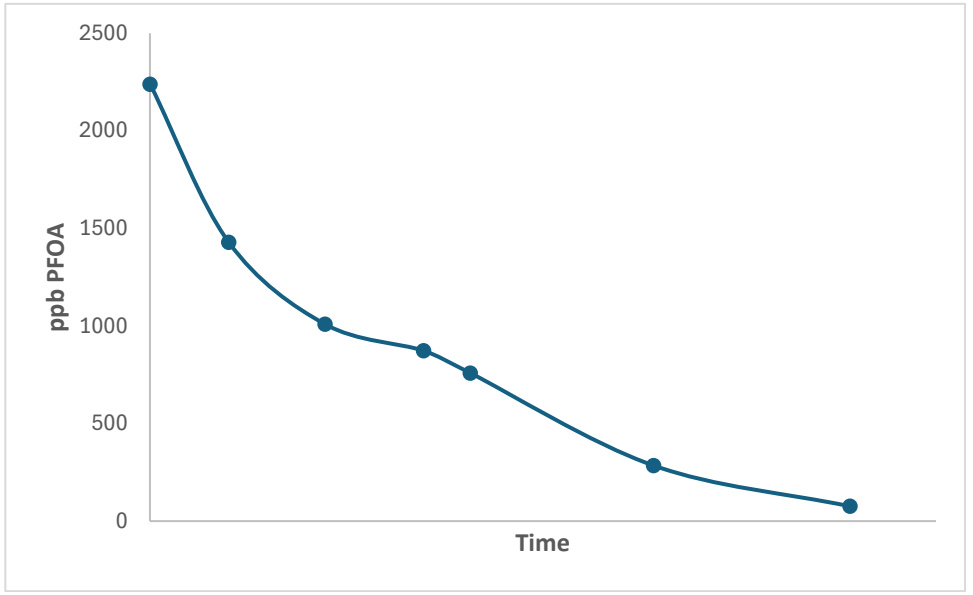
PFAS concentration unit

PFAS free water

Example PFAS treatment with Nyex.3 Electrodes



Treatment of PFOA from 48 ppm to 0.54 ppm (99% removal)



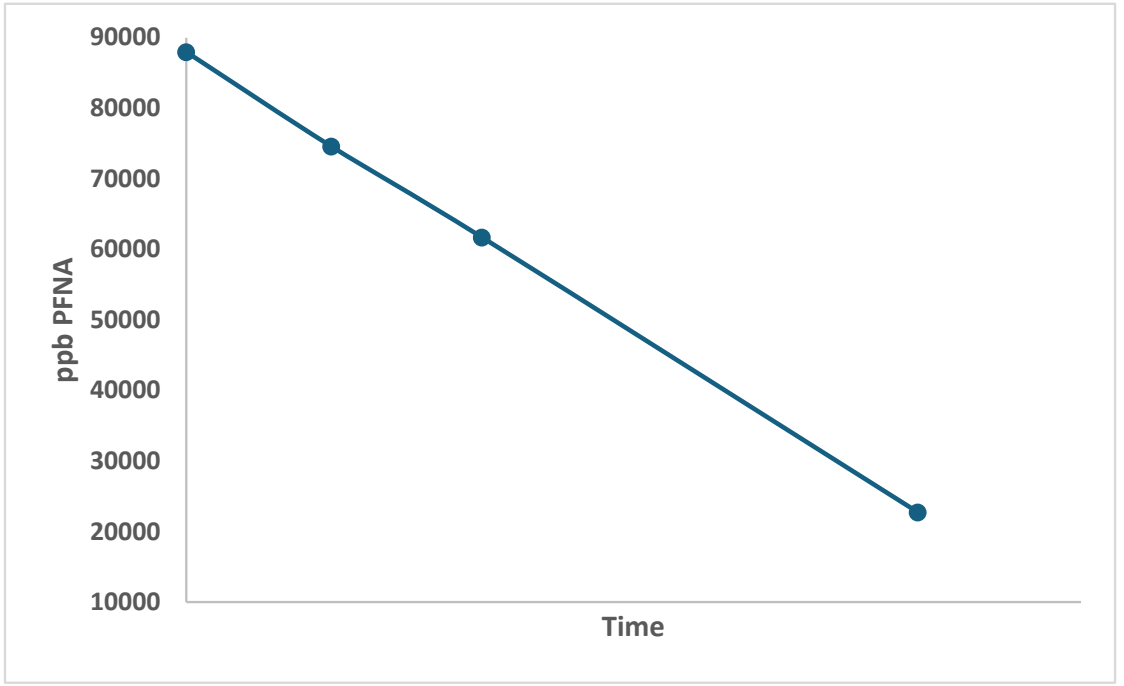
Treatment of PFOA reduced from 2240 ppb to 77 ppb (97% removal)

Nyex.3 can destroy PFAS to low levels, but treatment slows below ppm levels. Integration with separation technologies can solve this problem.

Example PFAS treatment with Nyex.3 Electrodes

- Some separation technologies use solvents to regenerate their media. Florenox can still destroy PFAS when solvents are present (Right)
- RO treatment of solution containing PFBA and PFOA gave Permeate with close to limit of detection (0.25ppb) and Concentrate that can be treated further by Florenox (Below)

Solution	ppb	
	PFBA	PFOA
Initial	472	367
Permeate	<LOD	0.3
Concentrate	920	600



Treatment of PFNA from 88 ppm to 22 ppm with 5% methanol present

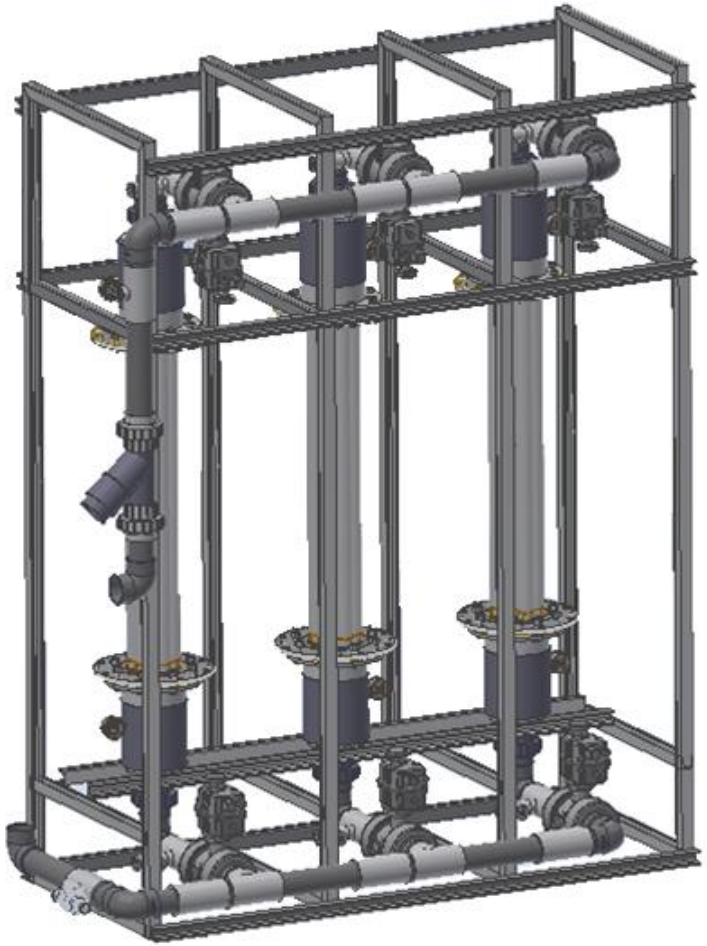
Arvia's PFAS Electrochemical Destruction Technology - Pilot

nyex florenox

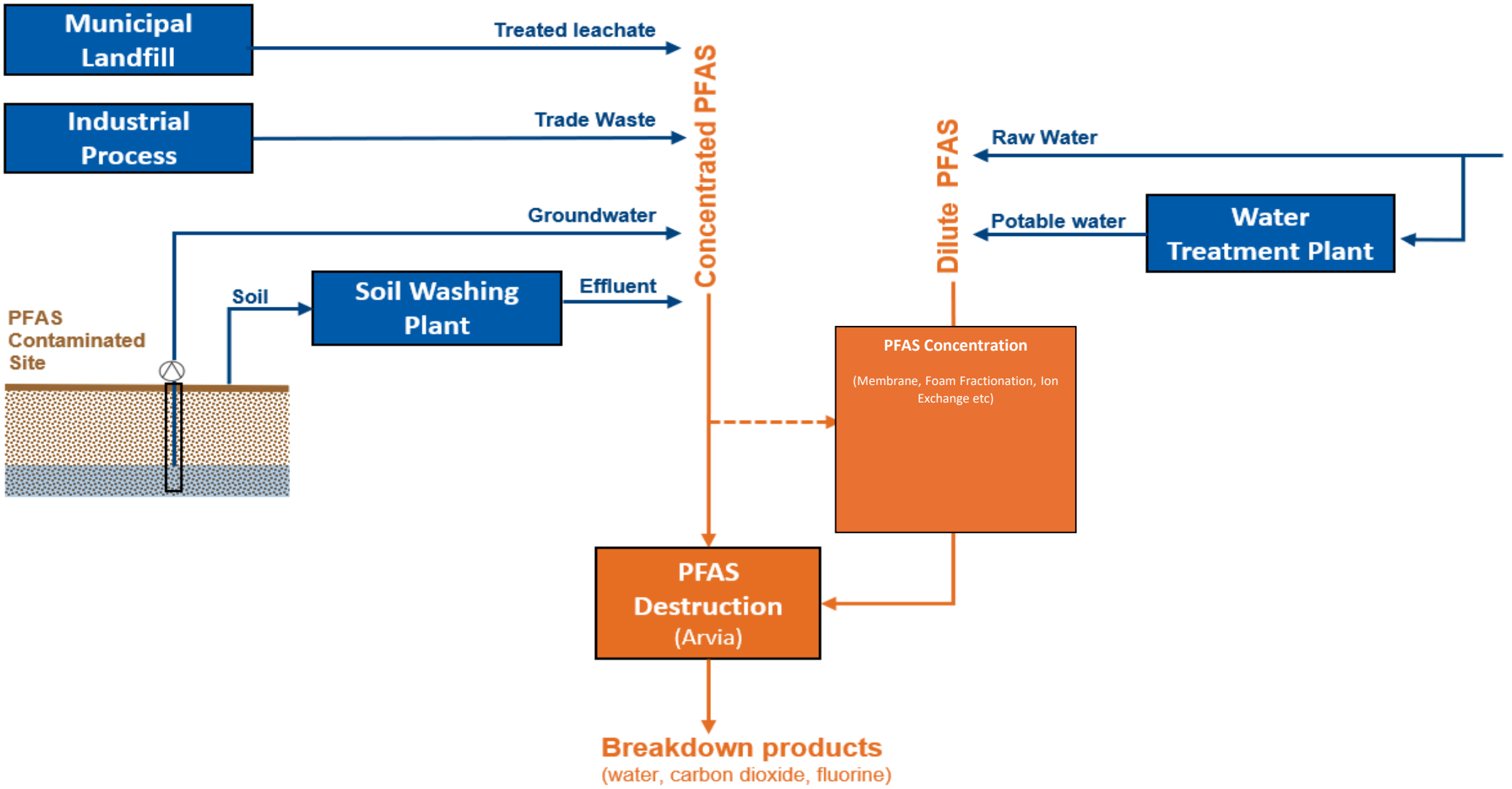
Challenge 4: Integrating Technologies for a Full Technical Solution

Arvia are currently exploring integration of Florenox™ pilot plant with concentration technologies:

- In-house combination of Florenox™ with RO that is tasked to meet the regulatory demand
- Collaboration with Molymem Ltd and the University of Manchester on Innovate UK funded project (CEAMS) on integration of Molymem's innovative membrane filtration technology with Florenox™
- Treatment of real wastes from separation technologies, such as foam fractionation, ion-exchange, adsorption media to assess suitability of their integration with Florenox™



PFAS Management Vision



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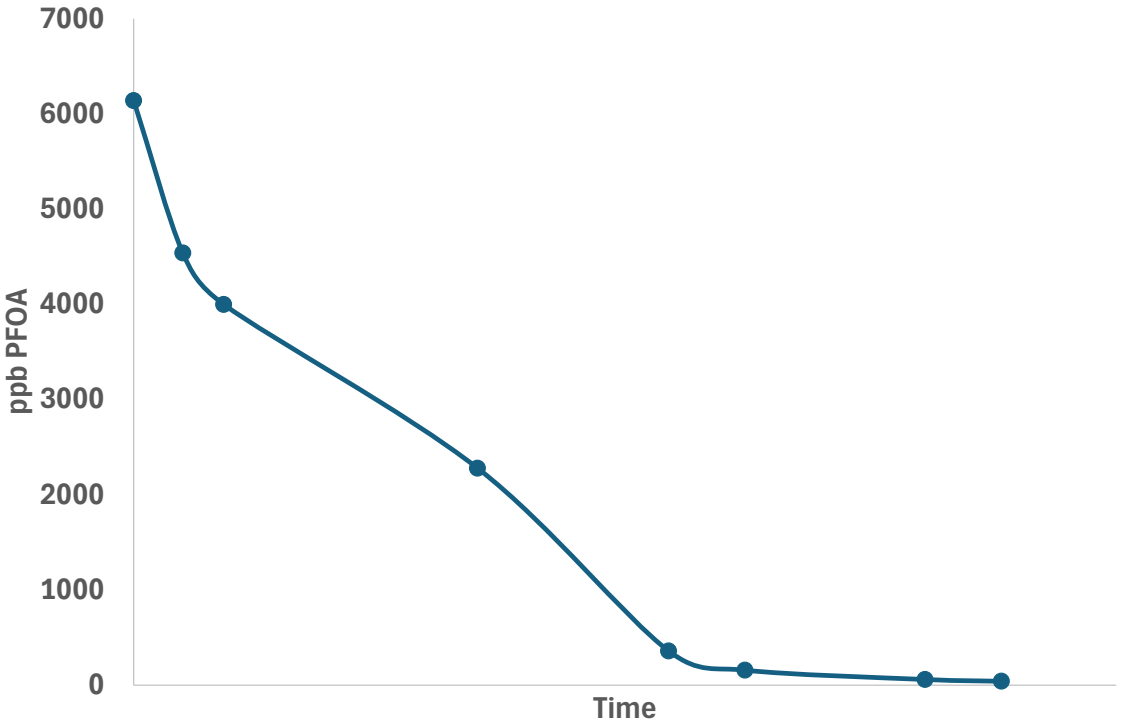
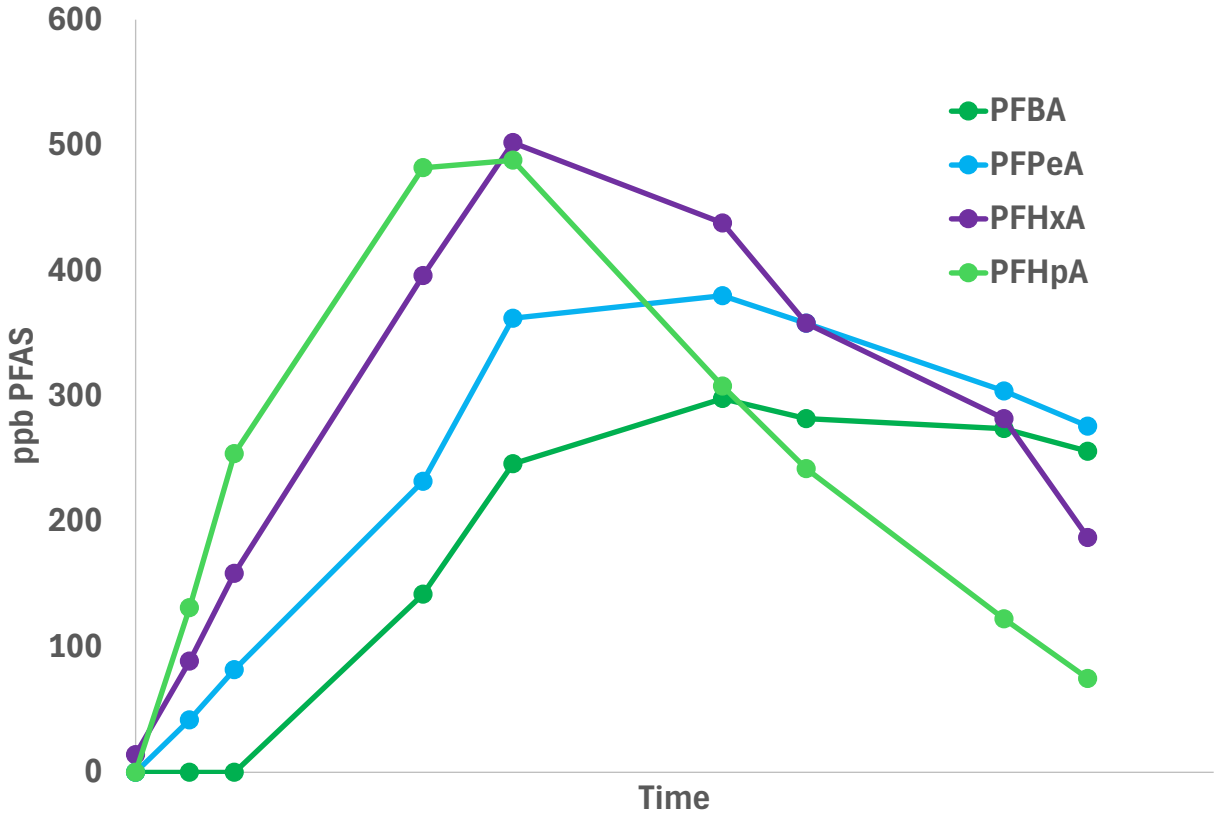
Case Studies

CEAMS Project – PFOA in the presence of NOM

99.3% PFOA removal, 86.2% PFAS removal. Shorter chains increase then decrease in order



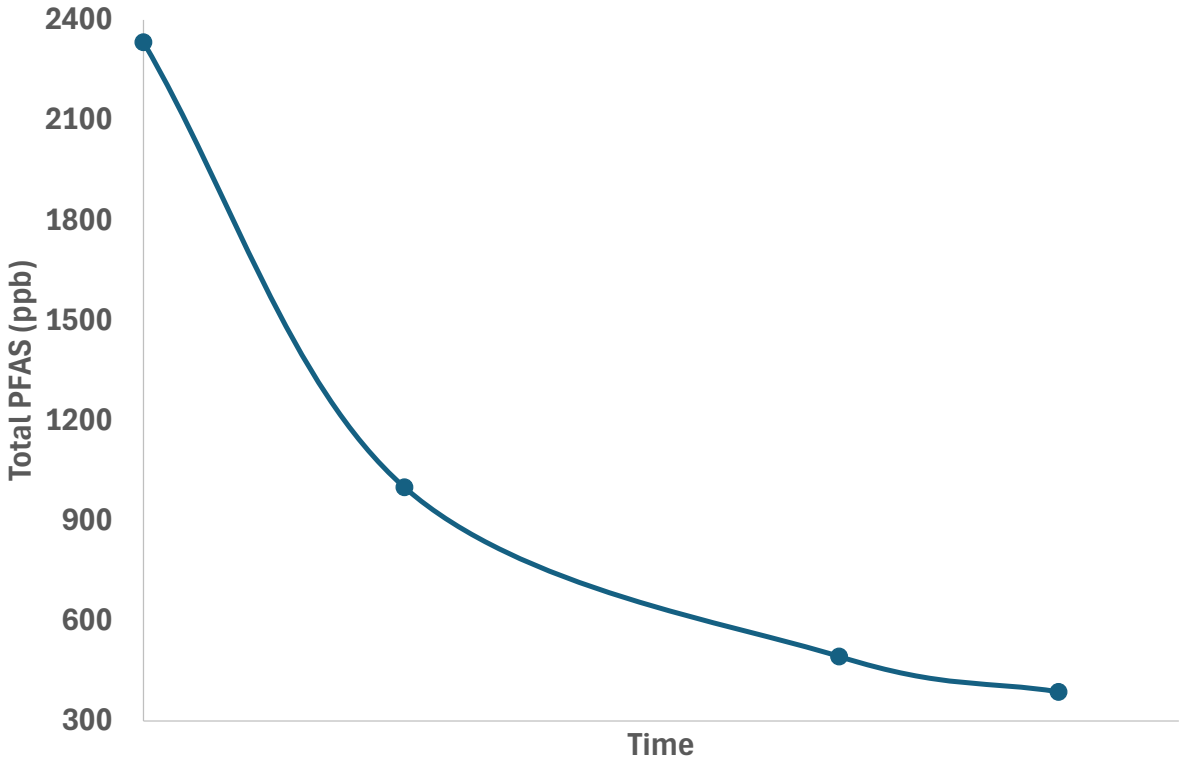


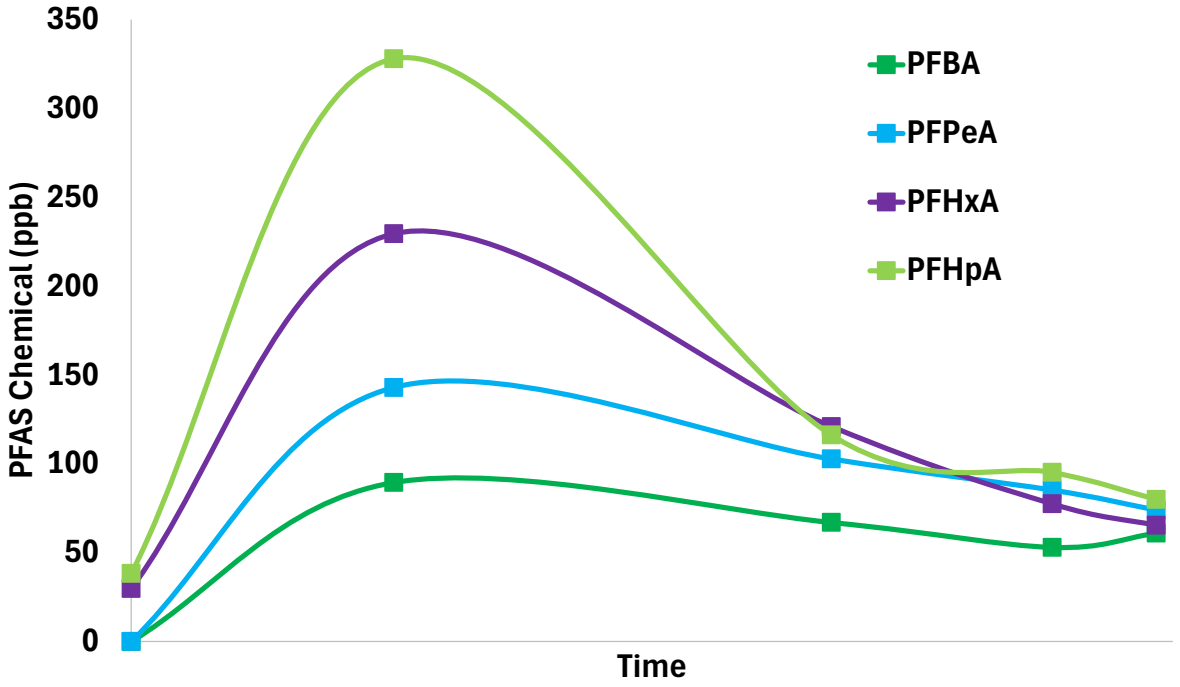
MOLYMEM
Clean Water & Air

MANCHESTER 1824
The University of Manchester

Release of Fire Fighting Foam at Airport

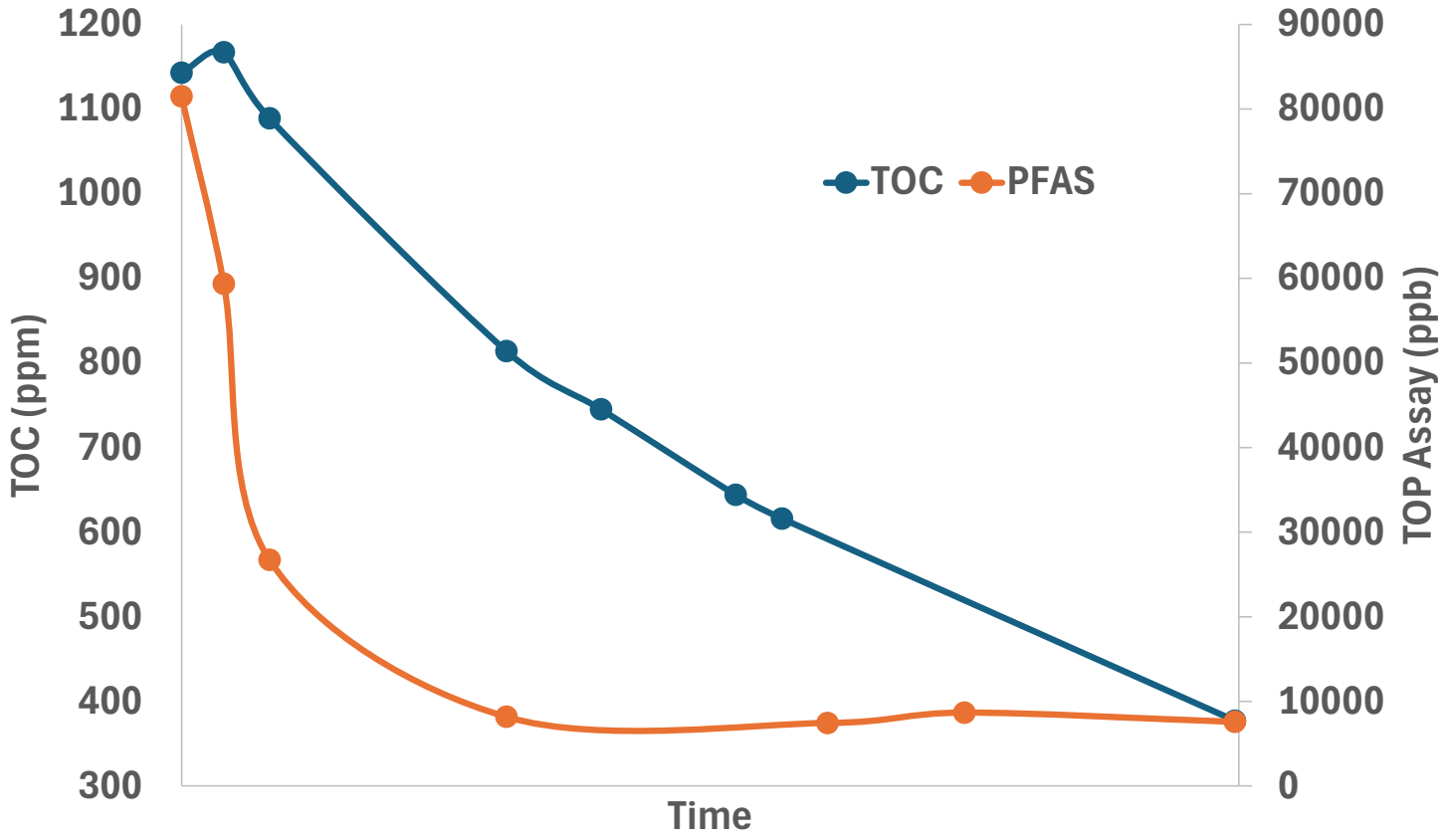
98.2% total PFAS removal by Total Oxidisable Precursor (TOP) assay





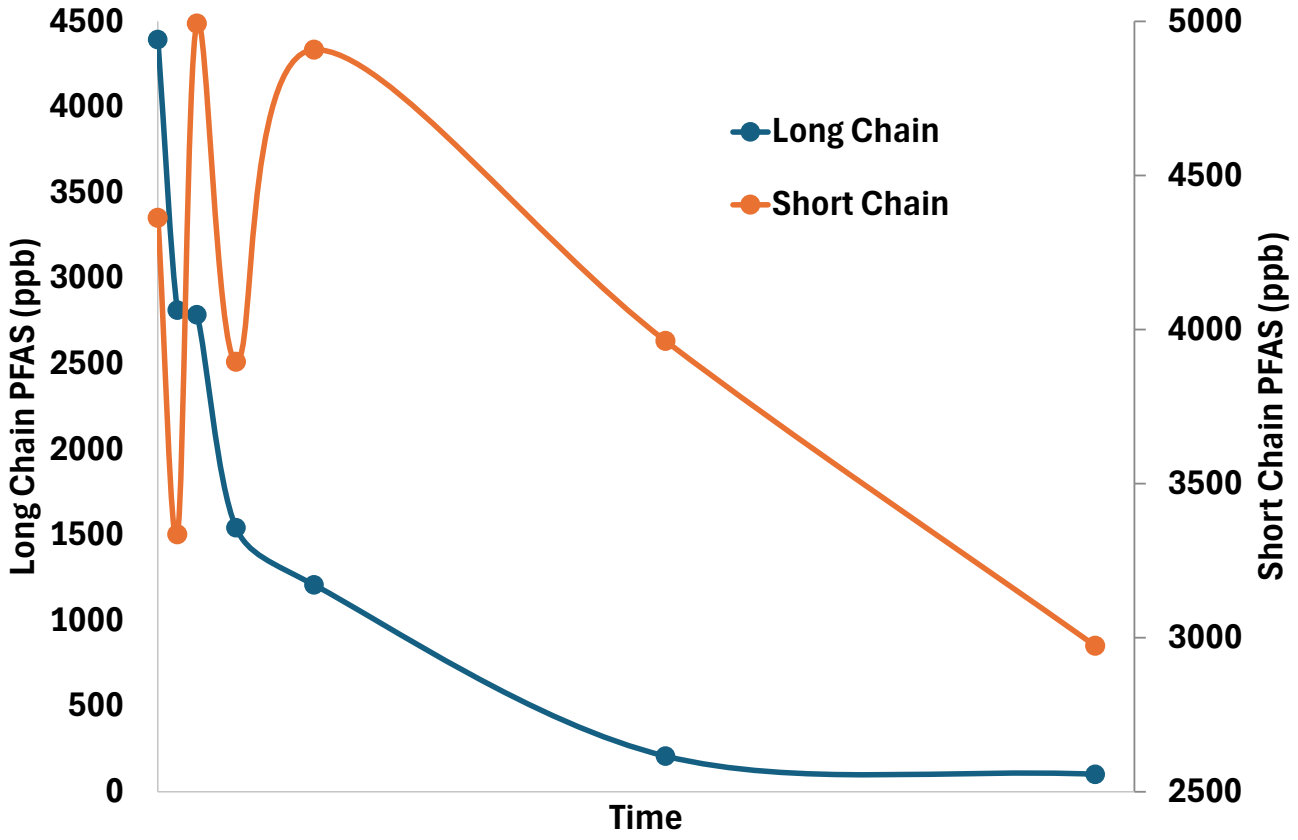
Release of Spent Fire Fighting Foam from Extinguishers

91% total PFAS removal (TOP assay) 67% TOC removal



Mixture of 8 PFAS

PFBA, PFBS, PFHxS, 6:2 FTS, PFOA, PFOS, PFNA, GenX
Short Chain: C4 to C6 Long Chain: C7 to C9
97.7% removal of long chain, 32% removal of short chain



Analytical Challenges

Arvia seeking a mass balance for the destruction process which presents an analytical challenge

- There are thousands of PFAS molecules, many of which are not analysed. TOP assay attempts to breakdown precursors into simpler molecules that can be quantified, but don't know if this captures all the variants. TOF analysis quantifies total organic fluorine, which should align with TOP assay
- Arvia can do TOP assay and have a method for 28 PFAS down to C4.
- Requirement to measure C2 and C3 compounds and any volatiles in off-gases
- Arvia happy to talk to companies to test real-time PFAS analytical kit to improve the time between treatment and results

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