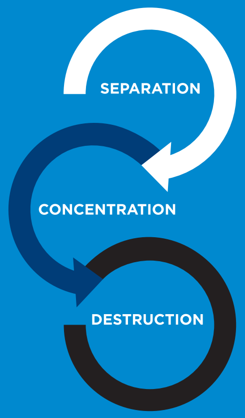


SAFF® Surface-Active Foam Fractionation

Sustainable Lead Treatment in a Multi-Stage Wastewater Treatment Plant

Presenting for David Burns (EPOC Enviro) is Dr. Kent Sorenson, Allonnia (US Distributor)

CASE STUDY FOCUS

Waste Water: Landfill Leachate, Telge Sweden.

- Supplied from Australia
- Remote Monitoring/Control + Field Control
- Installed Jan 2021
- Contract: $330m^3$/day
- Criteria: 50ng/l (PFOS)
- Performance: 200-500m^3/day (catchment vol. dependent)
- Rem. J. article (in-submission)

EPOC ENVIRO

SAFF® TECHNOLOGY EVOLUTION & UNDERSTANDING

1) Laboratory Bench-scale Technology comparison study (2015/2016).

2) Dedicated Treatability Lab (2016-Present), socializing R&D with desktop SAFF Loan Apparatus (5x sites).

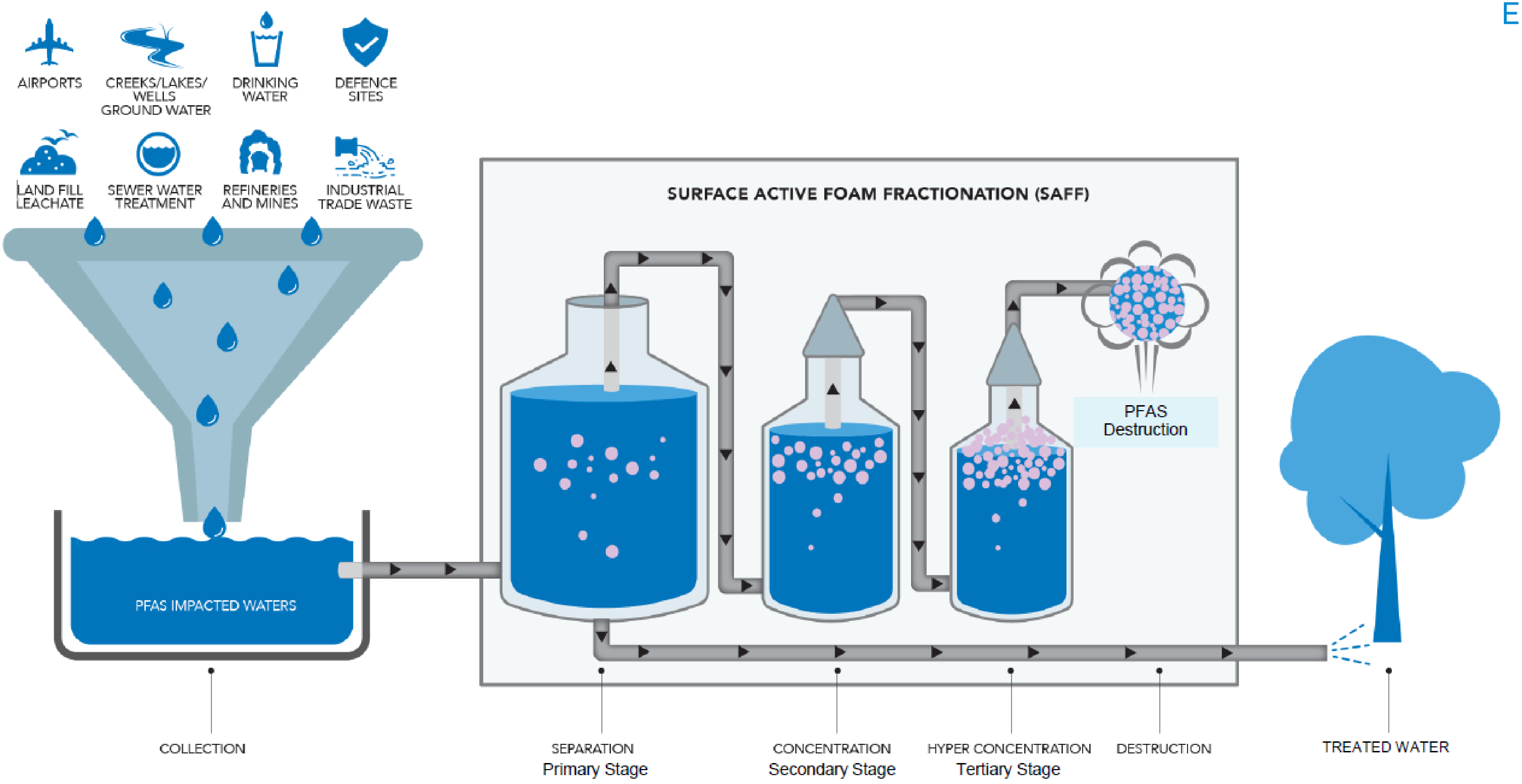
3) First SAFF40 ex-situ GW treatment field trial, Oakey Australia (2019).

4) Second SAFF40 ex-situ SW (leachate) field trial, Telge Sweden (Jan 2021).
    - Contractual Objective: remove PFOS <50ng/l (15ML landfill leachate catchment characterized by complex chemistry, excessive foaming and a much broader suite of PFAS compounds compared to the Oakey 3M Lightwater® suite.
    - Results: improved stripping recoveries for both long and short chain PFAS, most likely due to the non-PFAS amphiphilic substances also present in the leachate feed.

5) SAFF® waste foamate (super-concentrate) is suited for pairing with on-site waste destruction cells (e.g. CDM Smith's ECO®, AECOM's Defluoro®, Battelle's Annihilator®, etc.

6) <u>Eight</u> SAFF units in field trial + <u>Four</u> pre-delivery to further field prove US-ITRC Technology status.

HOW DOES IT WORK?



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SAFF40® CONTAINER

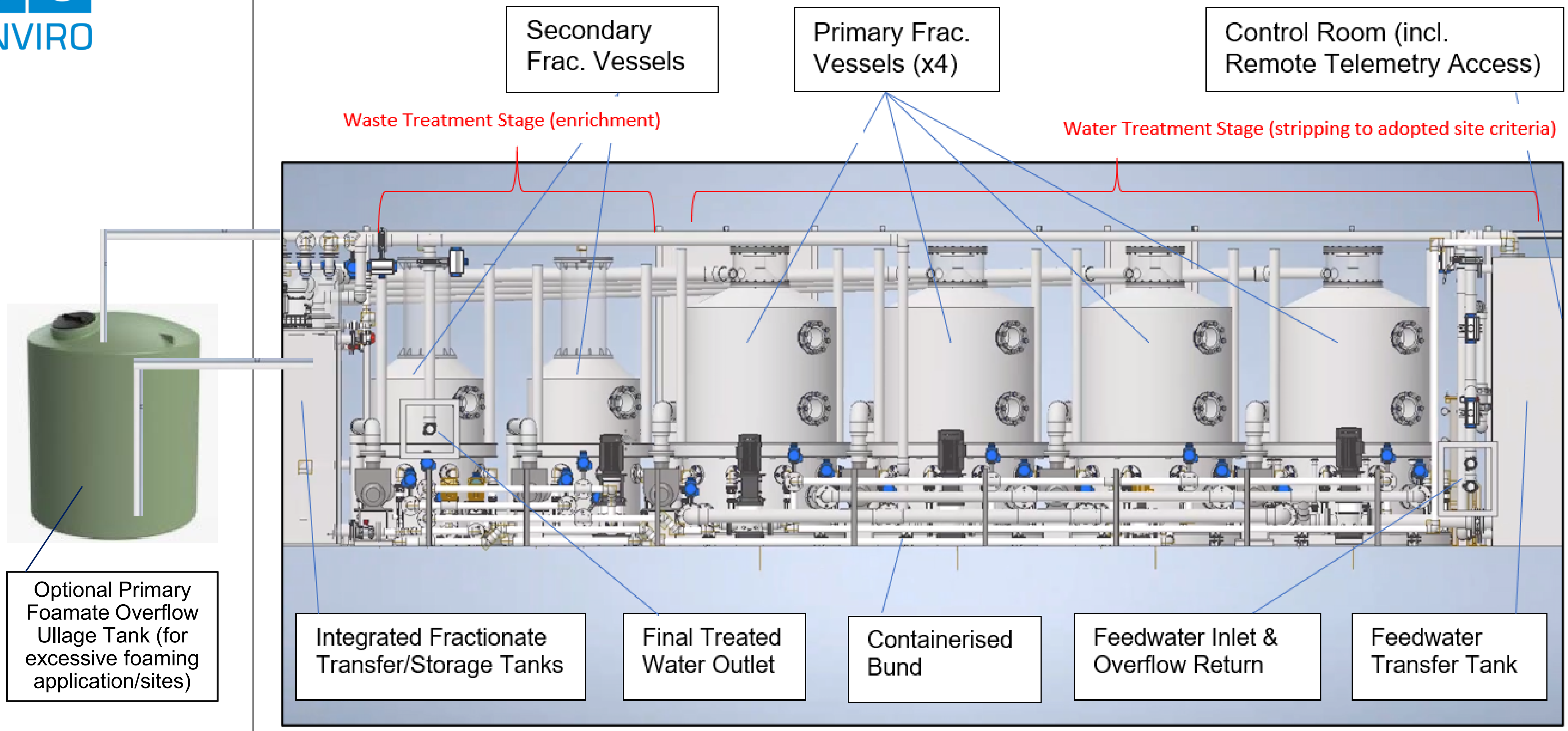
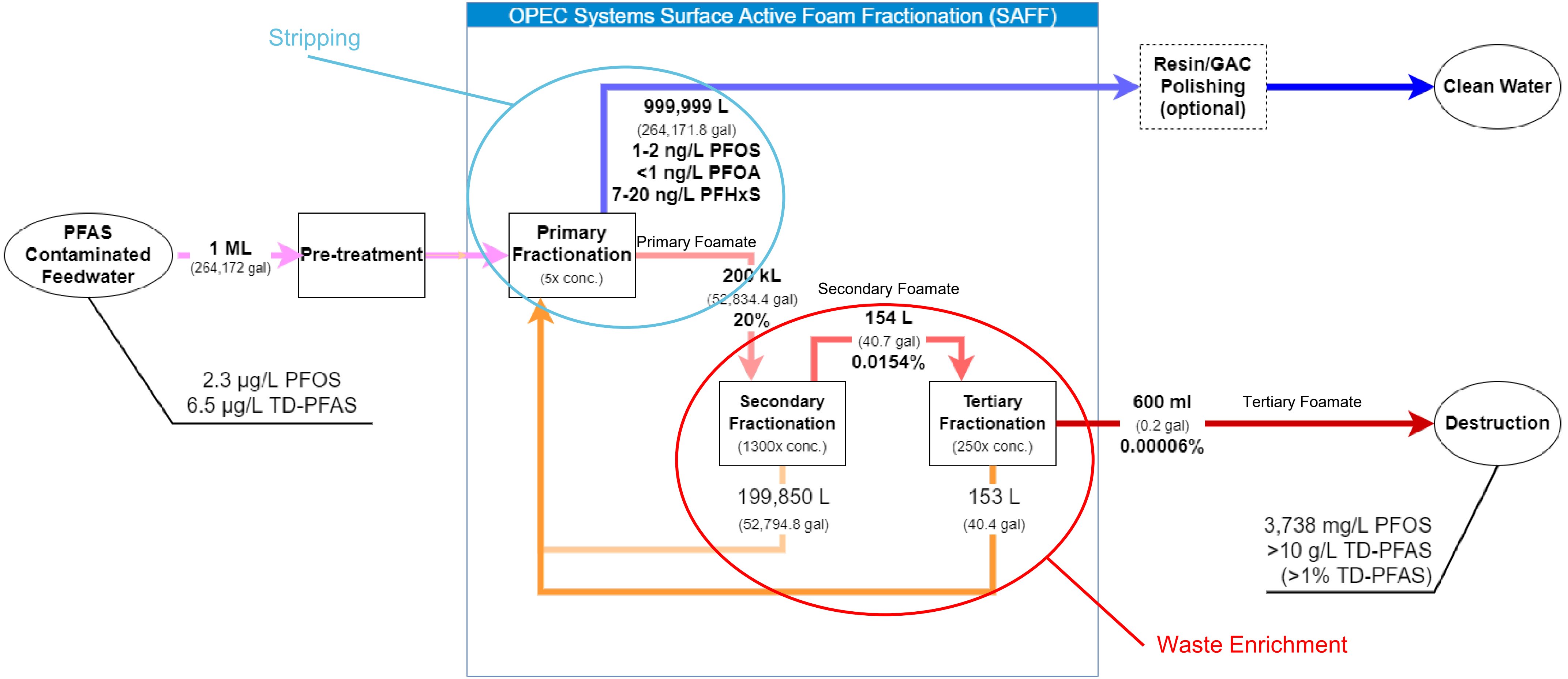


Figure-1: Schematic of containerised SAFF40™ system (elevation view showing key process stages).

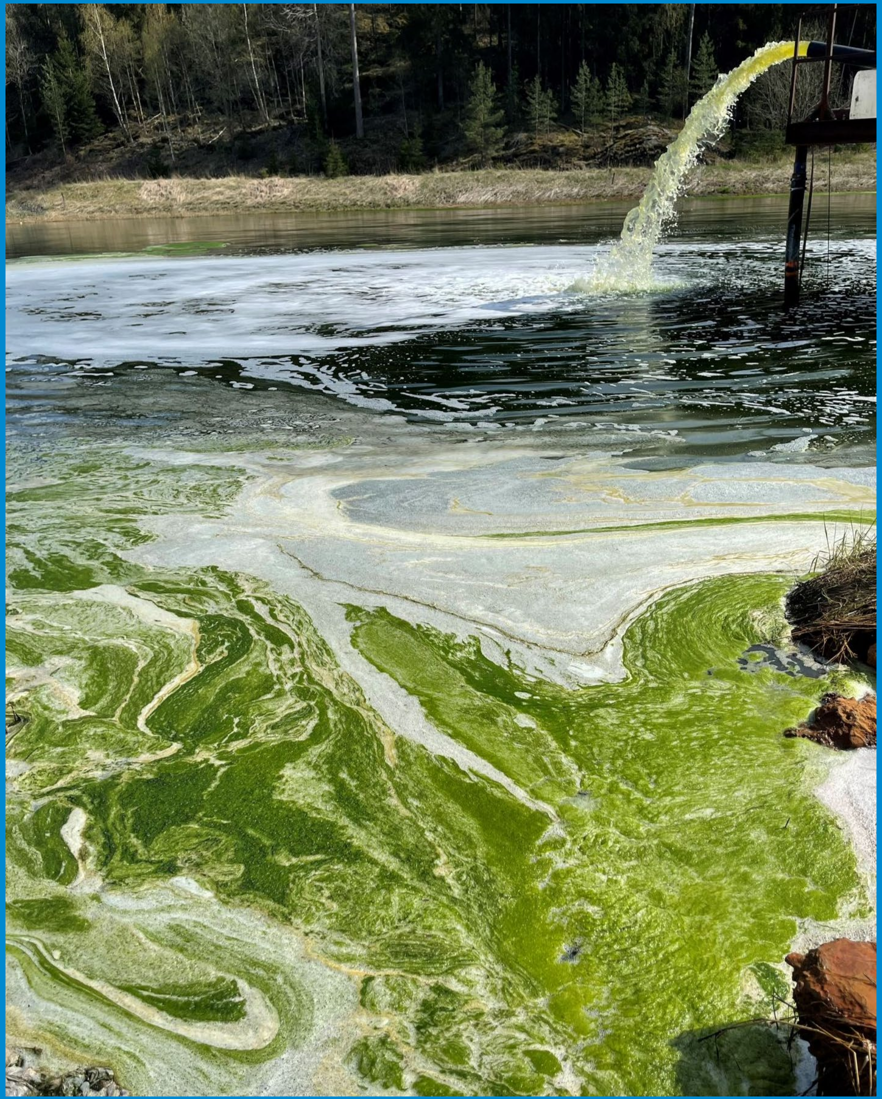
SAFF ® CONCENTRATION PROCESS



Based on data collected during field trial from Oakey plant (May 2019 - June 2020)

MODE OF TRANSPORTATION TO SITES (Winter Jan. 2021; Telge, Sweden)

EP
OC
ENVIRO



LEACHATE CATCHMENT (Spring 2021; Telge, Sweden)

Telge Leachate Data (in-submission with Rem. J.)

EPOC ENVIRO

PERFORMANCE DATA

- Water Treated as of 31st Oct. 2021: 72.5ML (US conversion 19MG), zero contractual failures.
- Enrichment/Concentration of final tertiary foamate (PFAS waste) estimated at 20,000x to 100,000x (pending further validation).

Table-1: SAFF40 Primary Fractionation/Stripping Results, 23x Sampling/testing Events, Jan. 2021 – Oct. 2021.

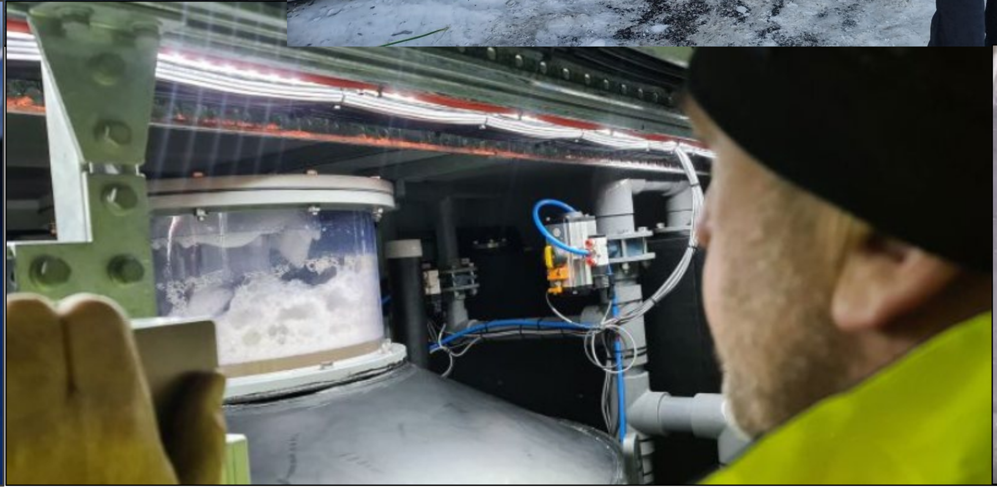
Swedish SLV-11 PFAS Suite				Removal Percentage Modelling (Oct. 2020)		Full Scale Treatment Results (Jan. to Oct. 2021)			
				① Predictability model [1]	② Bench Scale Testing [1,4]	Av. Feedwater Conc. [2]	Av. Treated Water Conc.		③ Treated Water Removal Percentage [4]
		Adsorption Isotherm Coefficient [7] (K_H m[x10^6])	C-chain	Aeration 21mins	Aeration 15-60mins	(ng/l)	(Site Adopted Criteria)	(ng/l)	Aeration 21mins
1.	PFDA	-	C10	100%	80% [5]	4.9	-	1.0	79% [7], 98% [6]
2.	PFNA	9.3	C9	100%	97% [5]	83	-	≤0.97	99% [7], 99.9% [6]
3.	6:2-FTS	-	C8	100%	73% [5]	41	-	≤0.95	100% [5]
4.	**PFOS**	**23**	**C8**	**98%**	**96-100% [4,5]**	**191**	50	**≤2.3**	**100% [4], ≥98.8% [6]**
5.	PFOA	2.3	C8	98%	98-100% [5]	586	-	≤1.3	99.8% [7], 99.9% [6]
6.	PFHpA	0.58	C7	85%	96-99% [5]	275	-	6.4	98% [7], 98% [6]
7.	PFHxS	0.97	C6	98%	98-99% [5]	97	-	<0.98	99.0% [7], 99.9% [6]
8.	PFHxA	0.22	C6	50%	36-77% [5]	541	-	329	39% [5]
9.	PFPeA	0.058	C5	<20%	7-20% [5]	531	-	493	7.1% [5]
10.	PFBS	0.18	C4	<5%	19-42% [5]	112	-	92	17% [5]
11.	PFBA	0.017	C4	<1%	6-18% [5]	317	-	318	Nil.
∑ Detectable PFAS (SLV-11)				-	-	2,770	90 [3]	1249	55% [5]

Table-1 Footnotes

(1) Desktop Audit means review of historical lab reports, Bench testing means experiments using lab apparatus and site water,
(2) Approx. 500m³ feedwater treated for commissioning phase, refer to site details overleaf,
(3) SLV-11 PFAS criteria (drinking water) not applicable to waste-water effluents, currently observed as a reference trend,
(4) Removal percentage (%R) is calculated by comparing treatment results to the Site Adopted Criteria (PFOS 50ng/l; REVAQ certification system),
(5) Removal percentage (%R) is calculated by comparing treatment results to the reported laboratory LOR,
(6) Removal percentage (%R) is calculated using the "liberal" data treatment process (where <LOR results are treated as being equal to zero),
(7) Removal percentage (%R) is calculated using the "conservative" data treatment process (where <LOR results are treated as being equal to 95% of the reported LOR), and
(8) Adsorption coefficient PFAS species in de-ionised water-air interface at pH7, Brusseau (2019).

- Primary Fractionate (foamate) was discharged back to the leachate catchment whilst validating, demonstrating PFAS stripping.
- Secondary & Tertiary Foamate returned to leachate catchment whilst validating, demonstrating process.

TREATMENT IMAGES FROM SWEDISH TELGE LANDFILL SITE


PERFORMANCE DATE : RATES OF REMOVAL

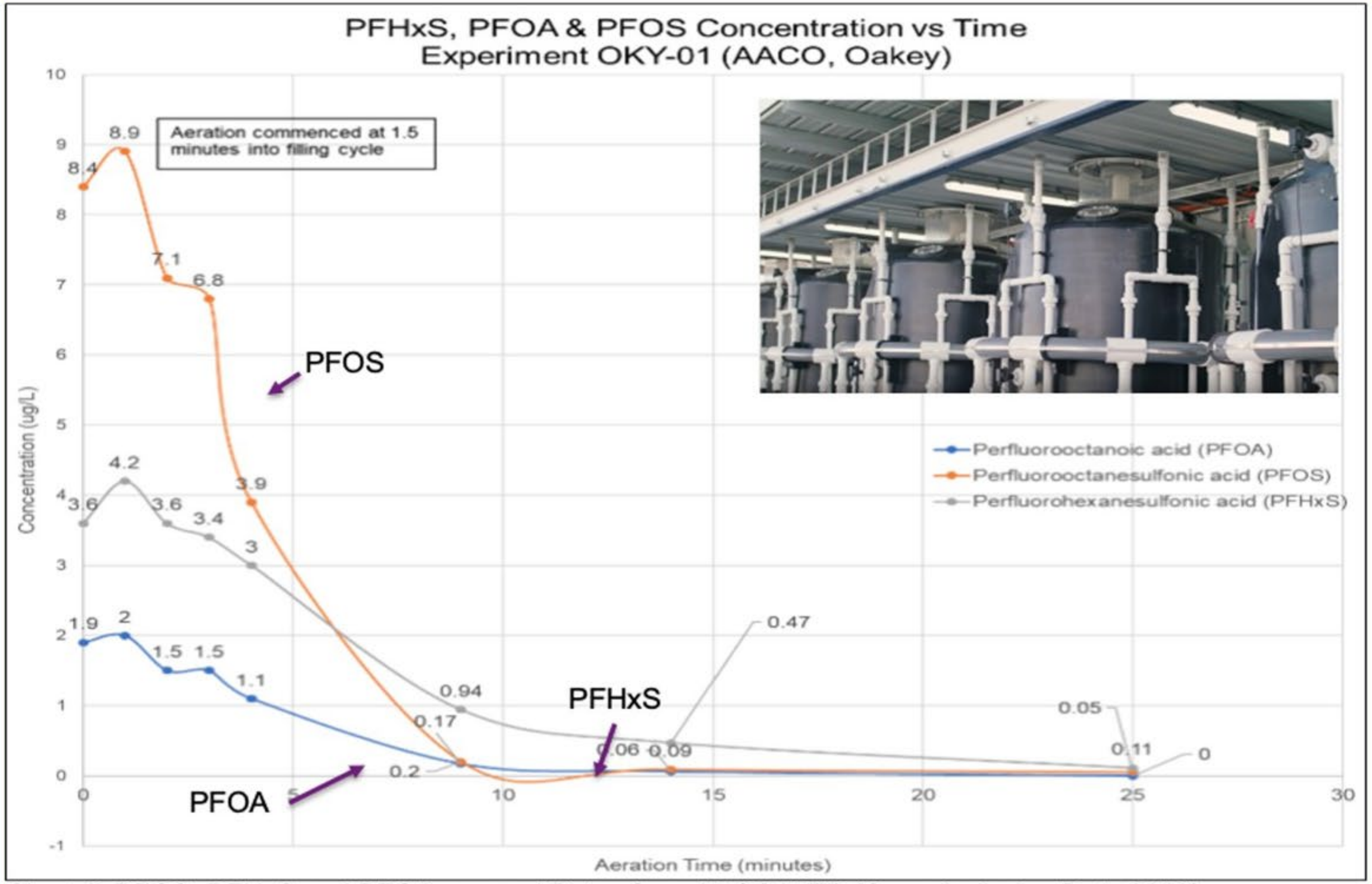


Chart-3: PFOS, PFHxS and PFOA removal Rates from AACO WTP (Commissioning Data 2019).

KEY POINTS

Stripping with water recirculation.

(1) PFOS: 10 mins
(2) PFOA: 12 mins
(3) PFHxS: 18 mins

OPEX (O&M) COSTS FOR TELGE LANDFILL LEACHATE SITE

EPOC ENVIRO

- Labour – USD $0.05/m^3 (treated)
- Consumables - ZERO
- Energy – USD $0.05/m^3 (treated)
- Waste – USD $0.02/m^3 (treated)

Total OPEX – USD $0.12/m^3 (treated)

AACO GW DATA (REM. J. SEPT. 2021)

EPOC ENVIRO

PERFORMANCE DATA

- Water Treated as of Feb 2022: 75ML (US conversion 20MG), zero contractual failures.
- Removed PFAS concentrated into 32L (provided to destruction cell developers under direction from Aust. Defence).

Table-1: AACO GW (QLD< Australia) SAFF40 Primary Fractionation/Stripping Results, Oct. 2019 to Oct. 2021.

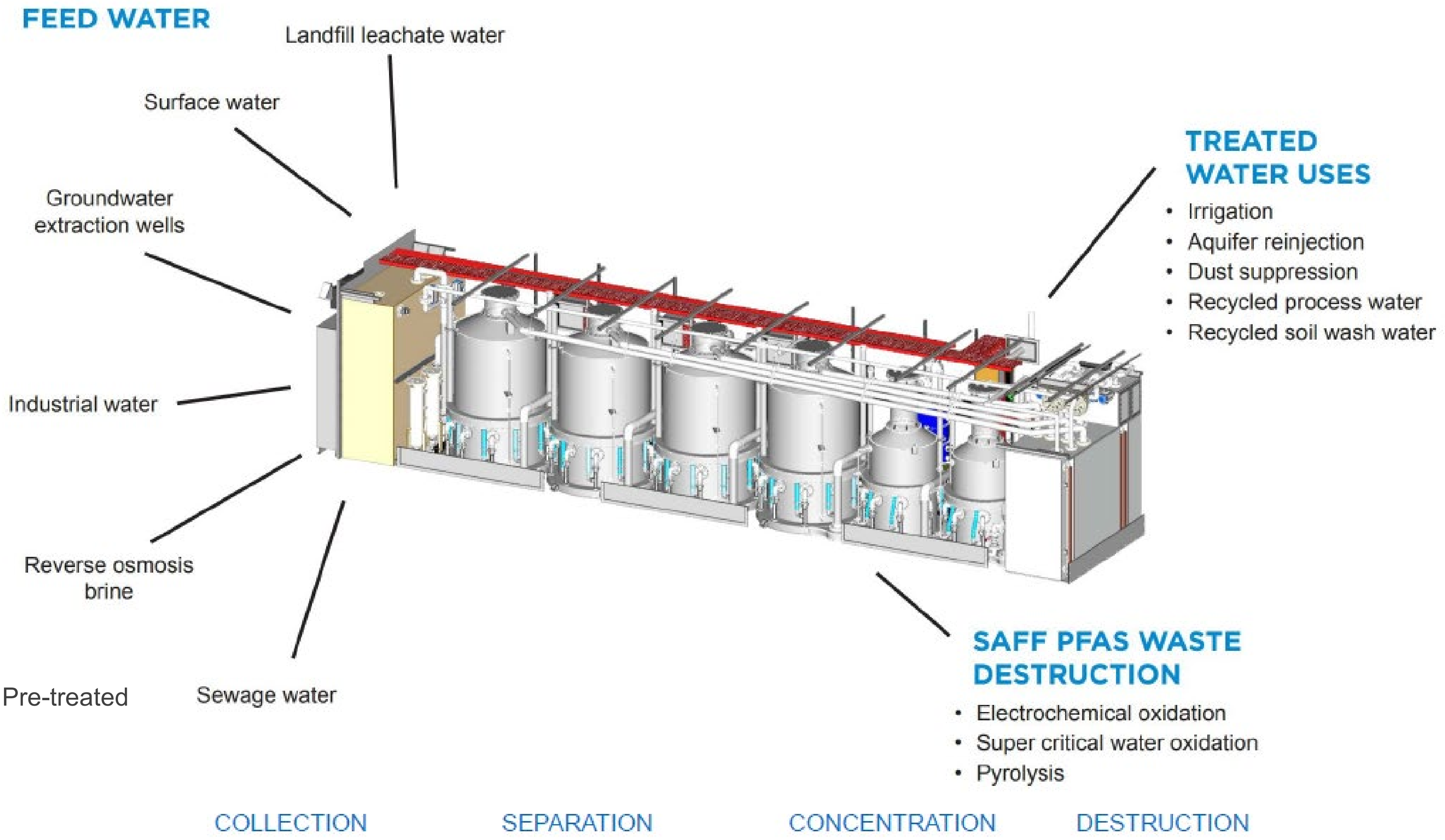
NEMP (2020) PFAS Suite				Removal Percentage Modelling		Full Scale Treatment (Twelve Month Average Performance)			
				① Predictability Model (1)	② Bench Scale Testing (1,4)	Feedwater Conc. (2)	Treated Water Results		③ Treated Water Removal Percentage (4)
Adsorption Isotherm (5) Coefficient (K_H m[x10^6])			C-chain	Aeration 21mins	Aeration 15-60mins	(ng/l)	(Site Criteria)	(ng/l)	Aeration 21mins
P1	PFOS	23	C8	98-99%	98% (4)	2,790	70	≤ 4	99.8% (4)
P2	PFOA	2.3	C8	98-99%	98% (4)	480	560	≤ 1	99.8% (4)
P3	PFHxS	0.97	C6	95-97%	97% (4)	1,030	70	≤ 17	98.4% (4)
P4	Combined PFOS + PFHxS			96-98%	97-98% (4)	3,810	70	≤ 11	99.1% (4)
1.	8:2-FTS	-	C10	100%	98% (4)	32	-	≤ 1	100% (4)
2.	PFDA	-	C10	100%	98% (4)	156	-	≤ 3	98.8% (4)
3.	PFNA	9.3	C9	100%	98% (4)	116	-	≤ 1	100% (4)
4.	6:2-FTS	-	C8	100%	98% (4)	100	-	≤ 6	100% (4)
5.	PFHpS	5.1	C7	95%	75% (4)	104	-	≤ 20	80.8% (4)
6.	PFHpA	0.58	C7	95%	70% (4)	367	-	68	81.5% (4)
7.	PFHxA	0.22	C6	<50%	51% (4)	755	-	402	46.7% (4)

Table-1 Footnotes

(1) Predictability modelling means a review of historical lab reports, Bench scale testing means experiments using lab apparatus and site water.
(2) Approx. 30,000m^3 feedwater treated, refer to site details overleaf.
(3) Australian & New Zealand Heads of EPA (HEPA) NEMP (2020) PFAS drinking water criteria adopted as site criteria for treatment purposes.
(4) Removal percentage (%R) is calculated by comparing treatment results to feed and trace lab LOR (1.0 *ng/l*), 6:2-FTS (5.0 *ng/l*).
(5) Adsorption coefficient PFAS species in de-ionised water-air interface at pH7, Brusseau (2019)

- Groundwater
- Concentration Factor (also known as waste Enrichment) not restricted by excessive foaming in feedwater nor secondary, tertiary foamate processing.

SAFF – VERSATILITY



PROJECTS

SAFF40 Commercial Scale Progress

- **SAFF40: Oakey, Australia**
  - Installed Dec 18
  - 70,000 m^3 treated
- **SAFF40-001: Telge (Sodertelje), Sweden**
  - Arrived Feb 2021
  - 72.5m^3 treated
  - No pre-treatment except bag filters
- **SAFF40-002: Malmo Sweden**
  - Arrived 2 August, 2021
  - 2,000, m^3 treated
  - No pre-treatment except bag filters
- **SAFF40-003: CDM Smith, USA**
  - Arrived 31 August, 2021
  - Commissioned Sep, 2021
- **SAFF20-001 – Arlanda, Sweden**
  - Arrives 31 November, 2021
- **SAFF20-002 – California, USA**
  - Arrives 31 February, 2022

Oakey, Australia

Gothenburg, Sweden

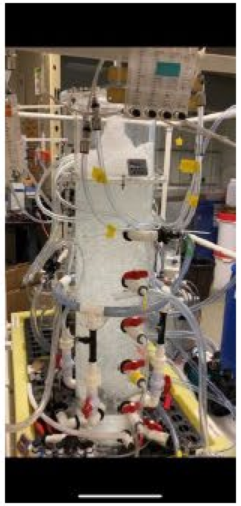
CDM Smith East Coast, USA

Sodertelje, Sweden

RESEARCH

SAFF Sponsored Research

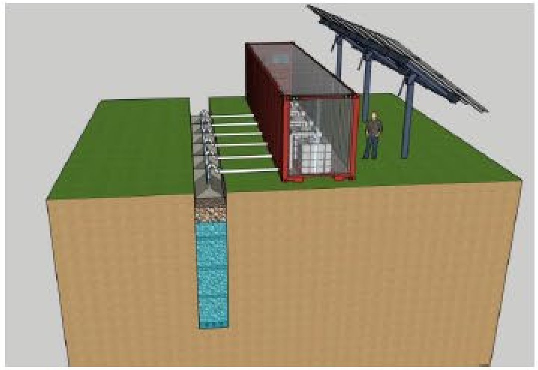
- **ARC Grant – Soil Liqui-Fractionation**
  - PFAS impacted soil treatment for surface soils
  - $900k (+$160k from OPEC), 3 years
  - MQU and UNSW, Commenced 2020
- **ESTCP (USA) – In trench fractionation**
  - Funnel and gate approach to PFAS impacted groundwater treatment
  - US$1.4M, 2 years, Commences Sep 2021
- **Horizon 2020 (EU) – PFAS Remediation (SCENARIOS)**
  - PFAS remediation study with SAFF20
  - €1.45M – 2 year large scale field trials
  - Sites in Spain and Sweden, Commences 2022
- **Horizon 2020 (EU) – PFAS Remediation (LIFE SOURCE)**
  - PFAS remediation study with SAFF20
  - €1.05M – 2 year large scale field trials
  - Sites in Germany and Italy, Commences 2022
- **Ramboll Norway – AFFF Manufacturing Site**
  - PFAS in soil lab and field trials
  - €200,000 – 3 month lab/field trial
  - Bergen, Norway, Commenced May 2021



SAFF Water testing, USA

Soil Washing, Sweden

Soil Washing, Norway

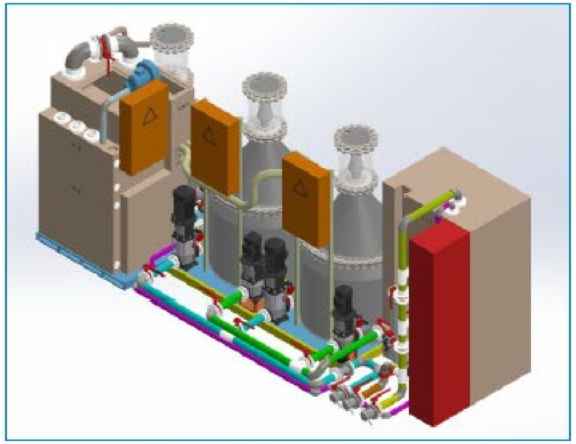


Trench Based Downhole Foam Fractionation, USA

SAFF Internal Research

- **PFAS in Raw Sewerage Water Treatment**
  - Boydel Waterminer/OPEC SAFF Combination
- **SAFF40 for US trials: PFAS from soil and water**
  - 50% funded trials on 4 x US Defence Bases
  - US$300k, 1 year
- **SAFF40 for Swedish Trials: PFAS from Leachate**
  - 50% funded trial on Sodertelje Landfill Leachate
  - US$300k, 3 year
- **High Performance SAFF Trials**
  - 100% OPEC funded trials
  - 20 times better performance (Primary CF from 10 to 200x)
  - PFAS removal with ultra low PFAS contamination (single PPT)
- **HP SAFF Alternative Applications**
  - Removal of micro-plastics, pharmaceuticals and various other surface active compounds
  - Drinking water and trade waste discharge
- **Foam deluge and appliance washdown**
  - Combined with PFAScrub solvent to polish fire fighting appliances
  - SAFF allows reclamation and recycling of solvent

PFAS in Raw Sewerage:
Electro-coagulation + SAFF



SAFF20 Research Unit

UPCOMING WEBINAR – APRIL 12TH 2022

SESSION 1 : AUSTRALIA
12PM AWST / 2PM AEST

SESSION 2 : EUROPE
10AM UTC / 11AM BST / 12PM CEST

SESSION 3 : NORTH AMERICA
12PM PDT / 3PM EDT

Register now at epocenviro.com

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David Burns: dburns@epocenviro.com

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