

Presentation of Sustainable PFAS treatment technologies

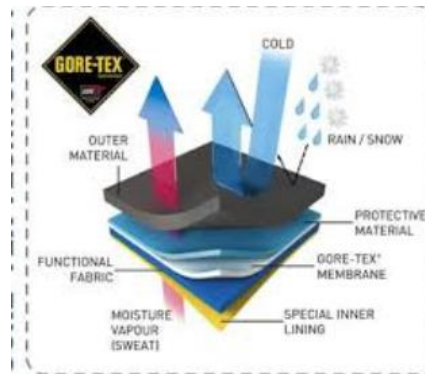
SAFF – Surface Active Foam Fractionation

Helena Hinrichsen, Founder och Head of R&D
Envytech Solutions AB

Talk Layout

- What is PFAS, and why it is a FAST !! growing issue in Leachates
- Short summary of available PFAS water treatment technologies and their challenges
- Presentation SAFF- Surface Active Foam Fractionation – The first sustainable and suitable treatment method for complex waters and leachates
 - SHORT History
 - Results from full scale projects and Pilots
 - How it works and why
 - Summary of abilities and cost – Yes it is true! We will tell you the operational costs !

PFAS – Per- and Polyfluoroalkyl Substances - Forever chemicals



PFAS in leachates and waste

- As many products, plastic, metal textile and (what else) contain PFAS, it leaches into our environment from landfills and waste storages
- A mix of substances from short chains to long chains
- Landfills and waste storage facilities becomes point sources
 - ➔ Leads to the creation of complimentary contamination source zones
 - ➔ Leachate pass treatment systems not designed for PFAS
 - ➔ Contaminates groundwater and surface waters, and many more environmental impacts

Leachate treatment soon a must in Sweden, Denmark and US.

PFAS Treatment technologies - Water

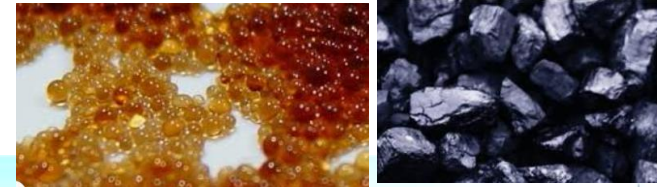
Adsorption

- Activated Carbon
- Ion exchange mass



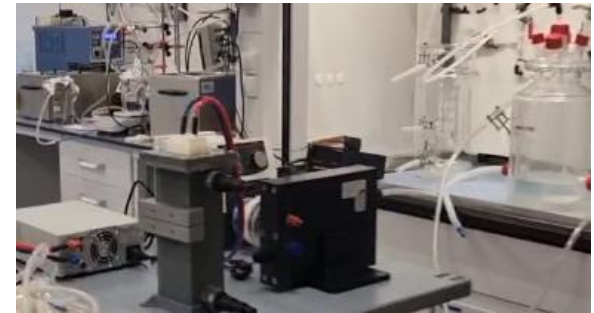
Concentration

- SAFF – Surface Active Foam Fractionation



Destruction

- Electrochemical Oxidation
- SCWO – super critical water oxidation
- Thermal destruction
- Sub-critical destruction



Envytech Solutions – Adsorption tech pre-treatments

Filter medias are sensitive for:
particles, pH, conductivity
cross-contaminants, other water chemistry , ex
BOD, DOC, COD TOC

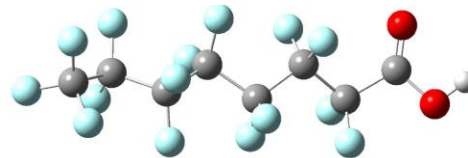
YES! 99,9% removal etc.
But To what cost – All and all

- Cost for rental / buy of pre treatment tech, vessels
- Cost of running plants
- Chemicals for flocculation/precipitation
- Pre-filter medias
- Filter medias
- Service for pre treatment, backflushing etc
- Service for filtermedias exchange
- Cost for sludge handling system
- Cost of transport and deposition of sludge, WHERE?
- Cost of waste from used pre filter, incl Transport and deposition, WHERE?
- Cost of waste used filters, incl. Transport and deposition, WHERE?



SAFF – Surface Active Foam Fractionation

The Heavy Lifter in PFAS water treatment



SAFF – Surface Active Foam Fractionation

Developed by OPEC systems
Australia as a result of a grant from
Australian Defence

First full scale plant commissioned in
May 2019 in Oakey, Australia

Envytech <3 OPEC September 2019

First full scale mobile unit
commissioned in Sweden February
2021

Chosen technology for EU grants
Horizon2020 as well as EU LIFE
To evaluate leachate treatment and
other complex waters



SAFF™
Surface Active Foam Fractionation

'AIR IN – PFAS OUT'

Sustainable Lead Treatment –
in a Multi-stage WTP (PFAS)



envytech
Miljö & teknik



SCENARIOS Project EU

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SAFF – Surface Active Foam Fractionation

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allonnia



**Exclusive Distributor Scandinavia / Europe
UK – in partnership with Cornelsen**



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It started in Australia – Oakey Military Base

- Military Base
- Fire fighting Foam usage
- First SAFF for PFAS in the world
- 3 year since start
- > 80 000 m³ treated
- Now becoming head treatment option for Australian Defence
- For PFAS water treatment

		*** Aust. Defence Approval to Share ***				
		OPEC Systems; AACO Defence Base (Army Aviation Centre)				
		GW (including ad-hoc site civil SW additions), Alluvial Site				
		Full-scale Remediation				
		Rem. J Paper in-submission (Sep 2021)				
		SAFF40-3YR FT (Commissioned May 2019)				
		12Mth Av. Data (collected weekly Oct 2020 - Oct 2021)				
		Aeration				
		Venturi: 21mins				
		Treatment Vol: 100-250m ³ /day (max. 500m ³ /day)				
Brusseau et.al. 2021						
Adsorption Coefficient (K _H) m[x10 ⁻⁶]	C-Chain	PFAS Species	Feed Water Conc (ug/l)	Treatment Results T ₂₁ (ug/l)	% Removal	
0,017	C4	PFBA	0,224	0,142	36.6%	
0,18	C4	PFBS	0,18	0,092	48.9%	
0,058	C5	PFPeA	0,594	0,362	39.1%	
-	C5	PFPeS	0,168	0,079	53%	
0,22	C6	PFHxA	0,755	0,402	47%	
0,97	C6	PFHxS	1,026	<0.017	98,4%	
0,58	C7	PFHpA	0,367	0,068	81%	
5,1	C7	PFHpS	0,117	≤0.001	100%	
2,3	C8	PFOA	0,475	<0.001	100%	
23	C8	PFOS	2,786	<0.004	100%	
-	C8	6:2-FTS	0,10	<0.006	100%	

Telge Återvinning – Results

Some results over a 16 month period

>150 000 m3 treated

Flow rate: 20 m3/h

Waste: ca 1-2 m3/ 40 000 m3 treated

Ämne	Removal rate % Telge SAFF40 18 min	Removal rate % Telge SAFF40 18 min	Removal rate % Telge SAFF40 18 min	Removal rate % Telge SAFF40 18 min	Removal rate % Telge SAFF40 18 min	Removal rate % Telge SAFF40 18 min	Average Removal Rate >80 000 m3
	2021-02-27	2021-03-20	2021-05-28	2021-07-02	2021-08-20	2021-09-25	
PFHxS (Perfluorhexansulfonsyra)	99%	100%	100%	100%	100%	100%	100%
PFNA (Perfluornonansyra)	98%	100%	100%	100%	100%	100%	100%
PFOA (Perfluoroktansyra)	100%	100%	100%	100%	100%	100%	100%
6:2 FTS (Fluortelomer sulfonat)	98%	100%	100%	100%	100%	100%	100%
PFOS (Perfluoroktansulfonsyra)	99%	100%	99%	98%	97%	99%	99%
PFDA (Perfluordekansyra)	58%	100%	100%	100%	100%	100%	93%
PFHpA (Perfluorheptansyra)	100%	100%	99%	99%	97%	99%	99%
PFHxA (Perfluorhexansyra)	69%	91%	39%	44%	19%	38%	50%
PFBS (Perfluorbutansulfonsyra)	43%	87%	6%	18%	0%	18%	29%
PFPeA (Perfluorpentansyra)	22%	60%	0%	0%	16%	0%	16%
PFBA (Perfluorbutansyra)	0%	0%	0%	0%	0%	3%	1%

Welcome to Telge Återvinning



Telge Återvinning – Site specifics

And we do have VERY MUCH! algae and zooflagellates in our water



miniSAFF – Bench scale testing unit



miniSAFF – Bench scale testing unit

IVL test for Avfall Sverige Rapport 2021:02
Foam Fractionation (leachate and municipal waste water)

Leachate from 5 landfills tested by IVL and Envytech

Ämne	Antal kolatomer	OPEC Prediction model GW (full scale)	IVL/Envytech tests with leachate	Half life in Human body (years)
PFDA (Perfluordekansyra)	C10	100%	100%	5,6
PFNA (Perfluornonansyra)	C9	100%	100%	2,8
6:2 FTS (Fluortelomer sulfonat)	C8	100%	100%	0,08
PFOA (Perfluoroktansyra)	C8	100%	100%	3,3
PFOS (Perfluoroktansulfonsyra)	C8	100%	100%	5,7
PFHpA (Perfluorheptansyra)	C7	80%	80%	0,44
PFHxS (Perfluorhexansulfonsyra)	C6	99%	99%	9,9
PFHxA (Perfluorhexansyra)	C6	20-30%	30%	0,06
PFPeA (Perfluorpentansyra)	C5	25-35%	20%	0,1
PFBA (Perfluorbutansyra)	C4	20-20%	10%	0,009
PFBS (Perfluorbutansulfonsyra)	C4	30-40%	30%	0,107
Summa PFAS		30-70%		

Rapport 2021:02

Avfall Sveriges Utvecklingssatsning
ISSN 1103-4092

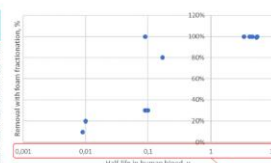
RENING AV PFAS-FÖROENAT VATTEN FRÅN AVFALLS-ANLÄGGNINGAR

Foam fractionation (leachate and municipal wastewater)

- Leachate from 5 landfills tested by IVL and Envytech in cooperation with OPEC Systems using bench-scale unit



Grundämne/ OPEC Systemet (full scale)	IVL/Envytech testar med leachate	Half-life in human blood, y	
PFOS	30-40%	30%	0,1
PFHxS	99%	99%	5,4
PFOS	100%	100%	4,2
PFBA	20-30%	10%	0,009
PFHxA	25-35%	20%	0,08
PFHpA	80%	80%	0,17
PFHxA	20-30%	30%	0,09
PFBA	100%	100%	5,5
PFNA	100%	100%	3,4
PFDA	100%	100%	4,6
6:2 FTS	100%	100%	0,08
PFAS11	30-70%		



Removes the potentially most toxic PFAS
Potentially extremely competitive option for waters with high DOC
Volume reduction factor needs to be confirmed for "dirty" water

IVL | PFAS REMOVAL METHODS

Source: OPEC Systems with more: <https://www.opecsystems.com/report20200404000000>

Malmqvist A., Lindqvist K., Skerfving P., 19/12/2020: Testing on foam fractionation for PFAS removal from leachate from landfills. IVL och Avfall Sverige rapport. Measurements, expected to be finalized by June 2020.



NSR Landfill – Results

Project period : september 2021-february 2022

Total volume treated: 27 000 m³

Flow rate: 18 m³/h

Waste: 220 l / 27 000 m³ treated

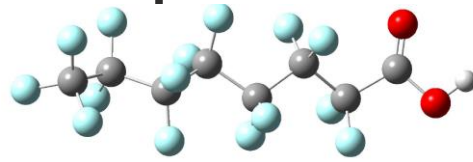
		Inlet	Outlet	Removal rate	Inlet	Outlet	Removal rate	Inlet	Outlet	Removal rate
Ämne	Enhet	2021-09-17	2021-09-17	2021-09-17	2021-10-15	2021-10-15	2021-10-15	2021-10-22	2021-10-22	2021-10-22
PFDA (Perfluordekansyra)	ng/l	11	<1,0	100%	19	<1,0	100%	8	<1,0	100%
PFNA (Perfluornonansyra)	ng/l	31	<1,0	100%	30	<1,0	100%	21	<1,0	100%
PFOS (Perfluoroktansulfonsyra)	ng/l	240	5,5	98%	230	3,4	99%	120	2,6	98%
PFOA (Perfluoroktansyra)	ng/l	330	4,3	99%	560	7,3	99%	490	3,8	99%
6:2 FTS (Fluortelomer sulfonat)	ng/l	870	32	96%	880	22	98%	830	10	99%
PFHpA (Perfluorheptansyra)	ng/l	280	110	61%	1000	79	92%	740	50	93%
PFHxS (Perfluorhexansulfonsyra)	ng/l	130	3,1	98%	200	3,3	98%	140	1,8	99%
PFHxA (Perfluorhexansyra)	ng/l	600	570	5%	640	620	3%	590	420	29%
PFPeA (Perfluorpentansyra)	ng/l	690	650	6%	660	740	0%	530	630	0%
PFBS (Perfluorbutansulfonsyra)	ng/l	140	130	7%	140	140	0%	120	99	18%
PFBA (Perfluorbutansyra)	ng/l	470	440	6%	310	310	0%	340	400	0%
Summa PFAS SLV 11	ng/l	3800	1900	50%	4700	1900	60%	3900	1600	59%

SAFF – Surface Active Foam Fractionation

How it works and why



PFAS – Quick repeat of the nature of PFAS molecules



Perfluorinated substances has:

Hydrophilic head – Head loves water

Hydrophobic tail – Tail hates water

- The bubble becomes the perfect environment
 - C6 PFAS and above – tail sticks in the bubble, easy to remove
 - More scientific wording: Langmuir constant $> 1 \times 10^{-6}$ can be caught



- Som C6 and shorter chains ($< 1 \times 10^{-6}$) do get caught but get released before getting collected – becomes top section swimmers

Mobile treatment, winter isolated

”Plug and play”

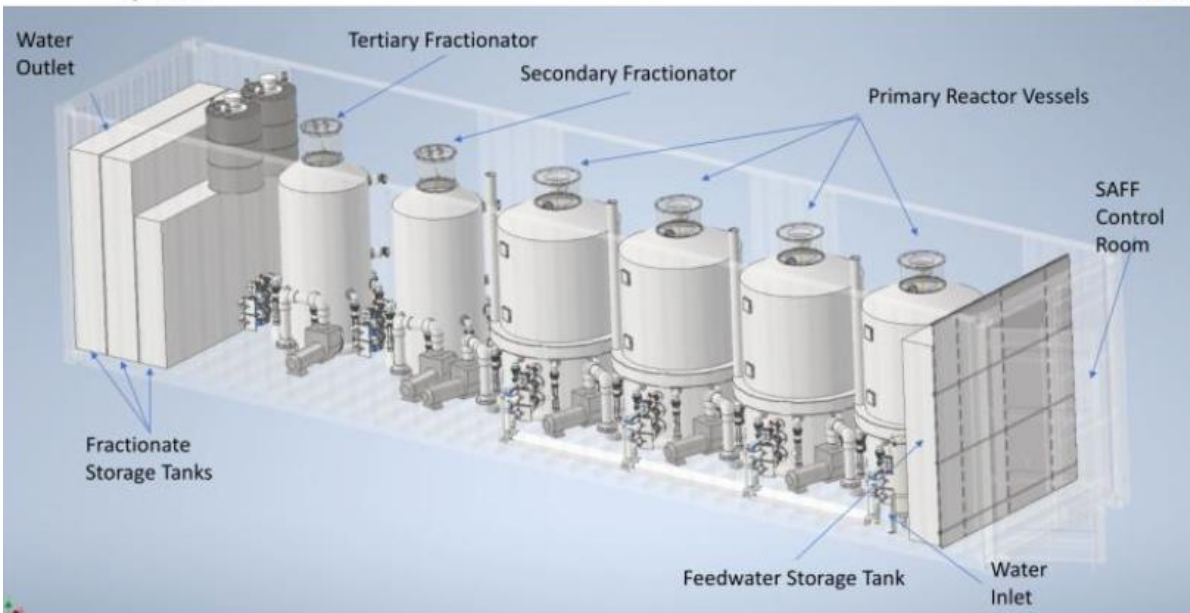
- Tuning after start up – needed because all waters are different, approx 2 days
- Remote surveillance, fine tuning, 24 h / 7 day controlled
- You can follow flow, status, electricity used, total volume and more via the app!
- Every pump, valve and sensor, reports data continuously. We can see exactly when, what and where a problem has occurred and can usually fix it remotely straight away



SAFF – Surface Active Foam Fractionation



ENVYTECH 40' CONTAINERISED SAFF SYSTEM



SAFF uses the air bubbles physiochemistry as the perfect environment for PFAS to get them out of solution and into a removable foam

By "final push", we get some shorter chain removal

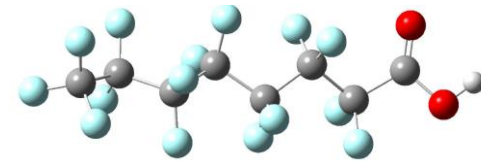


Primary step: 10 x conc

Secondary Step: 1500 x conc

Tertiary Step: 500-200 x conc

SAFF – Surface Active Foam Fractionation



How it works and why



SAFF – Surface Active Foam Fractionation



Primary Fractionation: 10 x concentrationen (of volume)

SAFF – Surface Active Foam Fractionation



Secondary Fractionation:
1 500 x concentrationen



Tertiary Fractionation:
50 – 200 x Concentration

Total concentration increase: 500 - 200 000 x concentration

SAFF Economics

Wonderful results!
But how much does it cost ?

Rental or Buy: Ask us for a quote

Capacity : > 40 m³/h or 20 m³/h

Installation: 40 h service technician. Included in rental at long time hire.

Electricity: 0,7 kwh / m³ treated – Sweden: < 0,1 euro/ m³ treated

Service: 16 h service technician per month – depending on water

Waste

From leachate: 0,2 - 3 m³ / 40 000 m³ treated

From GW: < 0,1 (10 liters) per 50 000 m³ treated



Possibility! No waste – "Closed loop" possibility within 6-12 months.

Envytech Solutions AB – Contact

Helena Hinrichsen

hh@envytech.se

+46 704 08 24 80

www.envytech.se

And for more info, see Envytech or
myself on LinkedIn

